CONCEPTUAL DESIGN AND APPLICATION OF LIQUID METAL MHD SYSTEM FOR HYDROGEN PRODUCTION

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Liquid Metal MHD Power Conversion systems have recently been proposed for direct electrical energy conversion of low grade thermal source of energy, light solar energy and waste heat. Such systems can be used for generating hydrogen by electrolysis of water. Some preliminary investigations have been presented in this paper.

Introduction. The future economical growth critically depends on long term availability of energy from sources that are affordable, accessible and environmentally friendly. Non-conventional energy sources such as solar, ocean, winds, waves etc. are only partially able to meet growing demand, besides none of these sources have all the desirable utilities of petroleum and natural gas. Hydrogen is a clean source of energy that has all the desirable qualities to replace the petroleum/gas. It can be stored until it is needed and transported to where it is required. It does not emit any pollutants during combustion and contribute minimum to global warming. Huge resources of hydrogen are available in the form of water. Any type of water can be utilized for producing hydrogen, whether it is soft, salty or waste water. One of the most efficient way to get the hydrogen from any form of water is electrolysis, where electricity can be converted into hydrogen with more than 80% efficiency [1]. Getting cheap electricity for this purpose is however a problem. The conventional power obtained from grids, which is based on fossil fuel is costly and pollutes the environment. Besides costly inverters are required for D.C. Power as applicable for electrolysis. For getting cheap and pollutant free, D.C. Power, Liquid Metal Magneto hydro Dynamics (LM-MHD) systems have been proposed, which can utilize low temperature and low heat sources such as solar systems and waste heat from various processes [2]. Satyamurty *et al.* [3] have proposed a gravitational prototype LM MHD system for utilizing solar and waste heat, however such system have large physical dimensions (length of riser is in excess of 25 m), low power densities and have, therefore, limited utility. Inertial MHD systems, on the other hand, have such limitations. In the following sections we propose an inertial LM-MHD system for the applications in electrolysis of water for hydrogen production.

1. Solar assisted LM MHD Rankin cycle with liquid metal cooled solar concentrations. A non gravitational two phase fluid flow solar assisted LM MHD system is shown in Fig. 1. In this system a liquid metal is heated in a solar concentrator and then enters a mixer. A water / organic liquid is injected into the liquid metal in the mixer, where it boils due to direct heat transfer from the latter. The thermodynamic fluid (water / organic salt) undergoes an isothermal expansion and accelerates the flow of two-phase mixture into the MHD channel with the help of a nozzle. The gas generated from the thermodynamic fluid is separated from the liquid metal in a separator and then cooled and condensed in the condenser from, where it is pumped to the mixer. The liquid metal is separated in the separator and cooled down into a diffuser, from where it is sent to the solar collector with the help of an EM pump.

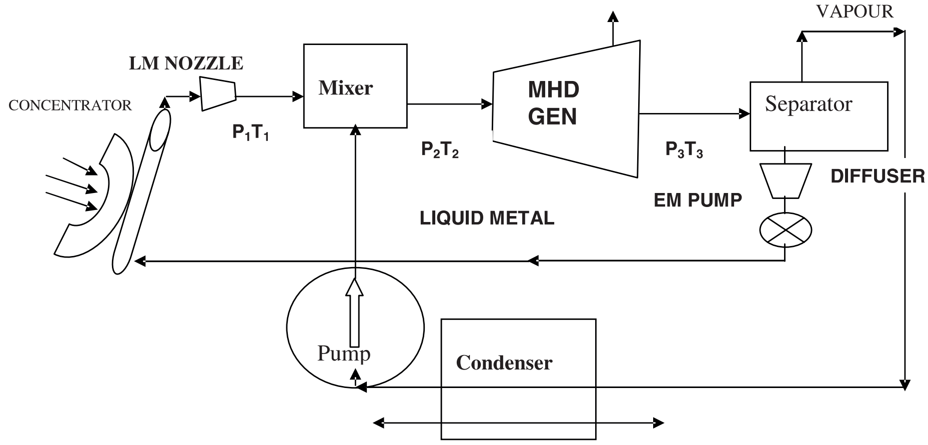

Fig. 1.

The overall system can be divided in to two sub-systems, namely, (i) a Solar Sub-System and (ii) a MHD Sub-System. The design of the solar sub-system depends on the choice of liquid metals. A list of the candidate liquid metals along with their properties is given in Table 1, while for the thermodynamic fluid, water / steam is chosen. For cycle analysis the contribution in terms of work extracted or work required by other components like mixer, separator, condenser, pump has to be included. The over all efficiency of the system depends on the respective efficiencies of different component of the sub-system of the solar and MHD, i.e., solar concentrator, condenser, pumps and heat exchanger. The component description and modeling is given in the following section.

1.1. Solar sub-system. The choice of a solar sub-system depends on the availability of the liquid metal to be used in MHD. Euro Trought – Parabolic Trought (ET-100) is commercially available for a 50 MW solar power plant with 549,000 m^2 of theEuroTrought Collector [4]. The main characteristic parameters of EuroTrought – 100 is given in Table 2.

The Euro Trought collector models are made up of 12 meter long collector modules. Each module comprises 28 parabolic mirror panels – 7 along the horizontal axis between pylons and 4 in the vertical cross-section. Each mirror is

Name of liquid metal	Atom. No.	Melting point, °C	Liquid state between tempe-ratures, °K	Heat capacity in KJ/Kg°C (Cp)	Electric resistivity at atm. press. $\mu\Omega$, cm	Density, kg/m$^3 \cdot 10^{-3}$
Sodium Na	11	97.8	371–1163	1.36	9.57	0.90
Lead Pb	82	327	600.6–2024	0.159	95	10.5
Lithium Li	4	179	453.7–1604	4.19	24	0.51
Bismuth Bi	83	271	544.5–1832	0.144	128.1	10.01
Mercury Hg	80	-39	298–629.88	0.134	90.96	13.6
Potassium K	19	63.8	336.4–1039	0.796	12.97	0.81
Sodium Potassium:						
56% Na		-11		1.13		0.89
22% Na		19		0.946		0.84
Lead bithmuth						
45% Bi		125		0.147		10.3

Table 1. Properties of liquid metals.

EuroTrought Model	ET-100
Focal length	1.71 m
Absorber radius	3.5 cm
Aperture width	5.77 m
Aperture area	545 m^2
Collector length	99.5 m
Number of modules per drive	8
Number of glass facets	224
Number of absorber tubes (4.1 m)	24
Mirror reflectivity	94%
Weight of steel structure and pylons, per m^2 aperture area	19.0 kg

Table 2.

supported on the structure at four points on its backside. This permits the glass to bend with in the range of its flexibility without effect on the focal point. The 100 meter long ET100 has 8 collector modules and an aperture area of 817.5 m^2.

1.2. Mixer. A liquid metal is heated in a solar concentrator (Fig. 1) as per requirement of the fluid outlet temperature range up to the highest temperature (400°C), the metal then proceeds to a mixer, where to a thermodynamic fluid (water) is injected in the form of small droplets. Thus droplets are heated by the surrounding hot metal. This result in expanding vapour bubbles through highly efficient direct heat contact. These bubbles accelerate the two-phase (liquid metal and vapour) mixer into the MHD channel and push the surrounding LM forward by the electromotive force caused by the interaction of the induced electric current and the magnetic field, where electrical energy is extracted. The LM in this case plays two important roles: (i) it serves as a heat source for expanding vapour, and (ii) it serves as an electroconductive medium.

The energy is observed by the liquid metal from the solar concentrator

$$Q_{in} = h_1 m_l C_{pl} \Delta T$$

where Q_{in} is the energy observed by solar concentrator per second; h_1 is the heat transfer co-efficiency; m_l is the mass per unit time of the liquid metal; C_{pl} is the specific heat of the liquid metal; $\Delta T = (T_o - T_a)$, where T_a is the ambient temperature, T_o is the maximum temperature.

The water droplets are introduced in the mixer when they come in contact with the liquid metal and are converted into vapour and the mixer attains certain equilibrium temperature T_i.

The heat balance equation may be written as follows:

$$L_1 m_l C_{pl}(T_o - T_a) = m_{wL} + m_w C_{pv} T_1 + m_L C_{pL}(T_i - T_a)$$

The mass balance equations and the combine momentum equation as per Satyamurty *et al.* [2].

The overall system efficiency may be calculated by an equation given by Kaushik *et al.* [5]

$$\eta_0 = \eta_{th} \times \eta_g \times \eta_{sc} \times \eta_{sy}$$

$$\eta_0 = 4.3\% \qquad \text{Kaushik } et\ al.\ [5]$$

The following parameters have been taken
(i) $Q_{in} = 1000$ kW
Expected power output $= 1000 \times 4.43 = 44.3$ kW
Energy consumption for hydrogen generation $= 4.7$ kWh/m^3
Hydrogen generated $= 44.3/4.7 = 9.425$ m^3.

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