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Magnetohydrodynamic Open Cycle Power Generator and Selection of Carrier Gas and Seed

Jayesh Petkar[1]

Alumnus, Dept. of Electrical Engineering, Zeal College of Engineering and Research, Pune, Maharashtra, India[1]

ABSTRACT: This paper opens with a review and discussion of he basic principles of MHD power generation. It is seen that the MHD generator operates in a manner similar to that of the conventional generator in which the “armature” of the MHD is a hot, high-speed, electrically conducting gas, while the force or torque required to move a metallic conductor through a field is replaced by a pressure gradient in the gaseous armature. Thus the function of turbine and generator are combined in a single machine. In gases, the Hall effect can be very pronounced and its influence on MHD generator design and performance is pointed out. It is shown that gases produced by conventional heat sources can be made adequate conductors of electricity for use in an MHD if a small amount of easily ionizable impurity called seed is added to the gas. Recent developments in superconducting materials, plus detailed studies of MHD-generator fluid mechanics in a large combustion-driven generator point to early realization of the potential of MHD.

KEYWORDS: MHD, Carrier gas, seed, collision profile, molecular weight

I.INTRODUCTION

The Magnetohydrodynamic power generation technology is the production of electrical power utilizing a high temperature conducting plasma moving through an intense magnetic field. The conversion process in MHD was initially described by Micheal Faraday in 1893. However the actual utilization of this concept remained unthinkable. The first know attempt to develop an MHD generator was made at westing house research laboratory(USA) around 1936.

The efficiencies of all modern thermal power generating sstem lies between 35-40% as they have to reject large quantities of heat to the environment. For the conventional power plants thermal energy is converted in to kinetic energy which is then converted into electrical energy. For MHD, thermal energy is directly converted to electrical energy, hence know as direct energy conversion system. The MHD power plants can be classified as open and closed cycle based on the nature of processing of the working fluid.

The MHD process can be used not only for commercial power generation but also for so many other applications. It is economically attractive from the design point of view and as far as bulk generation of power is concerned. The Extensive use of MHD in saving billions of dolloars towards fuel prospects, lead to much better fuel utilization but the potential of lower capital costs with increased utilization of invested capital also provides a very important economics incentice in this case. The high temperature of MHD process makes it possible to take advantage of the highest flame temperatures which can be produced by combussion of fossil fuels. Commercial nuclear reactors able to provide heat for MHD generators have yet to be developed. The combined use of MHD generatos with nuclear heat source holds a great promise for the future.

II. RELATED WORK

The U.S.S.R. National Programme on MHD Electrical Power Generation pur- sues a very active path which can, at present, be roughly divided into the following two stages:

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1. Construction by 1985 of a commercial MHD combined-cycle natural gas plant, followed by the construction of Several similar plants operating on oil in metropolitan areas, and
2. Construction of MHD power plants operating on coal, with start-up of the first commercial plant in the early nineties.

The two-stage approach is being pursued; however, the predominant fuel in MHD plants in the U.S.S.R. is expected to be coal. Adoption of the two-stage approach is expected to speed the commercialisation of MHD in the U.S.S.R. Stage 1 of the present U.S.S.R. programme, to be completed by the mid-l980s, has already started. The first “commercial” plant will be the U-500 Ryazan Power Station (250 MWe topping, 250 MWe bottoming cycle). Construction on site has been initiated, the design of the plant components has been completed and consultation by U.S.S.R. industries on the manufacturing of the components is taking place.

III. WORKING PRINCIPLE

The MHD generator can be considered to be a fluid dynamo. This is similar to a mechanical dynamo in which the motion of a metal conductor through a magnetic field creates a current in the conductor except that in the MHD generator the metal conductor is replaced by conducting gas plasma.

When a conductor moves through a magnetic field it creates an electrical field perpendicular to the magnetic field and the direction of the movement of the conductor. This is the principle, discovered by Micheal Faraday, behind the conventional rotary electricity generator. Dutch physicist Antoon Lorentz provided the mathematical theory to quantify its effects.

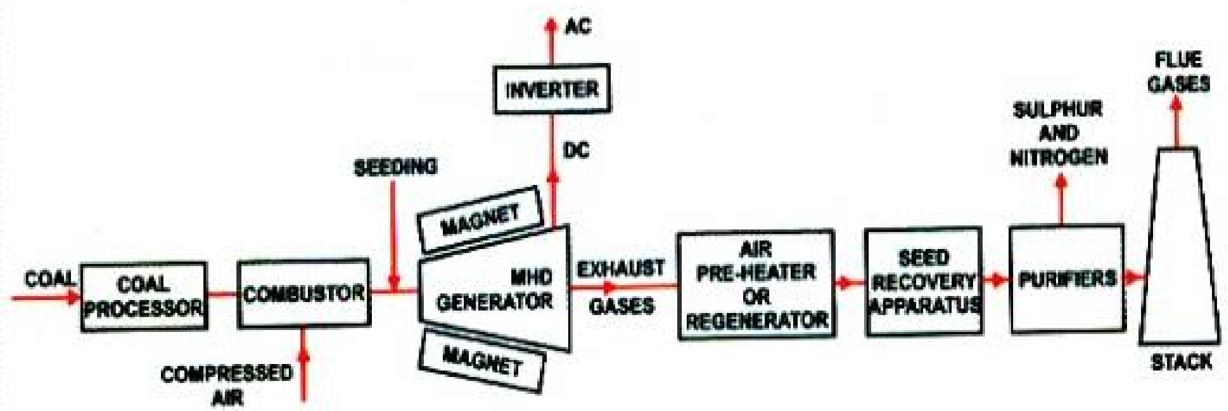

Fig 1. Open Cycle MHD generator

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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 and the magnetic field according to Flemings Right Hand Rule.

Lorentz Law describing the effects of a charged particle moving in a constant magnetic field can be stated as

$F = QvB$

Where

- F is the force acting on the particle.
- Q is the charge of the particle,
- v is the velocity of the particle, and
- B is the magnetic field.

IV. MHD SYSTEM

The MHD generator needs a high temperature gas source, which could be the coolant from a nuclear reactor or more likely high temperature combustion gases generated by burning fossil fuels, including coal, in combustion. With an open cycle type of generation, new working gas is constantly produced and fed into the channel of the generator. The substance added to the working gas to raise its conductivity leaves the generator together with the waste working gases. The possibility that the additive is deposited on the post-connected heat exchangers has to be taken into account but those are undoubtedly small.

V. SELECTION OF CARRIER GAS AND SEED

The prime system requirement is creating and managing the conducting gas plasma since the system depends on the plasma having a high electrical conductivity. Suitable working fluids are gases derived from combustion, noble gases and alkali metal vapours.

Since the gases used as flow media are ionized only to a limited degree because their temperature must be kept within tolerance by the components of the generator, it becomes necessary to seed the gas with an additional material in order to increase its conductivity. This seed material has atoms which ionize easily, for example, cesium, potassium and calcium, and by supplying electrons causes an increase in the electrical conductivity of the gas. However, it is not possible to raise the electrical conductivity by increasing the concentration of the seed material at will because the collision profiles of the seeded molecules are usually much greater than the collision profiles of the carrier gases, and an increase in the concentration of the seed material would lead to an increase of the mean collision profile also. In an open cycle MHD generator, using costly seed material like cesium will only increase the cost of operation and lower the efficiency of the same. Thus, cheaper alternatives like potassium can be used.

The electrical conductivity carrier gas mixed with appropriate quantity of seed depends upon:

- Collision profile - The collision profile of a gas stream is defined as a value that is proportional to the probability of collisions of gas atoms with an electron. Since these collisions of gas atoms with the electrons reduce the mobility of the electrons within an electrical field, a high collision profile is synonymous to a low electrical conductivity.

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- Molecular weight - The power density is inversely proportional to the molecular weight of the gas, therefore, in order to attain a high power density it will be advantageous to select a carrier gas with a low molecular weight.

Considering collision profile and molecular weight, noble gases such as helium and argon can be used. But both of these have a higher collision profile and molecular weight than a polyatomic hydrogen molecule. Hence, hydrogen as a carrier gas and potassium as a seed is used.

VI. OUTPUT POWER

The output power is proportional to the cross sectional area and the flow rate of the ionized plasma. The power generated per unit length by MHD generator is approximately given by,

$$\text{Power} = \sigma\mu B/P$$

Where,

- μ is the fluid velocity,
- B is the magnetic flux density,
- σ is the electrical conductivity of conducting fluid and
- P is the density of fluid.

VII. ADVANTAGES OF MHD GENERATOR

- Here only working fluid is circulated, and there are no moving mechanical parts. This reduces the mechanical losses to nil and makes the operation more dependable.
- The temperature of working fluid is maintained the walls of MHD.
- It has the ability to reach full power level almost directly.
- The price of MHD generators is much lower than conventional generators.
- MHD has very high efficiency, which is higher than most of the other conventional or non-conventional method of generation.

VIII. CONCLUSION

With the increased industrial and agricultural activities, power demand is also highly increased. In such situation, additional capacity of power is required. The answer to this is in non-conventional energy as the conventional sources are already depleting at a very rapid pace. The MHD power generator is in advanced stage today and closer to commercial utilization. It will not be long before the technological problem of MHD systems will be overcome and MHD system would transform itself from non-conventional to conventional energy sources.

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