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Magnetohydrodynamic Power Generation(MHD) using Salt Water as conducting fluid

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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 increased in next decade, hence the solution will be use of non-conventional energy. In non-conventional energy MHD is most reliable and lossless system. The advantages of using MHD power generation in the system will not only cuts back on carbon and other emissions but also ensure the longevity of our fossil fuel reserve. The downside of it is that only the Lorentz force law coupled with the definition of work has been invoked. Certain other problems, however, naturally present themselves for consideration. They include the problem of magnetic reconnection and a fluid thermal gradient which creates eddies in the charged moving fluid, dissipating the energy of the system. 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, so use of salt water for electricity generation will be most feasible solution.**

The aim of this paper is to study the viability of using salt water for generation of electricity and the power output that can be obtained by using salt water as a conducting fluid. When experimented with velocity of 2.23m/s, conductivity of 12.8 Siemens and magnetic field of 0.057wb/m2 the output was observed as 0.78V. 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 MHD power generation a promising alternative for generation of electricity.

Keywords-MHD Power Generation, Salt Water

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. 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%).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 scientists are thinking to eliminate the mechanical system and convert thermal in to direct electrical energy for the last 50-years and more.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.

MHD power generation is a new system of electric power generation which is said to be of high efficiency and low pollution. In advanced countries like India it is still under construction. This construction work is in progress at Trichi in Tamil Nadu under joint efforts of BARC(Bhaba Atomic Research Centre)BHEL,Associated Cement Corporation (ACC) and Russian Technologists.

As the name implies, Magnet Hydro Dynamics (MHD) is concerned with flow of the conducting fluid in the presence of magnetic and electric field. The fluid may be gas at elevated temperature or liquid metal like sodium or potassium. A MHD generator is a device for converting heat energy of fuel directly into electrical energy without conventional electric generator. Inthis system, a MHD converter system is a heat engine,in which heat is taken up at a higher temperature is partly converted into useful(electrical) work and the remainder is rejected at a lower temperature.Like all heat engines,the thermal efficiency of MHD converter (i.e. the proportion of heat taken up that is converts into useful work) is increased by supplying the heat at the highest practical temperature and rejecting it at the lowest practical temperature.

MHD generation looks the most promising of the direct conversion techniques for the larger scale production of electric power. It is observed that economic and physical factors will lead to design outputs of the order of 1000MW. In fact MHD is really of interest only for central power generation, its potentialities for a propulsion unit are remote.

The basic principle of MHD power generation is that when an electric conductor moves across a magnetic field, a voltage is induced in it which produces an electric current. This is the principle of conventional generator also, where the conductors consist of copper strips. In MHD generator, the solid conductors are replaced by a gaseous conductor; an ionize gas. If such a gas is passed at a high velocity through a powerful magnetic field, a current is generated and can be extracted by placing electrodes in a suitable position in the stream.

II. COMPARISON OF RENEWABLE AND CONVENTIONAL ENERGY SOURCES

Electrical energy is one of the necessary components in our life. Now a days, without electricity, it is difficult to sustain in the world of technology. So the energy sources are classified under two heads on the availability of the raw materials used for generation. So based on availability, there are two types of resources of energy:

1 Renewable energy sources
2 Non Renewable energy sources

As the name suggests, the sources of energy which cannot be renewed or reused are called non renewable energy sources. Basically, these are the energy sources which gets or will get exhausted in future. Some of the examples of this kind of sources are coal, oil, nuclear energy etc.

Secondly, renewable energy sources are the kind of energy source which can be renewed or used again and again. These kinds of sources do not exhaust of literally speaking these are available in abundance. Example of this kind includes:

1 Solar energy
2 Wind energy
3 Tidal energy
4 Geothermal energy
5 MHD (Magneto hydro dynamic) generation

Sometimes renewable energy sources are called non-conventional sources of energy. Since, these kinds of sources or ways of energy production with these resources were not used earlier. Similarly, the other non-renewable sources are also called conventional energy sources since these ways have been in practice for many years.

The main objectives of this paper are as follows:

1 To make the readers aware about various renewable energy technologies available in the world today.
2 To examine the MHD power generation using salt water.
3 Observing the voltage and power.
4 Analysis of parameters like conductivity, magnetic strength and velocity.

III. LITERATURE SURVEY

Detailed technical literature survey concerned with non-conventional systems, Magneto Hydro Dynamics (MHD) systems, from IEEE transactions, conferences, Applied Energy Journal and various national and international journals of repute were carried out and following are the salient features of literature survey in nutshell:

Considerable efforts have been expended towards increasing the efficiency of the standard variety of electric power generating equipment. It has been proposed to generate electricity by extracting energy from moving electrically conducting fluid, as it passes through a magnetic field. By using fluid conductor instead of a solid conductor the fluid may be driven through a magnetic field without employing rotating or moving mechanical parts.

Samuel O. Mathew, Obed C. Dike, Emmanuel U Akabuogu , and Jemima N. Ogwo , Magneto hydrodynamics (MHD) is the study of the dynamics of electrically conducting fluids such as salt water. The principle of operation of MHD power generator is based on Faraday's induction law. This work concerns the feasibility of developing MHD generator in which the working fluid is flowing salt water, such that a resource like the Atlantic Ocean in Nigeria can be used to generate electricity. Furthermore, the practical possibility of MHD in Nmahi River in Uburu, Ebonyi State can also be explored.In accordance to this the aim of the project is to calculate the power and voltage generated and analyze change in power depending on various parameters. Experiment is done for the same and power has been calculated.

IV. DIRECT ENERGY CONVERSION SYSTEMS

The possibilities of improving significantly the conventional energy conversion processes are mainly related to technological progress. They still have small margins and for this reason the researchers have turned to the development of other systems, socalled no-conventional. In the conventional conversion

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systems a significant loss of energy occurs in the transition from thermal to mechanical energy (thermodynamic conversion). Research is focusing its efforts on conversion processes that do not use this step. The absence of moving mechanical parts may allow the achievement of operating temperatures much higher than those typical of conventional processes, resulting therefore, at least potentially, a higher conversion efficiency. These processes are known as direct conversion, as primary and secondary energy is converted directly into electricity without the need to pass through a stage of mechanical energy. The direct energy conversion methods that nowadays are considered in terms of industrial application are:

• Photovoltaic generation systems (Photovoltaic Solar Cells)
• Electrochemical energy conversion (Fuel Cells)
• Magneto hydrodynamic generation (MHD)
• Electrogasdynamic generation (EGD)
• Thermoelectric power generation.

In the first two processes the conversion from the primary to the secondary energy form takes place avoiding the conversion in the intermediate thermal energy. The Figure 1 shows the energy conversion stages in the direct generation of electric energy

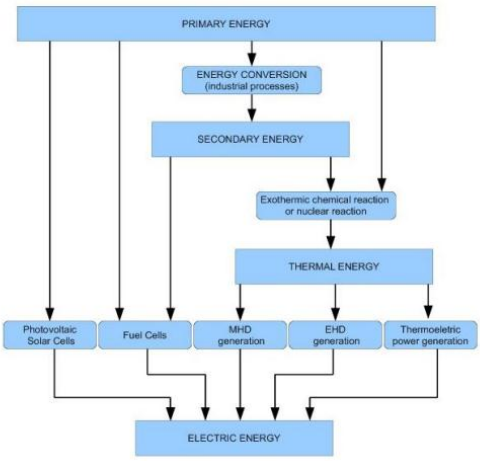

Fig1 Energy Conversion Stages

V. MAGNETOHYDRODYNAMIC 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 2.

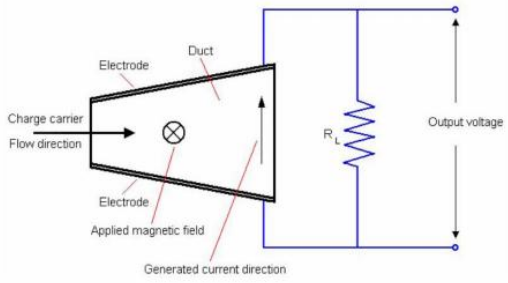

Fig. 2 Configuration of MHD generator

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, in the same conductor will be generated a Lorentz force that is perpendicular to the direction of the magnetic field and to the current. The induced emf(E) is given by

$Ei = u XB$

where u is the velocity of ionized gas and
B is the strength of magnetic field intensity.
The induced current density is given by

$i = \sigma XE$

where σ is the electrical conductivity of gas.
The retarding force on the conductor is the Lorentz force given by

$F = I X B$

In an 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 an high velocity gas flows into convergentdivergent duct and passes through the magnetic field an e.m.f is induced, mutual 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 work and power plant development and application 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. Materials such as cesium and potassium have ionization potentials low enough that they ionize at temperatures obtainable with combustion reaction in air. Recovery and reuse of seed materials from the MHD channel exhaust are usually considered necessary from both economic and pollution standpoints. Interest in MHD power generation was originally stimulated by the observation that the interaction of a plasma with a magnetic field could occur at much higher temperatures than were possible in a rotating mechanical turbine. The limiting performance from the point of view of efficiency of a heat engine is limited by the Carnot cycle. 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 metre 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. Apart of the MHD power generator, other apparatus are necessary to form the overall MHD system. It is necessary to burn the fuel and the oxidizer, to add the seed, and to make arrangements for exporting the generated electrical power. The fuel is usually fossil and the oxidizer is air, for obvious economic reasons. For large systems, some precautions should be taken to limit the amount of losses. The air may be enriched with more oxygen, and preheating of the incoming oxidizer becomes necessary to allow thermal ionization. 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.

VI. POWER GENERATION USING SALT WATER

When an electric conductor is moved so as to cut lines of magnetic induction, the charged particles in the conductor experience a force in a direction mutually perpendicular to the B 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 caused 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 magneto hydrodynamic 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 eg ($K \rightarrow K^+ + e$) 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 principle. The power output per unit fluid volume (W) is given by $W = K\sigma v 2B 2$ Where σ stands for the conductivity v stands for its velocity B stands for the magnetic flux density 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

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

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.

VII. 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

$Q=\frac{4.9\times10^{-3}}{16}$

$Q=3.0625\times10^{-4}\ m^3$

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

$A=1.3273\times10^{-4}\ m^2$

$Q=AV$

$V=\frac{Q}{A}$

$V=\frac{3.0625\times10^{-4}}{1.3273\times10^{-4}}$

$V=2.3$ m/s

$P=\frac{1}{4}\times\sigma\times V^2\times B^2$

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

$P=0.055$ W

VIII. EXPERIMENTAL SETUP

The basic arrangement of bottle, electrodes that are perpendicular to each other is shown. 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. There is a tub shown in the picture in which the Sodium chloride solution is kept with salt water.Now supply of single phase 230V is given to pump.Electrodes and magnets are placed such that electrodes are perpendicular to magnetic lines and the flow of brome that is NaCl solution.Both the magnets are placed and supply is given to the pump.The voltage that is observed in multimeter is 0.78 V.

Fig. 3 Voltage Generated

IX. CONCLUSION

Hence from our study we conclude that, using salt water as a conducting fluid electricity can be generated .As addition capacity of power will increased in next decade the answer is non conventional energy .In non conventional energy MHD is most reliable and lossless system. As salt water is available in abundance and there are very few application in which salt water is used as compared to quantity of salt water available in ocean , so we can utilized that.

We have seen that the advantages of MHD power generation using the system which include the absence of moving parts such as blades which may constitute hazard to swimming sea life, the absence of green house emissions, the fact that water used is returned to sea eventually, thereby not altering the ecosystem and the obvious implication of reducing dependence on conventional fossil fuels, which not only cuts back on carbon and other emissions, but also ensures the longevity of our fossil fuel reserve. The downside of it is that only the Lorentz force law coupled with the definition of work, which leads to an estimate of motional EMF in a medium such as flowing salt water, which contains charged ions, has been invoked. Certain other problems, however, naturally present themselves for consideration. They include the problem of magnetic reconnection and a fluid thermal gradient which creates eddies in the charged moving fluid, dissipating the energy of the system.

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