Journal of Electrical Engineering
The Institution of Engineers, Bangladesh
Vol. EE 31, No. I & II, December 2004

MHD Retrofit Scheme for Efficiency Enhancement of Thermal Power Plants : A Case Study

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ABSTRACT

Around 68% of electrical energy is generated by thermal power plants in India. These power plants run at very poor efficiency of 15-30% depending upon the season of the year. The over all efficiency of each unit of Harduaganj thermal power plants near Aligarh India, is given for different years and found to be quite low around 18% as an average. Efficiency of a proposed unit of Magneto Hydro Dynamics (MHD) channel of 20 MW (BHEL) is calculated and this channel is retrofitted as topper unit with Harduaganj thermal power plant which is used as trailer unit. The overall efficiency of this retrofit scheme is calculated and being reported in this paper. It is seen that the efficiency increases by more than 50% of its existing value. This can be further enhanced if larger size of MHD generator is used. This scheme enhances the efficiency, conserve coal and the pollution caused by thermal power plant is also reduced to a great extent. When the technology is matured, it will conserve coal which is a limited amount and expected that world reserves will be 80% over by the year 2250.

1. INTRODUCTION

The per capita consumption of electrical energy is taken as an index of development of any country. The wheel of modern civilization is moving by electrical energy. The demand of electrical energy is increasing overwhelmingly. It would be doubled by the year 2010 A.D. of what was required in India 1980. With increasing demand of electrical energy the installed capacity is also increasing marginally. The peak load demand is always ahead of generation. There is a gap of around 19% in supply and demand during peak period while it is around 9% during off peak period [1]. The anticipated peak load demand in India by the end of 10th five year plan (2006-07) would be around 144300 MW [2]. The gap is increasing with time, which would finally lead to energy crisis in near future, and this will buck the economic growth, which leads to political and social unrest. The conventional means of power generation in India are thermal, hydro and nuclear.

The major portion of power is generated through thermal power plant (TPP). The problem associated with such plant is its poor efficiency (15-30%). In addition to its poor efficiency, it emits hazardous gasses leading to green house effect and acid rain etc. A case study is carried out for the Harduaganj thermal power plant, near Aligarh India, retrofitted with an MHD channel. It is shown that efficiency of the overall system can be enhanced to a great extent. The Hrduaganj TPP capacity, year wise generation, plant load factor for different years is reported and details of the input fuels are also given.

2. SYSTEM PERFORMANCE

Harduaganj TPP has 3 plants namely A, B and C and out of these three plants two (B and C) are taken for case study. The total installed capacity of B and C plant is 450 MW. Plant B has 4 units each of 55 MW and plant C has 3 units out of which 2 units are of 60 MW and one of 110 MW. The electricity generated, the plant load factor and the calculated efficiency of the power plant is given in table 1.

Different inputs to the plant for the electricity generation are coal, light diesel oil (LDO), fuel oil (FO) and high speed petroleum (HSP). Their calorific values are listed in Section 5. The sample calculations are shown in Sections 6 and 7.

The average percentage increase in the efficiency of existing plant is 65% as calculated in Section 3.

The major advantages of the proposed scheme are the enhancement in the efficiency of the existing plant. Thus the amount of coal to be used for the same power output is reduced drastically. Moreover the pollution level in the exhaust is reduced to great extent because of the complete combustion of pulverized coal at temperatures around 2000 to 3000 Kelvins. The economic viability and commercial feasibility of the retrofit scheme is possible with large power output (>200 MW) [3]. It is seen from the table 1 that the efficiencies of TPP are very poor.

Table 1: Plant efficiency and load factor comparison.

	Plant C			Plant B		
Year	Gen. (MU)	PLF	η	Gen. (MU)	PLF	η
98 - 99	1056	52.27	18.4	669.02	36.27	18.45
00 – 01	1013	50.28	19.1	420.59	22.86	16.07
01 - 02	553	27.64	18.9	425.10	23.67	16.32

3. MHD RETROFIT SCHEME

In MHD power generation the hot conducting fluid interacts with strong magnetic field to produce D.C. power which is tapped with the help of electrodes. This power is then inverted and fed to the grid. The simplest MHD channel is shown in Fig. 1. The fluid coming out of the channel is still at very high temperature. The heat of this fluid can be properly utilized by using it in TPP to run its turbine.

This integration of MHD and TPP is called Retrofit [4]. The combustor, nozzele, channel and diffuser are added to the existing TPP. In the proposed scheme, a 20 MW proposed channel of BHEL is combined with Hrduaganj TPP. This channel works on Carnet's cycle for maximum efficiency [5].

The efficiency of the MHD system is calculated as,

$$\eta_{MHD} = (1 - T_2/T_1) \times 100\%,$$

where T_2 = Temperature of the fluid coming out of the diffuser (2400^0 K) and T_1 = Temperature of the fluid entering combustion Chamber (2800^0 K).

$$\eta_{MHD} = (1 - 2400/2800) \times 100\%$$
$$= 14.3\ \%.$$

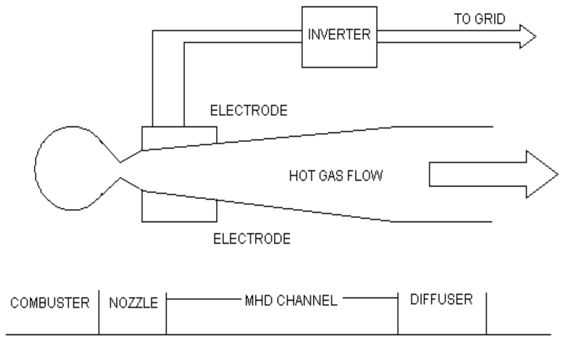

Fig. 1: MHD channel.

In the proposed scheme Harduaganj TPP is used as topper unit while MHD is used as trailer unit. The block diagram of overall system is shown in Fig. 2.

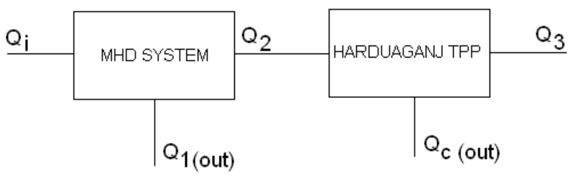

Fig. 2: The block diagram of overall system.

Efficiency of the overall system is calculated (using equations given in appendix) as[6],

$$\eta_{overall} = \eta_{MHD} + \eta_{HTPP} - \eta_{MHD} \times \eta_{HTPP}$$
$$= 0.143 + 0.18 - 0.143 \times 0.18$$
$$= 0.297 \times 100 = 29.7\ \%.$$

Percentage increase in the efficiency of existing plant

$$= \{(0.297 - 0.18)/0.18\} \times 100\ \%$$
$$= 65\ \%.$$

The major advantages of the proposed scheme are the increase in efficiency and saving in coal for the same amount of power. Pollution is also controlled because it is working at high temperature.

4. COST-BENEFIT DATA

Steam-MHD power plants with overall efficiencies of 46-50 percent Compared to the present conventional thermal power plant efficiency of less that 35 percent are very attractive. Detailed investigation of techno- economics of MHD power generation makes MHD a very favorable candidate especially in the context of escalating fuel prices. The increased efficiency from 35 percent to 50 percent of steam power plants amounts to saving of 1 million tones of coal per 1000 MW installed capacity. The cost of the various technologies is compared in Fig. 3.The highest cost goes to nuclear and lowest for advanced MHD-Gas turbine with 60 percent efficiency.

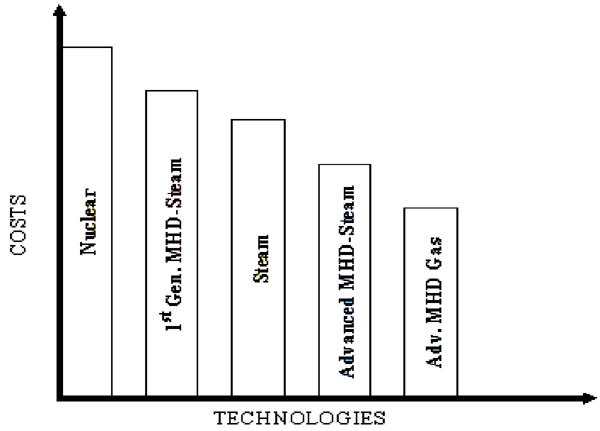

Fig. 3: Comparative capital costs of various technologies.

The electric power produced per unit of fuel by an MHD generator system is double of that from a conventional thermal power plant. This is the obvious boost to the economy of power generation. Anyway due to the high power consumption in the accessories themselves, the saving at present is not as much as mentioned above. Even then a reduction in cost by 20 to 30 percent is possible.

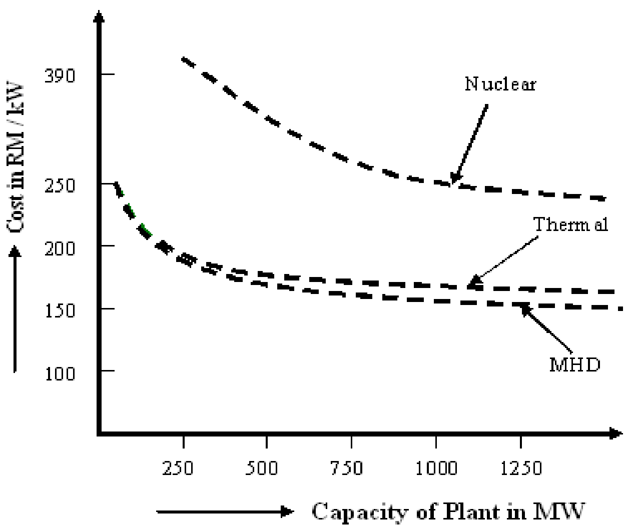

Fig. 4: Cost versus plant capacity for various technologies.

Prevention of heat wastage in MHD system is yet another reason for its being more economical. It is estimated that 50 percent of heat wasted in thermal plants is saved in MHD systems. In terms of fuel consumption, this technology will extract nearly twice as much electric power from each unit of fuel as the present technology can. The most cost effective use of MHD with coal is to design MHD power train as a topping cycle for a steam cycle plant. The need for pollution control devices for steam cycle and waste management for nuclear plants increases the overall cost. The MHD system will cut down this kind of cost. The over all cost of MHD power plant for 750 MW and above will be less compared to the other two as seen in Fig. 4.

5. STATEMENT OF COAL

Moisture %	= 1.215
Ash %	= 34.902
Volatile matter %	= 17.731
Fixed Carbon %	= 46.152
Calorific Value in K Cal. /kg	= 5216
Calorific Value of L.D.O. in k Cal. /klit.	= 8900
Calorific Value of F.O. in k Cal. /klit .	= 10000
Calorific Value of H.S.P. in kCal./klit.	= 10000

6. CALCULATION DATA

Calorific Value of Coal(KJ/Kg) = 5216 x 4.18
= 21802.92
= 21802.92/3600
= 6.056 KWh/kg

Calorific Value of L.D.O. = (8900 x 4.18)/3600
= 10.334(kWh/KJ)

Calorific Value of F.O. = (10000 x 4.18)/3600
= 11.611(kWh/KJ)

Calorific Value of H.S.P. = (10000 x 4.18)/3600
= 11.611 (kWh/KJ)

Total consumption of coal in the year 98-99
= 598550×10^3kg

Total consumption of L.D.O.	= 4217 kcal
Total consumption of F.O.	= 4410 kcal
Total consumption of H.S.P.	= 613.726 kcal

7. EFFICIENCY OF PLANT B

Energy input :

Coal	$= 6.056 \times 598550 \times 10^3$
	$= 3624818.8 \times 10^3$ kWh
L.D.O.	$= 10.334 \times 4217$
	$= 43578.4$ kWh
F.O.	$= 11.611 \times 4410$
	$= 51204.51$ kWh
H.S.P.	$= 11.611 \times 613.726$
	$= 7125.97$ kWh

Total energy input,
$= 3624818.8 \times 10^3 + 435784 + 51204.51 + 7125.97$
$= 3624920709$ kWh

Total generation in 98-9 $= 669.02 \times 10^6$ kWh

Efficiency $= 669021 \times 10^6 / 3624920709$
$= 18.45\%$

8. CONCLUSIONS

Thermal power plants are the major source of electrical power. Due to improper utilization of the heat they run at very poor efficiency. These power plants are also the major source of environmental pollution. The efficiency of thermal power plants can be improved to a great extent if they are used in retrofit with MHD power plants. It is shown for the Harduaganj (India) case that the operating efficiency of the plant can be enhanced by more than 65% of its existing value. This will cause a great reduction in coal consumption and also in pollution level.

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APPENDIX

$\eta_{MHD} = Q_1/Q_i$

$\eta_{HTTP} = Q_C/Q_2$

$Q_1 = \eta_{MHD}\, Q_i$

$Q_C = \eta_{HTTP}\, Q_2$

$Q_2 = (Q_i - Q_1) = (1-\eta_{MHD})Q_i$

$Q_3 = (Q_2 - Q_C) = (1-\eta_{MHD})Q_i - \eta_{HTTP}\, Q_2$

$\quad = (1-\eta_{MHD})Q_i - \eta_{HTTP}\,(1-\eta_{MHD})Q_i$

$Q_3 = Q_i(1-\eta_{MHD})(1-\eta_{HTTP})$

$\eta_{overall} = (Q_i - Q_3)/Q_i = 1 - [(1-\eta_{MHD})(1-\eta_{HTTP})]$

$\quad = 1 - [1 - \eta_{HTTP} - \eta_{MHD} + \eta_{HTTP} \times \eta_{MHD}]$

$\quad = \eta_{HTTP} + \eta_{MHD} - \eta_{MHD} \times \eta_{HTTP}$