ABSTRACT

Among the available alternatives, Magneto-hydrodynamic (MHD) power is a sustainable, reliable, and eco-friendly alternative with certain specific technological challenges to address. MHD systems for electrical power generation have been a subject of research interest for the last many decades. Progress in the field of MHD electrical power generation systems has been witnessed by the volume of theoretical and experimental research undertaken worldwide especially in the last few decades to harness MHD power in reality. This thesis primarily focuses on the following areas within the field of MHD power generation systems.

It provides the performance analysis study of a MHD power plant in four different configurations. The first analysis is based on the thermodynamic performance analysis of a coal-fired MHD plant considering the variation in nozzle area ratio. This analysis is mainly limited up to the generator of the MHD in order to study the effects of nozzle area ratio variation on the generator performance in particular and the system in general. In this study, a constant nozzle inlet Mach number is considered with supersonic nozzles that has different throat-to-exit area ratio. The nozzle exit parameters, adiabatic flame temperature for coal combustion, and the performance parameters of the segmented type Faraday MHD generator are evaluated considering the nozzles separately. The results of this analysis showed that an increase/decrease in nozzle area ratio resulted in an increase/decrease in gas velocity at MHD generator inlet but with a reduction in temperature. However, the nozzle efficiency as well as the plant efficiency is found to be almost independent of either the area ratio or Mach number at nozzle exit. Moreover, the maximum voltage and the maximum power density are found to increase with increase in the area ratio.

Further, the nozzle exit velocity and the efficiencies are also found to vary with area ratio.

Next, this thesis presents the energy and exergy based performance analysis of a coal-fired MHD power generation plant. Under the stated necessary assumptions, the aim of this analysis is to evaluate the energy and exergy flow rates, energetic and exergetic efficiencies, total and net MHD power output, component-wise and overall plant energy losses and exergy destruction rates of the MHD system. The overall exergetic efficiency of the MHD plant is affected by the total rates of exergy of the inlet and the outlet flow streams. The exergy destruction rate was found to affect the exergetic efficiency of the MHD components, with least exergy destruction occurring in the air preheater whereas maximum destruction in exergy rate occurs in the nozzle of the MHD plant. The electrical power generated without the energy supply to run the air compressor was found to be 73.706 *MW* with a thermal energy input of 115.571 MW. With 16.394 *MW* compressor power input, the net electrical power was obtained as 57.312 *MW*. Due to the higher energy loss with 43.706 MW and exergy destruction with 48.7961 MW, further improvement will be needed in the design geometry and associated materials of the MHD generator. Similar results were obtained from the energy and exergy analysis in terms of losses with exception in the desulphurization unit. Low exergy destruction rates were observed in components such as the combustor, compressor, seed recovery unit, the sulphur minimizer and the stack as compared to the corresponding energy losses. The overall thermal efficiency of the present MHD plant was found to have an average performance in terms of energy with 49.59 %.

This thesis also analyses the performance of a combined MHD-GT plant based on the evaluation of exergetic parameters considering the effect of ionization of the combustion products mathematically. The energy and exergy rates based on the mass flow rate, pressure and temperature at different state points of the overall MHD plant were determined to evaluate the exergetic destruction rates, exergetic efficiencies and the power output of the combined plant. Results that are based on the values of the purely molecular and partially ionized combustion products of exergy destructions and exergetic efficiencies of the MHD components have been compared. In the molecular state, the total rate of exergy destruction in the MHD plant with the three main components namely the combustor, nozzle and the MHD generator, was found to be higher than those obtained using the partially ionised state by 42.322 MW. Using the partially ionized combustion products in the analysis, the exergetic efficiency of the MHD improved approximately by 22%. However, the combined net power output with purely molecular species in MHD combustion products was higher by 77.342 MW though practically infeasible as far as MHD power generation is concerned. The model was then validated under identical conditions of pressure, temperature and mass flow rate with a reference model. The results of the validation were found to be in line with the present study with small variations in the energy and exergy rates.

Finally, the thesis conducts a performance assessment of a standalone MHD power plant through divisions of the entire exergetic desolations in each individual system component into portions that are either avoidable or unavoidable together with divisions of each type into endogenous or exogenous types. Initially, the system is analyzed using the standard energy and exergy approach. The estimated values for the energy and exergy flow rates at various points of the flow stream have been specified by considering the real working conditions of the MHD system.

The total rate of exergy desolation was obtained by summing up the various portions in different combinations. While obtaining the unavoidable portion in a particular component, the operation in that unit was analyzed under the assumptions of maximum efficiency and negligible wastage termed as unavoidable operation. The various assumptions in the study considers the probable upgradation that are likely to be achievable in the imminent future. Also, the mexogenous part of exergy destruction that is associated with the exogenous portion was taken into account in the analysis. While splitting the exergy desolation rate, the hypothetical, actual, and the unavoidable cases were assumed for the evaluation of the exergy parameters and to realise their effectiveness.

The results obtained from the splitting of the exergy desolation rate showed that the maximum desolation in exergy rate occurred in the combustion chamber (CC) which is 82.121 MW. Also, it was the CC where the highest value in both types of desolation rates occurred. The avoidable and avoidable endogenous exergy desolation rate was relatively high in the MHD power generator. A higher avoidable, and avoidable endogenous exergy desolation rates in the generator imply a greater influence of the MHD generator on other MHD power generation system units. The OTSG was another component in the MHD system where the unavoidable and the exogenous portions of the exergy desolation rates were significant. A higher unavoidable and exogenous parts of the exergy desolation rates in the once-through steam generator (OTSG) signify that there is a minimum possibility of augmenting its performance when attached to the MHD system. Further, the OTSG does not influence much on the other components. The overall system efficiency (exergetic) was found to be 22.93 %. For the overall system, the endogenous part of exergy desolation was more implying high functional linkages among the MHD components.

Therefore, the possibilities of up gradation in system performance can be augmented by the lower rate of exergy desolation of non-avoidable nature.

Thus, there is reasonable scope for augmentation of the MHD power generation system through appropriate technical strategies such as development of more efficient MHD generator through variation in the applied magnetic field and in gas conductivity together for the maximum power density and proper selection of operating conditions.