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MAGNETO HYDRODYNAMICS POWER GENERATION

Keshav Prasad Dansena[1], Prakashkumar Sen[2], Gopal Sahu[3]
[1]*Student, Mechanical, K.I.T. Raigarh, Chhatishgarh, India*
[2,3]*Faculty, Mechanical, K.I.T., Raigarh, Chhatishgarh, India*

***Abstract*- Magneto hydrodynamic (MHD) power generation process is basically based on the physics background ofspace plasma. The basic principle is the Faradays Law of electromagnetic induction. In this device plasma (Ionized gas)is the working fluid similar to the mechanism that happening in the magnetosphere of our earth's atmosphere. Excepthere the process is controlled and we increase the fluid density and pressure to get maximum efficiency in thegenerating power. Mist problems come from the low conductivity feature in the gas at high temperature. Hightemperature gaseous conductor at high velocity is passed through a powerful magnetic field and a current is generatedand extracted by placing electrodes at suitable position in the gas stream, and hence the thermal energy of gas isdirectly converted in to electrical energy. In this paper the process involved in MHD power generation will bediscussed in detail along with the simplified analysis of MDH system and recent developments in magnetohydrodynamics and their related issues.**

***Index Terms*- Electromagnetic Induction, Hall Effect, Magneto Hydrodynamics, Mhd Generator, Plasma**

I. INTRODUCTION

The whole world is already familiar with the which primary or secondary energy is directly converted conventional power generating resources like HYDL into electrical energy without passing through the stagethermal and nuclear resources etc. In all the conventional of mechanical energyinto mechanical energy and then this mechanical energyis converted into electrical energy. The conversion of potential energy into mechanical energy is significantlyhigh i.e. 70-80% but conversion of thermal energy into Electrochemical energy conversion (Fuel cells)mechanical energy is significantly poor i.e.40-45%.This requires huge capital cost as well as maintenance cost[1].All across the world researches are trying to convert thermal energy directly into electrical energy by eradicating the mechanical process involved in energy conversions which have significant energy losses. Research is now focusing its efforts on conversion process that do not involve mechanical energyconversion step. In the absence of moving mechanical part may allow in achieving the operating temperature much higher than the typical conventional processes to attain effective power generating systems .thesewhich primary or secondary energy is directly convertedin to electrical energy without passing through the stageof mechanical energy [2]. Some of the direct conversion methods are described below:

1. Magnetohydrodynamics generation (MHD)
2. Photovoltaic generation system (solar cells)
3. Electrochemical energy conversion
4 Thermoelectric power generation

The reason for using new and direct energyconversion methods is to overcome the flaws in theconventional energy generating systems. The possibilityof using new sources of energy seems enhanced by thedevelopment of new direct energy converters. There are many methods of converting direct thermal energy toelectrical energy. In the following section one of the main direct energy converting technology.Magneto hydrodynamics is discussed in detail.

Historical Overview: In 1893, Michael Faraday was thefirst person who gives the idea of energy conversion inMHD. Almost for the half of century no work was doneon this concept. Later on in 1938, West house researchlaboratory (USA) took the first step in utilizing theconcept for developing a MHD generator. "Process forthe Conversion of Energy" was the initial patent on MHDgiven by B. KARLOVITZ, in 1940.

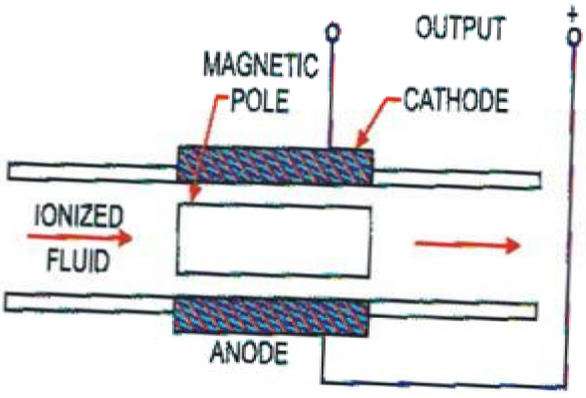


Fig1. : Basic Principle.

The MHD-steam power plant U-25 having a capacity of 75MW of which 25 MW is generated through MHD was implemented. [7]. IN 1975, the pilot plant was installed in TIRUCHIRAPALI by BARC. The Japanese program in the late 1980s concentrated on closed-cycle MHD. Which nitrogen, sodium and NAK are used asworkingfluid and Italians took interests in the development of thistechnology.

Working Principle of MHD Generators: When anelectric conductor moves across a magnetic field, avoltage is induced in it which produces an electriccurrent. This is the principle of the conventionalgenerator where the conductors consist of copper Mistrips. In MHD generator, the solid conductors arereplaced by a gaseous conductor (an ionized gas).If such a gas is passed at a high velocity through apowerful magnetic field, a current is generated andposition in the stream. The principle can be explained asfollows:

"An electric conductor moving through a magnetic fieldexperiences a retarding force as well as an induced electricfield and current."

This effect is a result of Faradays Law of Electro -Magnetic Induction.

The induced EMF is given by

EIND = u x B [1] [1]

Where

u = Velocity of the conductor.

B = Magnetic field intensity.

The induced current is given by

IIND = C x EIND [2]

Where

C = Electric conductivity

The retarding force on the conductor is the Lorentzforce given by

Find = IIND x B [3]

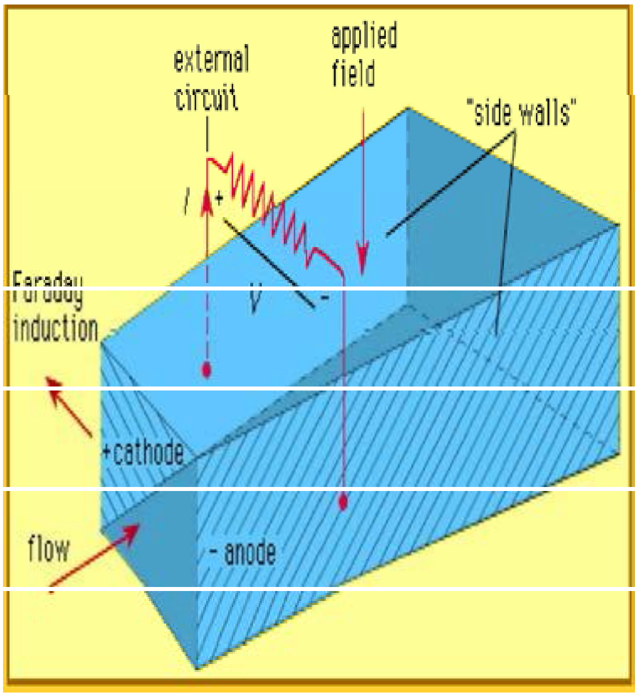


Fig2. : Faraday generator

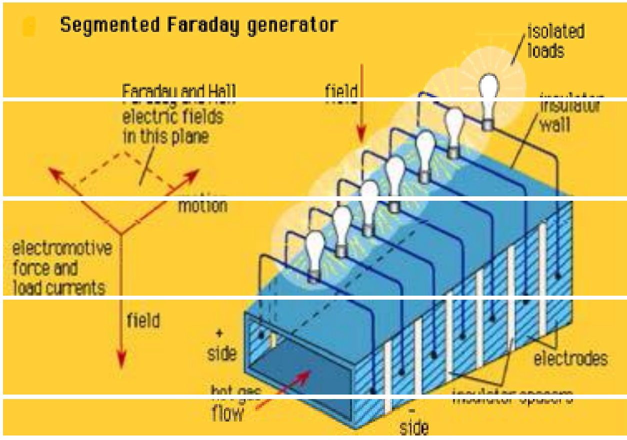


Fig3. : Segmented Faraday Generator.

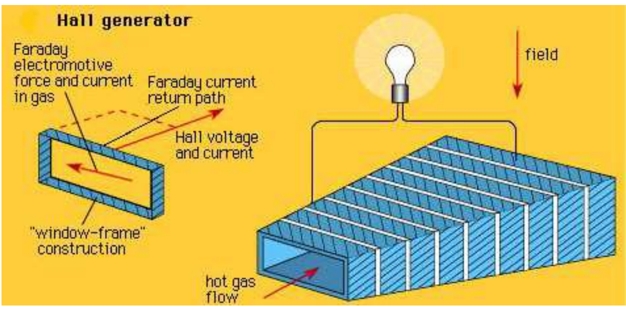


Fig4. : Hall generator.

The electromagnetic induction principle is not limitedto solid conductors. The movement of a conducting fluidthrough a magnetic field can also generate electricalenergy. When a fluid is used for the energy conversiontechnique, it is called MAGNETO HYDRO

DYNAMIC(MHD), energy conversion.The flow direction is right angles to the magneticfields direction. An electromotive force (or electricvoltage) is induced in the direction at right angles to bothflow and field directions. The conducting flow fluid isits competitive good performance the electrical

Faraday generator:forced between the plates with a kinetic energy andpressure differential sufficient to overcome the magneticinduction force Find. The end view drawing illustrates theconstruction of the flow channel. An ionized gas isemployed as the conducting fluid. Ionization is producedeither by thermal means i.e. by an elevated temperature or

by seeding with substance.

Types of MHD Generators:A system with MHD generatorhas high potential of an ultimate efficiency i.e. 60 to 65%which is much improved than the efficiency ofconventional thermal power station i.e. 30 to 35%. Outputpower of MHD generator for each cubic meter channelvolume is directly proportional to square of gas velocityand gas conductivity and square of the strength of themagnetic field through which the gas flows. over forconductivity of the plasma (ionized gas) must be abovethe temperature range of 2000K. Usually a number ofissues like generator efficiency, economics Toxic productsetc. are occurred during the working of MHD generator.

MHD generator is classified in three different designs which are mentioned.

1.Faraday generator.**2.**Hall generator.

3.Disk generator.

Power Cycle Phenomenon for MHD Generator: The powercycle of MHD generator is basically a thermal powercycle. Schematic diagram illustrate MHD-gas turbinegenerator replaced the gas turbine which is used in theconventional cycle a compressor is used to elevate thepressure and then heat is added to increase temperatureof gas for ionization than ionized gas is accelerated bypassing through the nozzle before entering MHDgenerator after passing through MHD generator theionized gases decelerated and electrical energy isobtained. Thermal efficiency of MHD is given by:

$$\eta = \frac{Workoutput}{Heatinput} = \frac{(h_3-h_4)-(h_2-h_1)}{(h_3-h_2)}$$

Where; indicated enthalpies are stagnation values of flowing fluid or gas should be highly ionizedkinetic energy of flowing gas. The stagnation enthalpy ofthe flowing gas is as follows:

$$h_o = h + \frac{u^2}{2}$$

Here; u is the flowing gas velocity.

In MHD generator, the velocity of the ionized gas issufficiently high so that the kinetic energy of the flowinggas depicts the substantial portion of the total energy

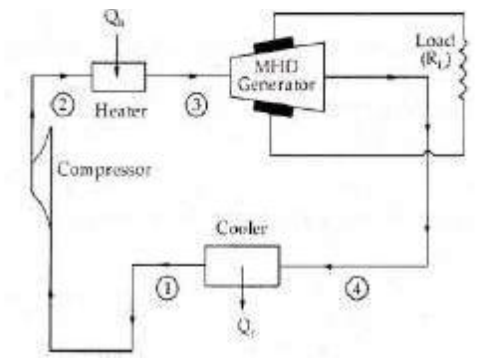


Fig5. ;Power cycle for MHD generator

Simplified Analysis of MHD Generator: Followingassumptions are made in the analysis of MHD generator:

1 .Velocity and pressure of fluid or flowing ionized gasmust be kept constant.

2. Magnetic flux also remains the same throughout.

3.Maximum heat is utilized instead of transfer to thesurroundings.

4. Fluid or gas flow remains uniform.

II. CONSTRUCTION

Its construction is very simple. MHD generator resembles the rocket engine surrounded by enormous magnet. It has no moving parts & the actual conductors are replaced by ionized gas (plasma). The magnets used can be electromagnets or superconducting magnets. Superconducting magnets are used in the larger MHD generators to eliminate one of the large parasitic losses. As shown in figure the electrodes are placed parallel & opposite to each other. It is made to operate at very high temperature, without moving parts.

Since the plasma temperature is typically over 2000 °C, the duct containing the plasma must be constructed from non-conducting materials capable of withstanding this high temperature. The electrodes must of course be conducting as well as heat resistant.

Because of the high temperatures, the non-conducting walls of the channel must be constructed from an exceedingly heat-resistant substance such as yttrium oxide or zirconium dioxide to retard oxidation.It can be

considered as fluid dynamo similar to mechanical dynamo.
The key component is Superconducting Magnets
There are two types of MHD power generation

i. Open cycle MHD.
ii. Closed cycle MHD.

1) Open cycle MHD system- working, fluid-potassium seed combustion product. Temperature in OC MHD is about 2500oC. DC Superconducting magnets of 4~6Tesla are used. Here exhaust gases are left out to atmosphere & the capacity of these plants are about 100MW.

2) Closed cycle MHD system

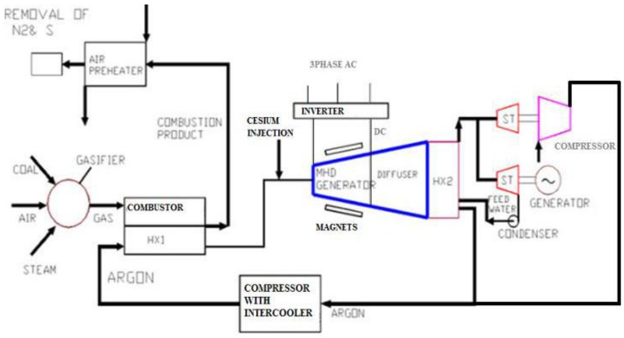


Fig6. -Working fluid-CESIUM seeded helium.

Temperature of CC MHD plants is very less compared to OC MHD plants. It's about 1400oC.DC Superconducting magnets of 4~6Tesla are used.Here exhaust gases are again recycled & the capacities of these plants are more than 200MW.

III. THE 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 no nozzle reduces the gas pressure and consequently increases the plasma speed through the generator duct to increase the power output. Unfortunately, at the same time, the pressure drop causes the plasma temperature to fall which also increases the plasma resistance. The exhaust heat from the working fluid is used to drive a compressor to increase the fuel combustion rate but much of the heat will be wasted unless it can be used in another process.

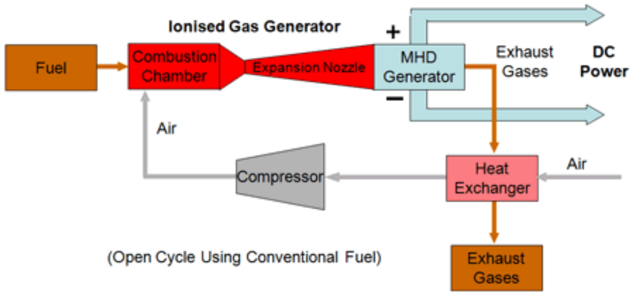


Fig 7 - MHD electric generation

A. The Plasma

The Plasma in the MHD is created by a process called thermal ionization, where the temperature of the gas is raised to the point so that the electrons are no longer bound to the atoms of gas. These free electrons make the Plasma gas electrically conductive. The gas is continuously seeded with potassium nitrate or potassium carbonate, making the gas electrically conductive at lower temperature.

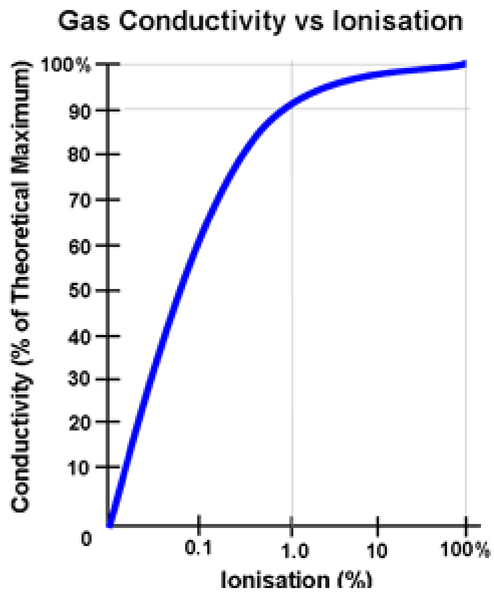
The prime system requirement is creating and managing the conducting gas plasma since the system depends on the plasma having a high electrical conductivity. Suitable working fluids are gases derived from combustion, noble gases, and alkali metal vapours. The gas plasma, to achieve high conductivity, the gas must be ionized, detaching the electrons from the atoms or molecules leaving positively charged ions of the gas. The plasma flows through the magnetic field at high speed, in some designs, more than the speed of sound, the flow of the charged particles providing the necessary moving electrical conductor.

B. Methods of Ionizing the Gas

Various methods for ionizing the gas are available, all of which depend on imparting sufficient energy to the gas. It may be accomplished by heating or irradiating the gas with X- rays or Gamma rays. It has also been proposed to use the coolant gases such as helium and carbon dioxide employed in some nuclear reactors as the plasma fuel for direct MHD electricity generation rather than extracting the heat energy of the gas through heat exchangers to raise steam to drive turbine generators. Seed materials such as Potassium carbonate or CESIUM are often added in small amounts, typically about 1% of the total mass flow to increase the ionization and improve the conductivity, particularly of combustion gas plasmas. Note that on the logarithmic scale, the 90% conductivity can be achieved with a fairly low degree of ionization of only about 1%

C. Power Output

The output power is proportional to the cross-sectional area and the flow rate of the ionized 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. A MHD generator produces a direct current output which needs an expensive high power inverter to convert the output into alternating current for connection to the grid.



D. 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 used as the energy source to raise steam in a steam turbine plant. Total plant efficiencies of 65% could be possible in such arrangements.

IV. ADVANTAGES

1. In MHD the thermal pollution of water is eliminated. (Clean Energy System)
2. Use of MHD plant operating in conjunction with a gas turbine power plant might not require to, reject any heat to cooling water.
3. These are less complicated than the conventional generators, having simple technology.
4. There are no moving parts in generator which reduces the energy loss.
5. These plants have the potential to raise the conversion efficiency up to 55-60%. Since conductivity of plasma is very high (can be treated as infinity).
6. It is applicable with all kind of heat source like nuclear, thermal, thermonuclear plants etc. Extensive use of MHD can help in better fuel utilization. It, contribute greatly to the solution of serious air and thermal pollution faced by steam plants.

Disadvantage

1. The construction of superconducting magnets for small MHD plants of more than 1kW electrical capacity is only on the drawing board.
2. The construction of superconducting magnets for small MHD plants of more than 1kW electrical capacity is only on the drawing board.
3. Construction of generator is uneconomical due to its high cost.
4. Construction of Heat resistant and non conducting ducts of generator & large superconducting magnets is difficult.
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V. POSSIBLE DEVELOPMENTS IN MAGNETOHYDRODYNAMICS (MHD)

Since the invention of MHD power generating technology a lot of research and development is in progress. This paper also highlights the possible development in energy conversion using liquid metal instead of gases in MHD generators. In liquid metal Magneto hydrodynamics energy conversion (LMMHDEC) thermodynamic fluid i.e. gas or vapour is mixed with electro dynamic fluid i.e. liquid metal (Li) because heat capacity of liquid is greater than gases and as a result high thermal energy conversion reached approximately near to the ideal Carnot cycle.

Liquid metal Magneto hydrodynamics energy conversion (LMMHDEC) was proposed by Elliott is based upon high temperature RANKINE cycle. In LMMHDEC lithium (Li) is used as MHD fluid and (Cs) is used as a vaporizable fluid. This vaporizable fluid ionizes and accelerates the MHD liquid through a strong magnetic field at higher velocity. When MHD liquid passes through intensive magnetic field with high velocity its kinetic energy is directly converted into electrical energy. The MHD fluid and vaporizable fluid are separated before passing through MHD generator with the help of separator and remaining liquid fluid is allowed to pass through MHD generator to generate electricity. After leaving MHD generator the liquid metal returns back to the mixer nozzle. Passing through a diffuser and heat source device the vaporizable fluid which separates from liquid metal at separator flows through regenerative heat exchanger and condenser unit then returns back to mixer nozzle through pump, and this mixer is ready to flow in a loop. A double cycle MHD system is displayed below which shows the liquid loop and vapor loop.

VI. CONCLUSION

All the conventional thermal and hydro power plants are associated with immense losses due to thermo mechanical and hydro mechanical operating systems. This causes various efficiency losses i.e. mechanical breakage, thermal leakage, frictional losses. The MHD power generation is in advanced stage today and closer to commercial utilization. Significant progress has been made in development of all critical components and sub system technologies. Coal burning MHD combined steam power plant promises significant economic and environmental advantages compared to other coal burning power generation technologies. It will not be long before the technological problem of MHD systems will be overcome and MHD system would transform itself from nonconventional to conventional energy sources. The conventional conversion systems have significant losses
(thermo-dynamics conversion) and these traditional systems are also failed to fulfill the needs of energy of the modern world. So, the performance from the point of efficiency and reliability is limited which can be improved by the combined operation with MHD generators. MHD generator has no moving part which allows working at higher temperature around 3000 degree C without any mechanical losses. In near future, MHD power generation system can improve the efficiency of other conventional systems.

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