MAGNETO HYDRODYNAMIC POWER GENERATION

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ABSTRACT:

This paper is a researched study on Magneto hydrodynamic power generation, which provides a way of generating electricity directly from a fast moving stream of ionized gases without the need for any moving mechanical parts i.e. turbines or rotary generators. It is based on the physics background of space plasma. The basic principle on which it works is the Faraday's law of electromagnetic induction. In this device, plasma (ionized gas) is the working fluid similar to the mechanism that is happening in the magnetosphere of our atmosphere. Except for the fact that the process is controlled and the fluid density and pressure can be increased to get maximum efficiency in the generating power.

Most of the problems arise due to the low conductivity of the gas at high temperature, however high temperature gaseous conductor at high velocity can be passed through a powerful magnetic field and current can be generated and extracted by placing electrode at suitable positions in the gas stream. Hence the thermal energy of gas is directly converted in to electrical energy.

Keywords: Electromagnetic induction, hydrodynamic, magnetosphere, Faraday’s law, ionized gas, magnetic field

[1] INTRODUCTION

We are all aware of power generation using hydro, thermal and nuclear resources. In all the systems, the potential energy or thermal energy is first converted in to mechanical energy and then the mechanical energy is converted in to electrical energy. The conversion of potential energy in to mechanical energy is considerably high (70 to 80%) but conversion of thermal energy in to mechanical energy is considerably poor (40 to 45%). In addition to this the mechanical components required for converting heat energy in to mechanical energy are large in number and considerably costly. This requires huge capital cost as well as maintenance cost also. The development of science
and technology has made it easy to discover new non-conventional source i.e. Magneto Hydrodynamic Power generation.

MHD power generation is elegantly simple technique. Magneto Hydro Dynamics (magneto-fluid-dynamics or hydro-magnetics) is the academic discipline which studies the dynamics of electrically conducting fluids. Examples of such fluids include plasmas, liquid metals, and salt water. The generator used in this process is called Magneto Hydro Dynamic Generator. It resembles the rocket engine surrounded by enormous magnet. It has no moving parts & the actual conductors are replaced by ionized gas (plasma). Hence it has a very high efficiency. Magneto-hydrodynamic (MHD) power generation has been studied as a novel commercial power plant due to its inherent advantage of high-efficiency with high-working temperatures.

[2] HISTORY

The concept of MHD power generation was introduced for the very first time by Michal Faraday in the year 1832 in his Bakerian lecture to the Royal society. He in fact carried out an experiment at Waterloo Bridge in Great Britain for measuring the current, from the flow of river Thames in earth’s magnetic field.

The first MHD-steam power plant U-25 was put into operation was of 75MW unit in USSR of which 25MW is generated by MHD means in early 1970’s & this work has been progressing fruitfully. The first pilot plant was set up in Tiruchirapalli (by BARC). A five year plan was signed in February 1975 which included 22 spheres of applied science and technology connected with the MHD energy generation. The Japanese program in the late 1980s concentrated on closed-cycle MHD. In 1986, Professor Hugo Karl Messerle at The University of Sydney researched coal-fuelled MHD.

[3] WORKING PRINCIPLE

MHD power generation process is governed by M. Faraday’s law of Electromagnetic Induction. I.e. when the conductor moves through a magnetic field, it generates an electric field perpendicular to the magnetic field & direction of conductor). The flow of the conducting plasma through a magnetic field at high velocity causes a voltage to be generated across the electrodes, perpendicular to both the plasma flow and the magnetic field according to Flemings Right Hand Rule. The Lorentz Force Law describes the effects of a charged particle moving in a constant magnetic field. The simplest form of this law is given by the vector equation as shown in figure 1 and 2.
The vector $\mathbf{F}$ is perpendicular to both $\mathbf{v}$ and $\mathbf{B}$ according to the right hand rule.

**Figure: 1. Magnetohydrodynamic Power Generation (Principle)**

\[ F = Q \cdot (v \times B) \]

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.

**Figure: 2. MHD generator**

**[3] WORKING PROCEDURE**

It is the generation of electric power utilizing the high temperature conducting plasma (stream of high temp working fluid) moving through an intense magnetic field. It converts the heat energy of fuel (thermal energy) directly into electrical energy. The fuel is burnt in the presence of compressed air in combustion chamber. During combustion seeding materials are added to increase the ionization & this ionized gas (plasma) is made to expand through a nozzle into the generator. Magnetic field, a current
is generated & it can be extracted by placing electrodes in a suitable stream. This generated EMF is DC. It is shown in figure 3 below.

![Diagram: Magneto hydrodynamic (MHD) Electricity Generation](image)

**Figure: 3. Magneto hydrodynamic (MHD) Electricity Generation**

**Ionization of GAS:**
Various methods for ionizing the gas are available, all of which depend on imparting sufficient energy to the gas. The ionization can be produced by thermal or nuclear means. Materials such as Potassium carbonate or Caesium are often added in small amounts, typically about 1% of the total mass flow to increase the ionization and improve the conductivity, particularly combustion of gas plasma. 90% conductivity can be achieved with a fairly low degree of ionization of only about 1%. (Note also logarithmic scale) as shown in figure 4.

![Graph: Gas conductivity vs. Ionisation](image)

**Figure: 4. Gas conductivity vs. Ionisation**
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.

There are two types of MHD power generation

i. Open cycle MHD (figure 5),
ii. Closed cycle MHD (figure 6).

1. **Open Cycle MHD system**
   - Working fluid is 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.

This system includes on MHD generator with a compressor of high temperature. The thermal random has been about 30percent. The fluid makes the hot clean air by MHD external gas at industrial unit. Such cycle do not need any cooling water for steam distillation and returning heat. The gas leaves the channel actor with the temperature about 1900 C. Continuously, the heat can be pre-given for combustion air and steam is provided in a generator to produce steam in turbine unit. So, system is changed into a compound cycle and the total round is about 60 percent.

2. **Closed Cycle MHD system**
   - Working fluid is potassium seed combustion product.
   - Temperature in OC MHD is about 1400°C.
   - DC Superconducting magnets of 4~6Tesla are used.
   - Here exhaust gases are left out to atmosphere & the capacity of these plants are about 200MW.
In this kind of cycle, two generators are used with the capacity of conductivity resulted of ionization of seed material and fluid metal. The compressed gas expanded by an external source in a thermal converter and MHD generator. Besides the dropping of pressure and temperature, the gas heat is cached by a cooler and then compressed. The MHD generator allows choosing more due to lower temperature but system with open circle has higher thermal round.

Figure: 6. Closed cycle MHD system

[5] FARADAYS GENERATOR

A simple Faraday generator would consist of a wedge-shaped pipe or tube of some non-conductive material. When an electrically conductive fluid flows through the tube, in the presence of a significant perpendicular magnetic field, a charge is induced in the field, which can be drawn off as electrical power by placing the electrodes on the sides at 90 degree angles to the magnetic field. The main practical problem of a Faraday generator is that differential voltages and currents in the fluid short through the electrodes on the sides of the duct. The most powerful waste is from the Hall effect current. Faraday currents flow in a perfect dead short around the periphery of the disk. The Hall effect currents flow between ring electrodes near the centre and ring electrodes near the periphery. Another significant advantage of this design is that the magnet is more efficient. First, it has simple parallel field lines. Second, because the fluid is processed in a disk, the magnet can be closer to the fluid, and magnetic field strengths increase as the 7th power of distance. Finally, the generator is compact for its power, so the magnet is also smaller. The resulting magnet uses a much smaller percentage of the generated power.

[6] The Types of MHD Generators from the Aspect of Building

We can categorize into different groups according to the manner of electrodes connection with abroad load:

[6.1] Faraday Generator with Continuous Electrodes

This is the simplest type connected to an abroad load. An electrode with same potential causes the fluid circuit to be vertical on plasma flow. The central component to circuit follows more long
direction that causes large losses and also decreases the transverse component of circuit. The diagram of Faraday generator with continuous electrode has been shown in Fig.7.

![Diagram of Faraday generator with continuous electrode](image1)

**Figure: 7. Faraday generator with continuous electrode**

[6.2] Series Connections Generator with Discontinuous Electrode

In this generator electrodes have connected to gather diagonally and then load is connected to the initial and last net. It is possible to connect much more loads that may cause some difficulties, but we can control this problem by making some limitations. This problem is possible because the components of X and Y make the resultant that have angle with electrical field. Therefore, it is necessary to insulate the net walls in direction of electrical field. The diagram of Series connection of generator with discontinuous electrode has been shown in figure 8.

![Diagram of Series connection of generator with discontinuous electrode](image2)

**Figure: 8. Series Connection of Generator with discontinuous Electrode**

[6.3] Faraday Generator with Discontinuous Electrodes

In this type of generator, we can stop large losses by connecting each of the blade electrodes to an external load. Each of the circuit has different potential difference separately. The Fig. 5 shows this type of generator. The diagram of Faraday generator with continuous electrode has been shown in figure 9.
[6.4] Hull Generator
In this generator, the blade electrodes are shortly connected together and broad load is connected into the initial and last electrodes. The figure (8) shows this kind of generator that the production power is central by electrical circuit and field. The diagram of Hull generator has been shown in figure 10.

[7] Comparison of MHD power stations with other

MHD generator controllers have simple and cheap mechanisms. The existence of voltage converter causes to increase meant in costs of controlling. Also, there invertors by modern electrical power, as the costs has been rather low. MHD power stations have low effects on the environment due to low levels of contaminants. Distribution of pollution in MHD powerhouse is just from distribution of oxidized gases in MHD cycle into the air that can be removed by recycling and filtration. Flue consumption for these generators can be achieved in every place and it is accessible and also it is possible to use nuclear energy for fuel. Besides that, we can produce electrical power about 10000 MW and more in thermal station. In this generator, we time limitation on application due to high temperature and fear of danger from thermal, mechanical and corrosion tensions and also destruction of material properties.

[8] ADVANTAGES:
- In MHD the thermal pollution of water is eliminated. (Clean Energy System)
- Use of MHD plant operating in conjunction with a gas turbine power plant might not require rejecting any heat to cooling water.
• These are less complicated than the conventional generators, having simple technology.
• There are no moving parts in generator which reduces the energy loss.
• 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 infinite).

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 contributes greatly to the solution of serious air and thermal pollution faced by steam plants.

[9] **DISADVANTAGES:**

• The construction of superconducting magnets for small MHD plants of more than 1kW electrical capacity is only on the drawing board.
• Difficulties may arise from the exposure of metal surface to the intense heat of the generator and form the corrosion of metals and electrodes.
• Construction of generator is uneconomical due to its high cost.
• Construction of Heat resistant and non-conducting ducts of generator & large superconducting magnets is difficult.

MHD without superconducting magnets is less efficient when compared with combined gas cycle turbine.

[10] **CONCLUSION**

Improvement in corrosion science & superconducting magnets can make rapid commercialization possible, saving billions of dollars towards fuel prospects of much better fuel utilization. It can therefore be claimed that the development of MHD for electric utility power generation is an objective of national significance. The practical efficiency of this type of power generation will not be less than 60%. Hence it will be most significant in upcoming decade. If we solve this; making MHD cost effective; we will succeed. Otherwise MHD will be in proceedings and papers. It is expected to overcome all the demerits till the end of 2020.

**REFERENCES**