DESIGN ANALYSIS OF MAGNETOHYDRODYNAMIC (MHD) ELECTRICAL POWER GENERATION TECHNOLOGY.

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Abstract.
Power generation has been an age-long issue in African countries. Insufficient power generation has hampered many developmental activities as many manufacturing companies found it difficult to operate in this region. Efforts are on high gear to provide alternative sources of electrical energy. Solar, wind, dam technologies among others have been found helpful in many settings but each has its own peculiar limitations and disadvantages. In the south east of Nigeria, there are abundances of coal and gas deposits. This work therefore is poised towards harnessing these natural resources to generate constant electricity using the magneto-dynamics technology. In Magneto-dynamics technology plasma is directed in between two bar magnet, as the plasma is passing through the two bar magnet, electricity is generated. These coal and gas are available in large quantities for heating the liquids into gaseous (ionized) state. This work observed that this technology can be improved upon by increasing the ionization process. An obvious limitation of this technology cost of high rated inverter required to convert the direct current output voltage to alternating current being used by many devices.

Key words:
Magneto-hydrodynamic (MHD), coal and gas *plasma*, *ionization, electric field and magnetic field.*

INTRODUCTION

Electrical Power generation has been an age-long issue with the developing nations world over. Insufficient Electrical Power generation has hampered many developmental activities. This has negates the smooth operations of many business and domestic setups that they found it difficult to operate in these regions. Efforts are on high gear to provide alternative sources of electrical energy. Solar, wind, dam technologies among others have been found helpful in many settings but each has its own peculiar limitations and disadvantages.

Magneto hydrodynamic (MHD) 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 an energy device, the MHD generator has very interesting characteristics which make it suitable for a variety of special applications. In an MHD generator the functions of both turbine and electric power generator are combined into a single unit with a simple compact geometry. There are no rotating parts which eliminate vibrations and noise and limits wear and tear. The MHD systems operate at higher temperatures than mechanical turbines with consequent saving in area, weight and cost of the radiator of the space power systems and it also leads to better efficiencies. High power turbines operating at high temperatures and speeds are less reliable than MHD systems due to high stress values. The DC type electric power output and the start-up time as low as a few milliseconds makes this power generation scheme very attractive.

In the south east of Nigeria, there are abundances of coal and gas deposits. This work therefore is poised towards harnessing these natural resources to generate constant electricity using the Magneto hydrodynamic (MHD) technology. In this technology plasma is directed in between two bar magnet, as the plasma is passing through the two bar magnet, electricity is generated. Coal and gas are useful in heating the liquids into gaseous (ionized) state, plasma. This work observed that this technology can be improved upon by increasing the ionization process etc.

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.

PRINCIPLES OF MHD POWER GENERATION

MHD generator converts mechanical energy of the fluid directly into electric energy. It works with physics background of space plasma. Magneto hydrodynamic (MHD) generator is commonly known as a fluid dynamo. This is comparable to a mechanical dynamo where the motion of a metal conductor through a magnetic field creates a current in the conductor. In MHD generator, the metal conductor is replaced by conducting gas plasma. The movement of the conductor (plasma) through the magnetic field generates an electrical field perpendicular to the magnetic field. This principle was discovered by Michael Faraday's MHD generator converts mechanical energy of the fluid directly into electric energy. In a MHD channel a conducting fluid is passed through a transverse magnetic field B. The free charge carriers inside the conducting fluid have a component of velocity U along the flow direction same as that of the neutral particles. The charge particles experience a force perpendicular to both U and B. This leads to flow of electric current in the perpendicular direction.

The flow (motion) of the conducting plasma through a magnetic field causes a voltage to be generated (and an associated current to flow) across the plasma, perpendicular to both the plasma flow and the magnetic field according to Fleming's Right Hand Rule. In a MHD channel a conducting fluid is passed through a transverse magnetic field B. The free charge carriers inside the conducting fluid have a component of velocity U along the flow direction same as that of the neutral particles. The charge particles experience a force perpendicular to both U and B. This leads to flow of electric current in the perpendicular direction.

Lorentz Law describing the effects of a charged particle moving in a constant magnetic field can be stated as
$F = QVB$ ⋯⋯⋯⋯⋯⋯⋯.. eq 1
Where
F is the force acting on the charged particle
Q is charge of particle
V is velocity of particle
B is magnetic field.

MHD GENERATOR DESIGNS:

The heating of a gas to its plasma state can be enhanced by the addition of other ionizable substances like the salts of alkali metals. A number of issues like efficiency, economics, and toxic hypo ducts are being considered in the design and implementation of an MHD generator. Three most commonly MHD generator designs are the faraday generator design, the hall generator design, and the disc generator design.

FARADAY MHD GENERATOR:

A simple faraday generator would consist of a wedge-Shaped pipe or tube of some non-conductive material. When an electrically conductive fluid flowed through the tube, in the presence of a significant perpendicular magnetic field, a charge is induced in the field, which can be drawn from it as electrical power by placing the electrodes on the sides at 90 degree angles to the magnetic field there are limitations on the density and type of field used. The amount of power that can be extracted is proportional to the cross sectional area of the tube and the speed of the conductive flow. The conductive substance is also cooled and showed by this process. MHD generators typically reduce the temperature of the conductive substance from plasma temperatures to just over 1000^{0}C.
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. It is also characterized with powerful waste from the Hall Effect current. This makes the faraday duct very inefficient.

HALL MHD GENERATOR

The most common solution is to use the Hall Effect to create a current that flows with the fluid. The normal scheme is to the duct. The first and last electrodes in the duct power the load. Each other electrode is shorted to an electrode on the opposite side of the duct. These shorts of the faraday current induce a powerful magnetic field within the fluid, but in a chord of a circle at right angles to the faraday current. This secondary, induced field makes current flow in a rainbow shape between the first and last electrodes losses are less than a faraday generator and voltage are higher because there is less shorting of the final induced current.
However, this design has problems because the speed of the material flow requires the middles electrodes to be offset to "catch" the faraday currents. As the load varies, the fluid

flow speed varies, misaligning the faraday current with its intended electrodes, and making the generators efficiency very sensitive to its load.

DISC MHD GENERATOR

Presently, the most efficient MHD generator design is the Hall Effect disc generator design. It holds the efficiency and energy density records for MHD generation. It is in form of disc and a duct wrapped around the edge. The magnetic excitation field is made by a pair of circular Helmholtz coils above and below the dish. The faraday currents flow in a perfect dead short around the periphery of the disk. The Hall Effect currents flow between ring electrode near the center and ring electrodes near the periphery.

A number of features make disc MHD generator design the most efficient. First, it has simple parallel field lines. Also the fluid is processed in a disk making the magnet very close to the fluid thereby strengthens the magnetic field. Besides, the generator is compact for its power, the magnet is smaller, and the resulting magnet uses a much smaller percentage of the generated power.

Maxwell's equations

The basic laws of electromagnetism are explained in terms of four vector relations stated below, which are known as the Maxwell's equations. These relations are expressed in the form of gradient and curl of the electric field E and magnetic field B vectors.

E. dA = Q/ϵ .... *Gauss Law*

B. dA = 0 ··
Ampere Law

E x dA = −dB/dt ···················· *Faraday law*

B x dA = µ. (j + ϵ dE/dt) ··········· *eq 2*

Where,
Ω is the free charge density (coul/m),
J is the current density (amp/m2),
μ is the permeability of the medium (Henry/m),
ϵ is the permittivity of the medium (Farad/m).

The MHD System

The MHD generator needs a high temperature gas source, which could be the coolant from a nuclear reactor or more likely high tempera-

ture combustion gases generated by burning fossil fuels, including coal, in a combustion chamber.

The expansion nozzle reduces the gas pressure and consequently increases the plasma speed (Bernoull's law through the generator duct to increase the power output. Unfortunately, at the same time, the pressure drop causes the plasma temperature to fall (Gay-lussac Law) which also increases the plasma resistance, so a compromise between Bernouilli and Gay-Lussac must be found. The exhaust heat from the working fluid is used to drive a compressor to increase the fuel combustion rate but much of the heat will be wasted unless it can be used in another process.

The Plasma: The prime MHD system requirement is creating and managing the conducting gas plasma since the system depends on the plasma having a high electrical conductivity. The plasma can be likened to the fourth state of matter after the solid, liquid and gaseous states, in which the atoms or molecules are stripped of their electrons leaving positively charged ions. Suitable working fluids are gases derived from combustion, noble gases, and alkali metal vapors.

The Gas Plasma: To achieve high conductivity, the gas must be ionized by detaching the electrons from the atoms or molecules leaving the positively charged plasma. The plasma flows through the magnetic field at high speed, in some designs, more than the speed of sound, flow of the positively charge particles providing the moving electrical conductor necessary for inducing a current in the external electrical circuit.

Method of Ionizing the Gas: Various methods for ionizing the gas are available, all of which depend on imparting sufficient energy to the gas. It may be accomplished by heating or irradiating the gas with X-rays or Gamma rays. It has also been proposed to use the coolant gases such as helium and carbon dioxide employed in some nuclear reactors as the plasma fuel for direct MHD electricity generation. Rather than extracting the heat energy of the gas through heat exchangers to raise steam to drive turbine generators. Seed materials such as potassium carbonate or cesium are often added in small amounts, typically about 1% of the total mass flow to increase the ionization and improve the conductivity, particularly of

combustion gas plasmas.

Containment: Since the plasma temperature is typically over $1000^{\circ}C$, the duct containing the plasma must be constructed from non conducting materials capable of withstanding these high temperatures. The electrodes must of course be conducting as well as heat resistant plasmas used in nuclear fusion reactors have a different function and fun at much higher temperatures.

The Faraday Current: A powerful electromagnet provides the magnetic field through which the plasma flows, and perpendicular to this field are installed the two electrodes on opposite sides of the plasma across which the electrical output voltage is generated. The current flowing across the plasma between these electrodes is called the Faraday current. This provides the main electrical output of the MHD generator.

The Hall Effect Current: The very high Faraday output current which flows across the plasma duct into the load itself reacts with the applied magnetic field creating a Hall Effect current perpendicular to the Faraday current, in other words, a current along the axis of the plasma, resulting the lost energy. The total current generated will be the vector sum of the transverse (Faraday) and axial (Hall Effect) current components. Unless it can be captured in some way, the Hall Effect current will constitute an energy loss.

Various configurations of electrodes have been devised to capture both the Faraday and Hall Effect components of the current in order to improve the overall MHD conversion efficiency.

One such method is to split the electrode pair into a series of segments physically side by side (parallel) but insulated from each other, with the segmented electrode pairs connected in series to achieve a higher voltage but with a lower current instead of the electrodes being directly opposite each other, perpendicular to the plasma stream, they are skewed at a slight angle from perpendicular to be in line with the vector sum of the faraday and Hall Effect currents; allowing the maximum energy to be extracted from the plasma.

Power Output: The output power is proportional to the cross sectional area and the flow rate of the ionized plasma. The conductive substance is also cooled and showed in this process. MHD generators typically reduce the temperature of the conductive substance form plasma temperatures to just over $1000^{\circ}C$. An MHD generator produces a direct current output which needs an expensive high power inverter to convert the output into alternating current for connection to the grid.

Efficiency: Typical efficiencies of MHD generators are around 10 to 20 percent mainly due to the heat lost through the high temperature exhaust.

This limits the MHD's potential applications as a standalone device but they were originally designed to be used in combination with other energy converters in hybrid application where the output gases (flames) are used as the energy source to raise steam in a steam turbine plant. Total plant efficiencies of 65% could be possible in such arrangements.

MHD PLANT DESIGN

Plant design is simply a model that explains the pattern of a design in a laboratory to know how it will be perform in the field.

From practical design, we have two 12m width by 15m length bar magnet placed opposite each other or highly energize bar magnet and ionized gas (plasma) is pumped into the medium with the help of a pumper at a very high speed, according to magnetic theory, magnetic field is experienced around the medium which when the high speed plasma (ionized collide) with the magnetic flux, positive charge is produced at the terminal of south pole while negative charge is produced through the north pole with the help of electrodes which both positive and negative charge, the charge produced is measured with an ammeter and I recorded 0.1 volt.

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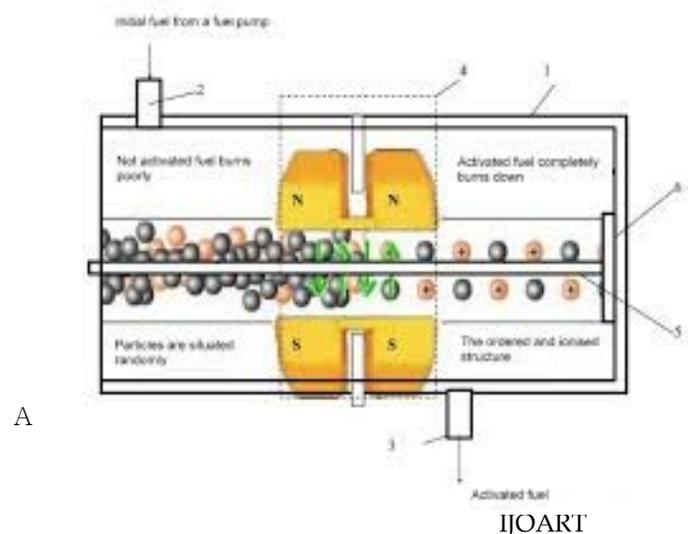
large charge can be produce through processing the size of the magnet; the nature of the plasma used and the increasing speed flow of the plasma. The D.C. output of the magnet dynamics can be converted to A.C. (Alternative Circuit) through the double cycle diode.

So through the plant design we can deduce that above technology can be obtain in the field after establishing a model and the model performed well in the laboratory.

Plasma:

Both lightening and electric sparks are every day examples of phenomena made from plasma. Neon lights could more accurately be called Plasma lights because the light comes from the plasma. The colors are as a result of relaxation of electrons in excited states to lower energy states after they have recombined with ions. These processes emit light in a spectrum characteristic of the gas being excited.

Plasma can be created by heating a gas or subjecting it to a strong electromagnetic field applied with a Laser or Microwave generator.

The presence of a significant number in charge carries makes plasma electrically conductive so that it responds strongly to electromagnetic fields. Like gas plasma does not have a defi-nite shape or a definite volume unless enclosed in a container. Unlike gas, under the influence of a magnetic field, it may form structures such as filaments, beams and double layers.

Bar Magnet:

Magnet is an electromagnetic force where magnetic field is experienced. An infinite number of parallel wires all carrying the same current.

CONCLUSION AND RECOMMENDATION

Magneto dynamics plasma is abundant, so to assemble magneto dynamic is not difficult. A power generator from magneto dynamics can be used to illuminate our home. With the help of big inverter, a D.C. output can be converted to A.C. output and sent to grid. It is not hard to build. Magneto dynamics can create employment to energy engineers. However Magneto dynamics gives D.C. output. Inverter that can convert D.C. output to A.C. and send to grid is highly expensive. It is not reliable to power larger network. Since it is D.C., protection is minimal. Magneto dynamics has to be improved in line to source of energy generation on like hydro and solar system.

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