International Journal of Trend in Research and Development, Volume 3(1), ISSN: 2394-9333
www.ijtrd.com

Review Note on Magnetohydrodynimics Power Generator

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***Abstract*:** From the last decade the demand for electricity is increasing at alarming rate and the demand for power is running ahead of supply. The present day methods of power generation are not much efficient & it may not be sufficient or suitable to keep pace with ever increasing demand. The recent severe energy crisis has forced the world to rethink & develop the Magnetohydrodynamics (MHD) type power generator. MHD is a highly efficient and unique method for power generation, which is based on plasma physics and its working principle is based on Faraday's Law of electromagnetic induction. The electricity is directly extracted from thermal energy of plasma (ionized gas) which is passing through the strong magnetic field. In this paper the process involved in MHD power generation will be discussed in detail along with the construction, types,working, related mathematical equations and Applications.

Keywords: *MHD Power Generator: Lorentz Force: Current Density: Magnetic Field.*

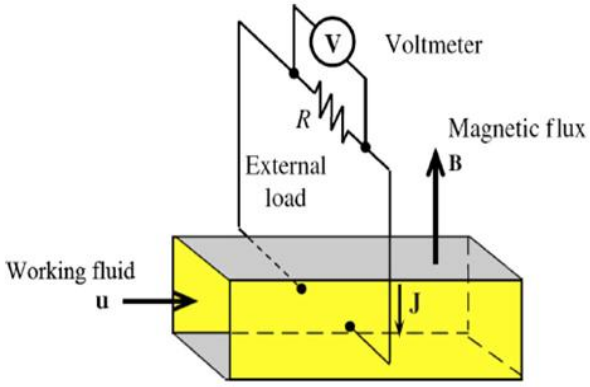
I. INTRODUCTION

The MHD generator transforms thermal energy and kinetic energy directly into electricity. MHD generators are different from traditional electric generators they operate at high temperatures without moving parts. MHD was developed because the hot exhaust gas of an MHD generator can heat the boilers of a steam power plant, increasing overall efficiency. An MHD generator, like a conventional generator, relies on moving a conductor through a magnetic field to generate electric current. The MHD generator uses hot conductive plasma as the moving conductor. The mechanical dynamo, in contrast, uses the motion of mechanical devices to accomplish this. MHD generators are technically practical for fossil fuels, but have been overtaken by other, less expensive technologies, such as combined cycles in which a gas turbine's or molten carbonate fuel cell's exhaust heats steam to power a steam turbine. Natural MHD dynamos are an active area of research in plasma physics and are of great interest to the geophysics and astrophysics communities, since the magnetic fields of the earth and sun are produced by these natural dynamos. All the conventional thermal and hydro power plants are associated with immense losses due to thermos 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.

II. BASIC PRINCIPALS AND MATHEMATICAL EQUATIONS

MHD power generation is based on Faraday's law of electromagnetic induction. When conductive fluid flows through a magnetic field that is perpendicular to the flowing direction, it will cut the magnetic lines and then the electromotive force is induced in the direction perpendicular to both magnetic field direction and flow direction.

"An electrically conducting fluid moving through a magnetic field experiences a retarding force as well as an induced electric field and current."



The set of equations which describe MHD are a combination of the Navier-Stokes equations of fluid dynamics and Maxwell's equations of electromagnetism.

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.

$$\vec{F} = Q\ (\vec{u}\ X\ \vec{B}\ )$$

where

- $\vec{F}$ is the force acting on the particle.
- Q is the charge of the particle,
- $\vec{u}$ is the velocity of the particle, and
- $\vec{B}$ is the magnetic flux density.

The vector $\vec{F}$ is perpendicular to both $\vec{u}$ and $\vec{B}$ according to the right hand rule.

A field of magnetic induction $\vec{B}$ is applied transverse to the motion of an electrically conducting fluid flowing in an insulated duct with a velocity $\vec{u}$. Charged particles moving with the fluid will experience an induced

electric field $\vec{u}\ X\ \vec{B}$ which will tend to drive an electric current in the direction perpendicular to both $\vec{u}$ and $\vec{B}$.

This current is collected by a pair of electrodes on opposite sides of the duct in contact with the conducting fluid and connected externally through a load. Neglecting the Hall effect, the magnitude of the current density for a weakly ionized conducting fluid is given by the generalized Ohm's law

$$\vec{J} = \sigma(\vec{E} + \vec{u}\ X\ \vec{B})$$

Where

$\vec{J}$ is the current density and E is the electric field

σ is the electric conductivity of the working fluid.

The Power density of the MHD power generator can be simply expressed as

$$P = K(1-K)\sigma u^2 B^2$$

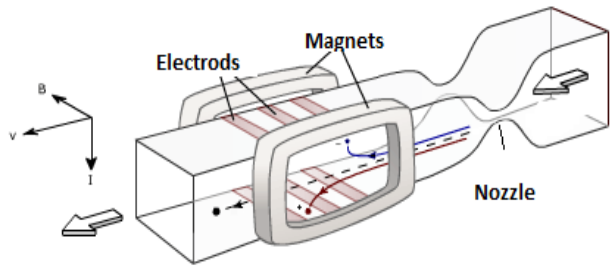
Where, K is the load coefficient

The electrical efficiency of a MHD generator is given by the equation

$$\eta_e = \frac{\vec{J}.\vec{E}}{\vec{u}.(\vec{J}\mathrm{X}\vec{B})}$$

III. 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.

IV. 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.

MHD power generation can be classified on the basis of working fluid as gaseous plasma MHD power generation and liquid metal MHD power generation.

Gaseous plasma-based MHD generator generally requires a relatively high operating temperature to ensure the gas has a reasonable value of electrical conductivity. Also, the flow speed should be fast enough to achieve relatively high-power output and efficiency.

The liquid metal MHD power generation can be operated in relatively low temperature, pressure, and flow speed since liquid metal has a much higher electrical conductivity than gaseous plasma. However, liquid metal is generally expensive, so the closed-cycle system must be adopted and the working fluid should be recycled again after passing through the magnetic field.

V. APPLICATIONS

A. Medical field:

- Being developed for cancer treatment.
- Treatment begins by injecting a patient intravenously with a drug that's either encapsulated into a magnetic microsphere (or nano-sphere) or conjugated on the surface of the micro/nano-sphere.
- A magnetic field is then applied to the target site of the patient, thus allowing them to deliver the drug locally.
- Very high concentration of chemotherapeutic agents can be achieved near the target site without any toxic effect to normal surrounding tissue or to whole body.

B. Transportation

- The vehicle will be powered by a magnetohydrodynamics techniques.
- Electrodes will cover each of the vehicle's surfaces and ionize the surrounding air into plasma

C. Geophysics

- MHD is used to predict the inverting of the Earth's magnetic poles.

- Based on the MHD equations, Glatzmaier and Paul Roberts have made a supercomputer model of the Earth's interior.
- Beneath the Earth's mantle, lies the core which is made up of two parts - the solid inner core and liquid outer core - both have significant quantities of iron.
- The liquid outer core moves in the presence of the magnetic field and eddies. These eddies develop a magnetic field which boosts Earth's original magnetic field.

CONCLUSION

It is a unique & highly efficient method of power generation with nearly zero pollution. It is the generation of electric power directly from thermal energy utilizing the high temperature conducting plasma moving through an intense magnetic field. In advanced countries this technique is already in use but in developing countries it's still under construction. Efficiency matters the most for establishing a power plant. MHD power plants have an overall efficiency of 55-60% but it can be boosted up to 80% or more by using superconducting magnets in this process. Whereas the other non conventional methods of power generation such as solar, wind, geo-thermal, tidal have a highest efficiency not more than 35%. Hence by using MHD power generation method separately or by combined operation with thermal or nuclear plants we hope to bring down the energy crisis at a high rate.

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