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Salt Water: A Reliable Alternative as Conducting Fluid for Magneto-Hydro Dynamic Power Generation

Anil D. Awchar[1], Dr.Hari Kumar Naidu[2], Partik Ghutke[3]
[1,2,3](Department of Electrical Engg. Tulshiram Gaikwad Patil College of Engineering and Technology, Nagpur, India)
Corresponding auther: Anil D. Awchar

Abstract : *In this paper the study of use of salt water as a conducting fluid, for electricity generation is presented. From the survey, it is found that the requirement of power will increase in next decade, hence the use of non-conventional energy will also be increased. In non-conventional energy systems, magneto-hydro dynamic (MHD) power generation system is one of the most reliable and lossless systems. The advantages of using MHD power generation in the system is to reduce on carbon and other emissions and to ensure the longevity of our fossil fuel reserve. Since salt water is available in abundance and there are very few applications in which salt water is used as compared to quantity of salt water available in ocean, use of salt water for electricity generation in MHD power generation system, will be most feasible solution. The aim of this paper is to study the viability of using salt water in MHD power generation system and the power output that can be obtained by using salt water as a conducting fluid. The possibility that the output can be varied by changing any of the three values combined with advantages like high efficiency and low pollution should make magneto-hydro dynamic power generation a promising alternative for generation of electricity.*
Keywords *- Conductivity, Flow rate, magnet, MHD Power Generation, salt water.*

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I. Introduction

As the world is facing critical problem of energy deficit, global warming and deterioration of environment and energy sources, renewable sources are getting more attention [1]. We all are aware of power generation using hydel, 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%) [2]. In addition to this, the mechanical components required for converting heat energy into mechanical energy are large in number and considerably costly. This requires huge capital cost as well as maintenance cost also [3].

Now – a – days, the researchers are working to eliminate the mechanical systems and convert thermal energy into electrical energy directly [4]. Unfortunately, no system is yet developed in large capacity (MW) to compete with conventional systems. In addition to this the efficiency of such conversion remained considerably poor (less than10%). Therefore, these power generating systems are not developed on large scale [5].

Magneto-hydro dynamic (MHD) power generation is a new system of electric power generation which is said to be of high efficiency and low pollution. In the countries like India, it is still under construction [6].

II. Basic Concepts Of MHD Power Generation

The magneto hydrodynamic power generator is a device that generates electric power by means of the interaction of a moving fluid (usually an ionized gas or plasma) and a magnetic field. As all direct conversion processes the MHD generators can also convert thermal energy directly into electricity without moving parts. In this way the static energy converters, with no moving mechanical part, can improve the dynamic conversion, working at temperature higher than conventional processes. The typical configuration of MHD generator is shown in Figure 1.

The underlying principle of MHD power generation is elegantly simple. Typically, an electrically conducting gas is produced at high pressure by combustion of a fossil fuel. The gas is then directed through a magnetic field, resulting due to the Hall Effect. The MHD system constitutes a heat engine, involving an expansion of the gas from high to low pressure in a manner similar to that employed in a conventional gas turbo generator.

In the turbo generator, the gas interacts with blade surfaces to drive the turbine and the attached electric generator. In the MHD system, the kinetic energy of the gas is converted directly to electric energy as it is allowed to expand. It is known, that if we have a current flowing in a conductor immersed in a magnetic field, Lorentz force will be generated in the same conductor. This force is perpendicular to the direction of the magnetic field and to the current. The induced emf (E) is given by

$$E = u \times B \quad (1)$$

where
u is the velocity of ionized gas and
B is the strength of magnetic field intensity.

The induced current density (i) is given by

$$i = \sigma \times E \quad (2)$$

where
σ is the electrical conductivity of gas.

The retarding force (F) on the conductor is the Lorentz force, which is given by

$$F = i \times B \quad (3)$$

In a conventional MHD converter, the electrical conductor is replaced by a plasma current at high speed and with high temperature to be partially ionized. So, the current flow is not only made of electrically neutral molecules but also with a mix of positive ions and electrons. When a high velocity gas flows into convergent – divergent duct and passes through the magnetic field, an e.m.f is induced, which is mutually perpendicular to the magnetic field direction and to the direction of the gas flow. Electrodes in opposite side walls of the MHD flow channel, provide an interface to an external circuit. Electrons pass from the fluid at one wall to an electrode, to an external load, to the electrode on the opposite wall, and then back to the fluid, completing a circuit. Thus, the MHD channel flow is a direct current source that can be applied directly to an external load or can be linked with a power conditioning converter to produce alternating current. The electric energy produced is proportional to the reduction of kinetic energy and enthalpy of the fluid current. MHD effects can be produced with electrons in metallic liquids such as mercury and sodium or in hot gases containing ions and free electrons. In both cases, the electrons are highly mobile and move readily among the atoms and ions while local net charge neutrality is maintained. Any small volume of the fluid contains the same total positive charges in the ions and negative charges, because any charge imbalance would produce large electrostatic forces to restore the balance. Most theoretical and experimental studies have focused on high temperature ionized gas as the working fluid. Unfortunately, most common gases do not ionize significantly at temperatures obtainable with fossil fuel chemical reactions. This makes it necessary to seed the hot gasses with small amounts of ignitable materials such as alkali metals.

A system employing an MHD generator offers the potential of an ultimate efficiency in the range of 60 to 65%. This is much better than the 35 to 40% efficiency that can be achieved in a modern conventional thermal power station. The power output of an MHD generator for each cubic meter of its channel volume is proportional to the product of the gas conductivity, the square of the gas velocity, and the square of the strength of the magnetic field through which the gas passes. For MHD generators to operate competitively with good performance and reasonable physical dimensions, the electrical conductivity of the plasma must be in a temperature range above about 1800K.

In practice a number of issues must be considered in the implementation of a MHD generator: Generator efficiency, Economics, and Toxic products. These issues are affected by the choice of one of the three MHD generator designs. These are the Faraday generator, the Hall generator, and the disk generator.

III. PROPOSED SYSTEM – POWER GENERATION USING SALT WATER

When an electric conductor is moved to cut the lines of magnetic induction, the charged particles in the conductor experience a force in a direction mutually perpendicular to the magnetic field and to the velocity of the conductor. The negative charges tend to move in one direction and the positive charges in the opposite direction. This induced electric field or motional EMF provides the basis for converting mechanical energy into electrical energy.

At present, nearly all electrical power generators utilize solid conductors which are made to rotate between the poles of a magnet. In the case of hydroelectric generators, the energy required to maintain the rotation is supplied by the gravitational motion of river water. Turbo generators, on the other hand, generally operate using a high-speed flow of steam or other gas. The heat source required to produce the high-speed gas flow may be supplied by the combustion of a fossil fuel or by a nuclear reactor.

For MHD power generation, the solid conductor of a conventional generator is replaced by a fluid conductor. The fluid can be a liquid metal or heated and seeded noble gas. In an open cycle MHD generator, a fossil fuel, burnt in oxygen or preheated compressed air, is seeded with an element of low ionization (such as potassium or cesium). This element is thermally ionized at the combustion temperature (usually over 2500K) producing sufficient free electrons (e.g. $K \rightarrow K^+ + e^-$) to produce adequate electrical conductivity. The interaction between the moving conducting fluid and the strong applied magnetic fluid across it, generates an E.M.F on the Faraday's principle.

The power output per unit fluid volume (W) is given by

$$W = K\sigma v^2 B^2 \qquad (4)$$

where
σ stands for the conductivity
ν stands for its velocity
B stands for the magnetic flux density and
K is a constant.

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

$$F = Q \cdot (v \times B) \qquad (5)$$

where
F stands for the force acting on the particle
Q stands for the charge on the particle
V stands for the velocity
B stands for the magnetic field.

The vector F is perpendicular to both v and B according to the right-hand rule. In a closed-cycle system of MHD, the fluid is continuously re-circulated through a compressor; the fluid consists of a heated and seeded noble gas or liquid metal.

IV. Calculations

Terms used:

Q= Flow rate in m^3
A= Area of the tube
d= Diameter of the tube
V= Velocity of the fluid
P= Power generated
σ= Conductivity of the fluid
B= Magnetic field intensity

$$Q = \frac{4.9\times10^{-3}}{16} \qquad (6)$$

$$Q = 3.0625\times10^{-4}\ m^3 \qquad (7)$$

$$A = \frac{\pi}{4}(1.3\times10^{-2})^2 \qquad (8)$$

$$A = 1.3273\times10^{-4}\ m^2 \qquad (9)$$

$$Q = A \times V \qquad (10)$$

$$V = \frac{Q}{A} \quad (11)$$

$$V = \frac{3.0625\times10^{-4}}{1.3273\times10^{-4}} \quad (12)$$

$$V = 2.3 \text{ m/s} \quad (13)$$

$$P = \frac{1}{4}\times\sigma\times V^2\times B^2 \quad (14)$$

$$P = \frac{1}{4}\times12.8\times2.3^2\times0.057^2 \quad (15)$$

$$P = 0.055 \text{ W} \quad (16)$$

V. EXPERIMENTAL SET UP

Step 1:The basic arrangement of bottle, electrodes that are perpendicular to each other is shown in Figure 2.

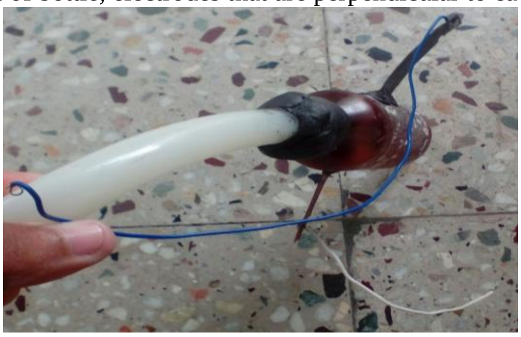

Figure 2 Basic arrangement

Step 2:Pump is there to supply or give velocity to fluid or brine. A pipe is connected to one end of the bottle. Bottle is used as channel.
Step 3:There is a tub shown in the Figure 3 in which the Sodium chloride (NaCl) solution is kept with salt water.
Step 4:Now supply of single phase 230V is given to pump.

Figure 3 Sodium Chloride (Salt) solution kept in tub

Step 5:Electrodes and magnets are placed such that electrodes are perpendicular to magnetic lines and the flow of brome that is NaCl solution.
Step 6:Both the magnets are placed and supply is given to the pump.
Step: 7The generated voltage which may be observed in multimeter is found to be 0.78 V.

VI. CONCLUSION

We can conclude that, using salt water as a conducting fluid, electricity can be generated. As salt water is available in abundance and there are very few applications in which salt water is used as compared to quantity of salt water available in ocean, salt water may prove to be very cheap and reliable conducting fluid compared to plasma.

However, the amount of electricity generated with the same amount of salt water as that of plasma, is less and the efficiency of the proposed system is also theoretically less.

It may further be noted that amongst all non-conventional energy sources, MHD is the most reliable and lossless system.

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