Experimental Investigation on Magnetic Hydro Dynamics Power Generation for Varying Velocity, Magnetic Flux and Distance between the Electrodes

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Abstract : Since the demand for electricity is increasing at alarming rate and the demand for power is running ahead of supply. The existing technologies used for the power generation are not efficient enough and it may not be suitable for the future energy demand. The energy crisis is forcing us to develop new methods. The magnetic hydrodynamic power generation is one of the methods which can be used has a high efficient power generation method with almost zero pollution. It is a generation of electricity directly from thermal energy utilizing the high temperature conducting plasma moving through an intense magnetic field. MHD power plants have a higher overall efficiency when compared to other conventional and non-conventional methods. In this research work, fabrication of the MHD generator was carried out and experimental investigation was done by using compressed air of pressure range 1 - 5 bar, diesel engine exhaust, preheated compressed air and high velocity air. And the preheated compressed air passed through MHD had the higher voltage when compared to the other fluids.

Introduction

Conventional energy resources derived from oil, coal, and natural gas have confirmed to be extremely efficient drivers of economic development. On the other hand, with the quick reduction of conventional energy resources and growing energy requirement, global prime energy utilization has grown. Because of certain environmental issues, many related organizations have encouraged intensive research for more efficient and green power plants utilizing advanced technology. [1] The whole world is already familiar with the which primary or secondary energy is directly converted conventional power generating resources like hydro into electrical energy without passing through the stage thermal and nuclear resources etc. In all the conventions of mechanical energy into mechanical energy and then this mechanical energy is converted into electrical energy. The conversion of potential energy into mechanical energy is significantly poor i.e., 40-45%. This requires a huge capital cost as well as maintenance cost. 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 energy conversion 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. These which primary or secondary energy is directly converted into electrical energy without passing through the stage of mechanical energy. Some of the direct conversion methods are: Magneto hydrodynamics generation (MHD), Photovoltaic generation system (solar cells), Electro chemical energy conversion and Thermo electric power generation. The reason for using new and direct energy conversion methods is to overcome the flaws in the conventional energy generating systems. The possibility of using new sources of energy seems enhanced by the development of new direct energy converters. There are many methods of converting direct thermal energy to electrical energy. [2] Direct energy conversion devices convert energy into electricity without any heat engine as an intermediate step.[3]

The Magneto hydro dynamic (MHD) Generator is now widely recognized as one of the more promising new methods for large scale electric power generation. The magneto hydrodynamic generator transforms the internal energy of a gas into electric power in much the same way that a turbines does, and the basic physical phenomena that are employed are the same in both cases. In turbines, the energy of a gas is converted into the motion of a solid conductor by means of turbine blades and a connecting mechanical linkage. In the MHD generator the gas itself is a conductor and by expanding through a nozzle moves itself. In either case, the motion of a conductor through a magnetic field gives rise to an electromotive force and a flow of current in accordance with Faraday's law of induction. The
potential advantages of the MHD generator over the turbine are to a degree analogous to the advantages of the turbine over the piston engine. As a result of their conceptual simplicity, turbines out-class piston engines in power handling capacity and reliability. Likewise, the MHD generator, which represents a still further increase in simplicity, also represents a still further increase in intrinsic power handling capacity and potential reliability. But beyond this, the MHD generator also represents a large step forward in temperature handling capability and thus efficiency. With respect to temperature the turbine is actually a step backwards, whereas the MHD generator is a large step forward and, in principle, can handle even the very high temperature that may be produced someday in the plasma of a fusion reactor. While the bulk of the present MHD development effort is directed toward fossil-fired plants, the advance of reactor technology toward higher temperature could eventually make it possible for nuclear plants to take advantage of MHD also. In order to conduct electricity, a gas must of course be partially ionized. Most common gases, such as air, CO, CO$_2$, or the noble gases, do not ionize appreciably until temperatures in excess of 4000 K are reached. However, if a common alkali metal-bearing compound such as potassium carbonate is added to a gas in small amounts (on the order of one part per hundred or less), sufficient thermal ionization can be obtained at temperatures of 2000K to 2500K. This process, called seeding, thus results in temperatures low enough to be withstood by some solid materials and to be produced in furnaces. At this point it may be helpful to summarize the major differences between the plasma in a fusion reactor and the plasma in an MHD generator. The latter will consist primarily of neutral particles, only about one in $10^4$ being ionized. The energy distribution of all particles will be essentially maxwellian and under most circumstances all will have the same mean energy which will correspond to only a few thousand Kelvin. [4]

In MHD conversion with ionized gas in the electronic field, according to the phenomena of Faraday’s law, has been seen an induction of electronic field in the vertical direction of fluid field vector and magnetic field vector. In 1831, Faraday was the first one who performed such an experiment by mercury that the researchers of that time discovered that it is possible to conduct gas with ionization. MHD generators in one circuit have been appeared as an electronic machine. That is, it's possible to use plasma for production of DC energy or conversely to accelerate plasma atoms by DC power. MHD power stations have fewer costs than the stations of nuclear fusion. However, the power generation is much more expensive than in fossil power stations. It has been tried to study and analyze the performance and structure of MHD generators. [5]

The MHD power generation technology deals with the production of electricity using a high temperature conducting plasma that passed through the intense magnetic field. The heat rejected by the MHD system can also be used to drive the conventionally used steam turbine system. An MHD can be designed to use different types of fuel such natural gas, fuel, coal and nuclear. Coal is mainly used as energy resource in MHD system. In case of MHD generator a pressure difference is needed to force the gas through the field when the current is drawn. The observed force of moving plasma to focus on plasma atoms

$$F = J \cdot B \quad (1)$$

Where $J$ is the density of plasma circuit and $B$ is the magnetic flux of density vector.

Thermodynamically, the operation of generator is similar to that of the turbine. Useful work is extracted from the gas flow at the expanse of the pressure and enthalpy drop and its efficiency can be observed for the different gas flow. It has no highly stressed moving part of closed tolerance. Its walls are cooled at below the temperature of the working fluid.

The electrical conductivity in the gas is function of temperature and being dependent on the one or more species in gas having low ionization potential. The potential difference is obtained by

$$U = V \cdot B \cdot d \quad (2)$$

Where $d$ is the distance between two electrodes, $V$ as the average speed of plasma and $B$ is density of magnetic flux.

MHD generator is classified in three different ways:
- Faraday generator.
- Hall generator.
- Disk generator.

**Faraday generator:**

It consists of a non-conductive wedge-shaped pipe or tube. When ionized plasma flows through the tube in the presence of a magnetic field than current is induced, which can be extracted by placing electrodes on the sides of wedged shaped pipe or tube at perpendicular to magnetic field. The main practical issue with faraday generator is differential voltages and currents in the fluid short through the electrodes on the sides of the tube.

**Hall generator:**
The Faraday field in hall generator across each sector of the channel is short-circuited and the sectors are series connected. This allows the connection of a single electric load between the ends of the channel. Consideration of the electric potentials at different points in the channel leads to the observation that an equi potential runs diagonally across the insulating walls and that electrodes may be appropriately staggered to match the equi potential. The series connection of these electrodes in this diagonal generator permits a single electric load to be used.

**Disk generator:**

This design currently grasps the efficiency and energy concentration records for MHD generation. A disc generator has plasma (ionized gas) or fluid flowing between the centre of a disc, and a duct wrapped around the edge. The magnetic excitation field is made by a pair of circular Helmholtz coils under the circular disk. [6]

### Materials and Construction

Materials used for the construction of MHD are Neodymium bar magnets, copper electrode plate and iron sheet. Neodymium magnet is widely used magnet and is made from the alloy of iron, boron and neodymium to form $\text{Nd}_2\text{Fe}_{14}$ tetragonal crystalline structure. The physical property of neodymium is given in below table and has the magnetic flux density 0.5 tesla.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>g/cc</td>
<td>7.5</td>
</tr>
<tr>
<td>Vickers Hardness</td>
<td>D.P.N</td>
<td>570</td>
</tr>
<tr>
<td>Compression Strength</td>
<td>N/mm²</td>
<td>780</td>
</tr>
<tr>
<td>Coefficient Of Thermal Expansion</td>
<td>°C</td>
<td>3.4x $10^{-6}$</td>
</tr>
<tr>
<td>Electrical Resistivity</td>
<td>Ω</td>
<td>150</td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>S/m</td>
<td>0.667x$10^8$</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>kcal/(mh °C)</td>
<td>7.7</td>
</tr>
<tr>
<td>Specific Heat Capacity</td>
<td>kcal/(kg °C)</td>
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</tr>
<tr>
<td>Tensile Strength</td>
<td>Kg/mm²</td>
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<tr>
<td>Young’s Modulus</td>
<td>N/m²</td>
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<tr>
<td>Compressibility</td>
<td>m³/N</td>
<td>9.8</td>
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<tr>
<td>Rigidity</td>
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<tr>
<td>Poisson’s Ratio</td>
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<tr>
<td>Curie Temperature</td>
<td>°C</td>
<td>310</td>
</tr>
</tbody>
</table>

**Table 1 Physical Properties of Neodymium Magnets**

The duct is made by using the iron sheet. The iron was bent into tapered duct shape. The tapered shape will help to increase the velocity of working fluid. 3 slots were made on the either side of the walls of the duct by the gas welding process.

Copper electrodes are placed in slots of the MHD generator by using M-seal. Here M-seal is used to fix the electrode plates as well as insulate the electrode plates from the duct. We put electrode plates on either sides of the walls and kept 2 pairs of Neodymium Magnets of 0.5 tesla placed on the top and bottom of the MHD generator. The MHD generator is as shown in the Fig.1.1

![MHD generator](image)

**Fig. 1 MHD generator**

### Experimentation

1. **Using compressed air**

   First experiment was conducted by using the compressed air as a working fluid with a pressure range of 1 to 5 bar. This air passes through the duct and cuts the magnetic flux, this produces the emf in the electrodes. The digital multi meter is used to measure the voltage, and the corresponding voltage was 13 mv.

2. **Using diesel engine exhaust**

   Here the diesel engine exhaust gas was used as the working fluid. The MHD generator was fitted at the end of the exhaust manifold. The temperature of the exhaust gas was 80°C, this gas cuts the magnetic flux and thus produces the emf in the electrode plates. Here electrodes were kept in such a way that more surface area comes in contact with the exhaust gasses. This will help to capture more electrons and hence 31 mv was produced.

3. **Using preheated compressed air**

   Here the preheated compressed air was used as the working fluid. LPG gas flame was used to preheat the air. The compressed air is heated to very high temperature. This high temperature was sent into the MHD generator, this air cuts the magnetic flux and produces the emf which was 200 mv.

4. **High speed air**

   The last experiment was conducted using the high velocity air passing through MHD generator cutting the magnetic flux and produces the emf in the electrode plates and 34 mv voltage was produced.
with velocity of 1.2 m/s and temperature of 60°C.

Each experiment was repeated for varying velocity, magnetic flux and distance between the electrodes. It was found that the voltage was increasing linear to velocity, magnetic flux and distance between the electrodes. Variation of the voltage with velocity, magnetic flux and distance between the electrodes are shown in the fig 2, 3 and 4 respectively.

**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 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°C without any mechanical losses. In near future, MHD power generation system can improve the efficiency of other conventional systems.

**References**

5. Reza Sedaghati, Ali Reza Rajabi and Hossein Sedaghati “A New Technology for Power Generation Based on Kinetic Energy of the Plasma” International