# An Overview of Technical and Economical Feasibility of Retrofitted MHD Power Plants from the Perspective of Bangladesh

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***Abstract*— A retrofitted MHD power plant is particularly attractive for older plants that have to be reconditioned since these may increase the generating capacity of the existing plants and at the same time, reduce the emission of pollutants and cooling water requirements. This would extend the life of an existing power plant and improve its environmental intrusion. The purpose of the paper is to study the feasibility of retrofitted MHD power plants if would have been adopted in the existing plants of Bangladesh. Many of the thermal power plants commissioned in Bangladesh are 30-40 years old. Retrofitted MHD power plants may be an option to increase the performance of these plants as there remains a large coal reserve in Bangladesh where the gas reserve is approaching towards its end. The feasibility studies of MHD plants demonstrated that combined cycles using both open and closed cycle MHD processes should be economically competitive. The technology has reached the stage where the feasibility of retrofit demonstration plant is considered by several countries including USA, Russia, China, Japan, India and Australia. A developing country like Bangladesh may step forward to adopt the technology to handle its recent energy crisis.**

***Keywords*- System Integration, Retrofitted MHD plants, Pollution control, Power conditioning, MHD-steam combined cycle.**

## I. INTRODUCTION

Retrofitting option in a power plant would enable it to generate with the existing large interconnected utility networks with sufficient reliability. Studies have been showed that the efficiency of a combined cycle MHD steam power plant can be at least more than 20% about that offered by a conventional steam plant [1]. This should be possible at capital costs comparable with existing steam plants. Since the late 1950's MHD has been under development as a candidate for control station generation using fossil fuels particularly coal [2]. The system schematic for a coal fired MHD plant is shown in fig.1 [3]. Two major limitations have been detected as prime constraint of MHD power plant integration to the utility. One is design and development of extremely high temperature sustainable system components (as MHD operates in a temperature range of 1500k-2500k). The other one is to determine the dynamic behavior of the plant when connected to the utility service (both transient and steady state stability) [3-4]. The first one will play the most important role to choose MHD as a retrofitting option in an existing plant. The second constraint will also come into consideration because MHD would require a separate interconnected DC network with high voltage rectification option (as the generated voltage would be DC for MHD power plant). Due to its high operating temperature compared to any conventional power generating technology, MHD could still add up to 15 percent at the top end of other combined cycles. MHD is potentially a natural choice for conversion of high temperature energy output from future nuclear power plants. As Bangladesh is in a process of commissioning a 1000MW nuclear power plant, a combined nuclear-MHD plant may be a suitable choice due to its two major advantages [5]:

- A reduction in thermal pollution
- No $CO_2$ emission as with fossil fuel driven plants

In most of the countries around the world including Bangladesh, solar and wind power has been introduced as a source of alternative energy, but only in a relatively small scale, since it has not been proved economic yet. Oil fired plant is still widely used (as peaking power plant), but attempts are being made to replace it and this is where MHD could fit in. MHD is the only plant where coal can be used directly without pre cleaning. A system planning strategy needs to be developed to determine whether a MHD plant can be established to respond to power system requirements.

A country like Bangladesh where energy crisis is one of the major rational concern, may step forward to consider MHD power plant as an option for power generation. With a large reserve of coal and replenishing reserve of gas combined cycle MHD-steam plant other than Gas- steam combined cycle may be an answer to the problem. A retrofitting or repowering old station with MHD as a topping can significantly improve the efficiency. The older steam power plants commissioned in Bangladesh are operating way below the acceptable efficiency range. This may be improved substantially by retrofitting MHD plants with some modification at an acceptable economical expenditure.

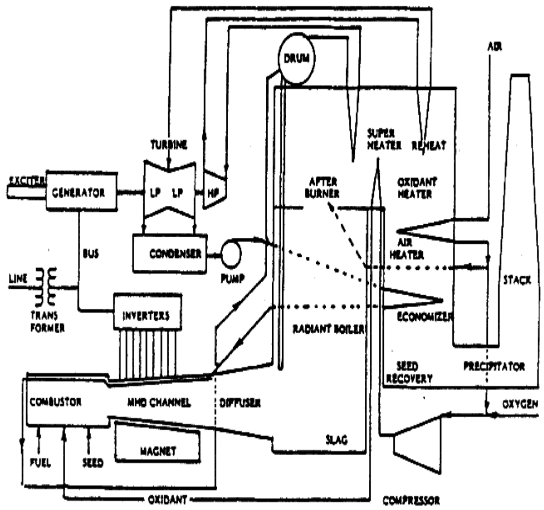


Fig.1 System schematic for a coal fired MHD plant.

## II. COMPARISION BETWEEN GAS-STEAM AND MHD-STEAM PLANT

To increase the efficiency of any existing thermaql plant retrofitting MHD in conjubction with steam plant as the bottming unit could be a very good choice. Among all the conventiional power plant, combined cycle Gas-Steam will offer the maximum efficiency 45% - 55%. A wide range of extensive research and studies carried out in a number of countries like United States, Russia and Japan indicate that a combined cycle MHD/steam plant could be able to achieve an overall efficiency of 60% or more which indicates that the final cost per kW-hr should be less than the existing steam plant, since higher efficiency means lower fuel costs. However if a comparison is made between combined cycle MHD/steam plant and conventional combined cycle gas turbines with coal gasification operating as topping plant with steam bottoming, does not detract MHD from its position since its operating temperature range is way beyond that of any other process used. MHD would still add 5-20% at the top end of the other cycles. A relative comparison of cost of electricity per kwhr for different generation plant as a function of capacity factor can be introduced to determine the system requirements. A graph illustrating these is shown in fig.3. Depending on the type of plant i.e. base plant (capacity factor 35-85%; 3000-7000 hrs/annum), intermediate plant (capacity factor 5-35%; 500-3000 hrs/annum), peak and emergency plant (capacity factor below 5%) the operation of MHD plant can be specified. Base load must be supplied with the most efficient plants. Plants used for intermediate load must provide reliable backup during outage of base load plant. The fluctuating load during peak period is handled by plants where they can be brought on to line rapidly can follow the load variation with ease.

MHD could be most suitable for fast load following although its high efficiency may make it suitable also for base load operation. From fig.3 we can conclude that it is most suitable for intermediate and base load plant. But the relative percentage of cost makes it most suitable at 80% capacity factor i.e. operating on a base load plant. As nonconventional and renewable energy sources are yet to be proven cost-effective, MHD can be used as an alternative due to its proven higher efficiency and flexibility in operation. With proper planning and system development MHD can be economical and in some cases more cost effective than the conventional power plants.

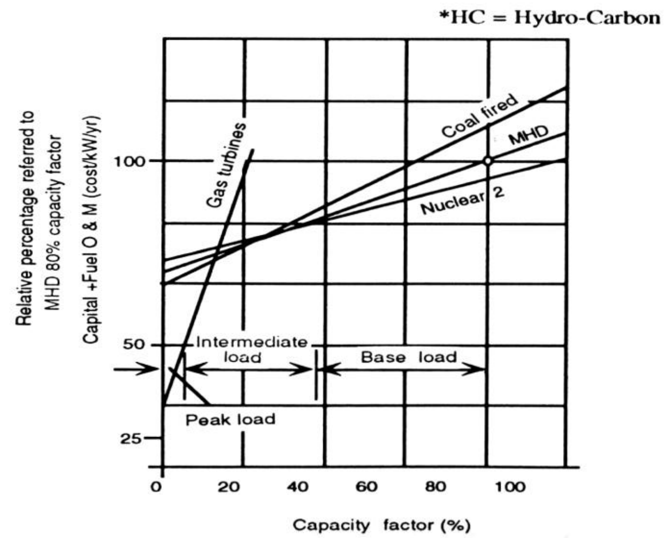


Fig.2 Relative cost of electricity per kW-hr for different generation plant.

## III. POWER SYSTEM REQUIREMENTS AND SYSTEM PLANNING

Planning of a power system covers a considerable range of aspects. The choice of a generating unit is governed by different factors such as capital cost, fuel availability, operating and maintenance cost, unit reliability, duration of service and pollution control. As shown in fig.3, different plants have different features as far as economics is concerned. The first factor to note is the capital cost per kW-hr; this is the money that has to be put up to a large extent before any power is generated and any income is flowing in. This varies from type to type and country to country. Then one has to allow for operating costs, including fuel costs and maintenance costs. The operating cost is measured by the slopes of the curves shown in fig.3, since this cost increases roughly in proportion with the time the plant is running per year, i.e. the capacity factor. The slope increases with increasing fuel cost; thus for nuclear plant this slope is much lower than for a coal fired steam plant. MHD with higher efficiency falls between the two. A gas turbine that can be installed relatively cheaply which uses expensive fuel and is therefore suitable for peaking and emergency application. MHD with its potentially rapid response capability differs from all the others in that it can run as base load plant and can offer rapid load-following capacity. If designed to cope with short overload capacity it could do both. A most critical factor is the reliability of the generating plant. For example, if reliability for two plants drops from, say, 80% availability to 70% then this would require a third plant. Extra reliability has to be included in the cost calculations. If reliability of an MHD plant can be made to reach 80% availability then its cost competitiveness would be unchallenged on practically all accounts.

## IV. MHD/STEAM RETROFIT PLANT: MHD AS TOPPING CYCLE PLANT

Retrofitting or repowering old power stations with modern plant-a gas turbine or an MHD plant-is being seriously considered by the utility industry today by adding such plant in a topping cycle. The major aim would be to increase power capacity and efficiency and reduce pollution on site. This has become a serious challenge at a time when electricity demand has been saturating and when system growth does not need any large scale expansion. A completely new MHD/steam combined cycle power plant would be more satisfactory in a technical sense, since a retrofit plant requires many compromises when connecting an MHD plant to an old station. However, a considerable effort has gone into assessment of reconditioning the many old and often small power stations that exist [2].

### *A. Typical Arrangement for Retrofitting an MHD Plant as a Topping Cycle*

There are basically three distinct approaches to retrofitting a coal-fired plant with MHD as topping cycle. Among these first two are open cycle and the third one is closed cycle. They are-
(a) Open cycle with coal or gasified coal as fuel, and with topping MHD unit and steam power plant as bottom unit.

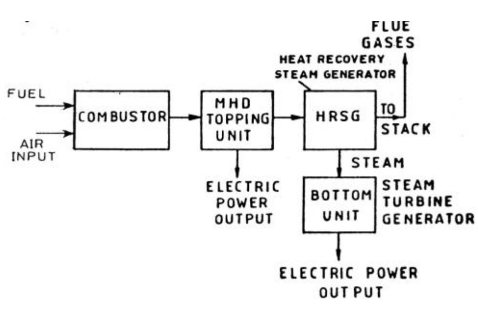


Fig.3 Coal fired, MHD topping unit with steam turbine bottom unit

Heat rejected by the topping MHD plant is used by the bottom steam turbine unit. Such plants are likely to be used as base load power plant.

(b) Open cycles with natural gas as a fuel, MHD as a topping unit with a gas turbine power plant. Heat rejected by the topping MHD plant is given to the gas turbine bottom unit. This type of plant may serve as peaking power plant or intermediate power plant.

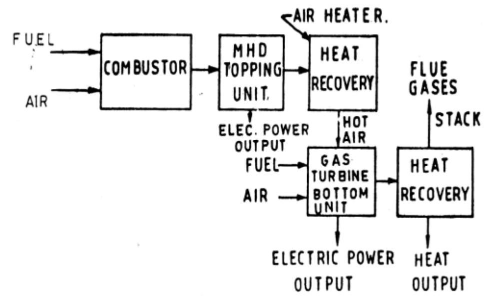


Fig.4 MHD topping unit with gas turbine bottom unit and Cogeneration of Heat and Power (CHF)

(c) Closed cycle with nuclear power reactor power plant with liquid metal as working fluid when MHD generator as a topping unit with a steam turbine unit at bottom.

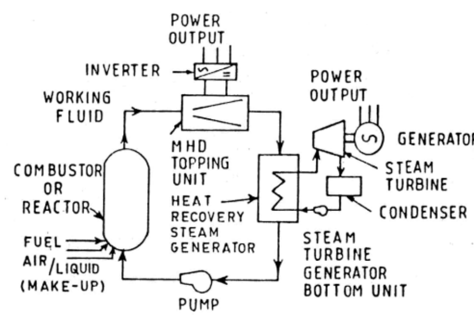


Fig.5 Closed cycle MHD and steam cycle

There is either a steam connection when both cycles could operate independently or a gas connection when the MHD generator feeds the exhaust gases directly into the downstream boiler after it passed through the regenerator. A detailed analysis should be carried out based on the following factors-plant layout, accessibility and space, fuel availability, suitability for steam or gas connection, economic variables, cost of capital, fuel cost, manpower, technological base, local system requirements, capacity and demand. The advantages of retrofitted MHD plants are stated below-

- Improved efficiency and heat rate
- Minimizes the need of building a new plant
- Environmental requirements
- Lower running costs
- Potentially improved availability of more supply
- Improved reliability
- Easing of legal and environmental conditions

- Possible government support

## V. TECHNICAL AND ECONOMICAL ANALYSIS OF MHD GENERATOR FROM THE PERSPECTIVE OF BANGLADESH

Technical and economical analysis must be carried out for different configurations of MHD if it is going to be introduced as a power generating source in a system. It has already been stated that an MHD is much more efficient than conventional thermal plants. Due to its higher efficiency, the fuel consumption of primary energy input will be lesser and fuels like coal, gas will be conserved. Improved efficiency will lead to lower operating costs and must be set against the extra capital requirements. Increased availability and operating life time can defer the need to install extra capacity elsewhere. The advantage of higher efficiency also reduces the generation cost per unit of energy.

TABLE I. COMPARATIVE COSTS FOR COAL FIRED AND MHD POWER PLANT

| Particular | MHD-Steam Plant | Conventional Steam Plant |
|---|---|---|
| Total cost of installation $/KW,(1900 Base) | 1880 | 1840 |
| Thermal Efficiency of Plant | 46% | 32% |
| Fuel Costs $/KWh | 0.002 | 0.0028 |
| Cost of Electricity $/KWh | 0.059 | 0.062 |

A simple example along with some data can be used to show the improvement of the efficiency of the MHD-steam plant. The exhaust of MHD generator is about 2500K, which is given to heat recovery steam generator (HRSG). The steam from HRSG is given to conventional steam turbine plant. Such a plant has higher thermal efficiency (45-55%) than simple coal fired steam power plant (25-35%).

The maximum Carnot efficiency of such a combined cycle is

$$\eta = \frac{\eta_1 - \eta_2}{1 - \eta_1}$$

Here,

$\eta$ = Carnot efficiency of combined (MHD top + Steam bottom) cycle

$\eta_1$ = Carnot efficiency of MHD topping cycle

$\eta_2$ = Carnot efficiency of MHD bottom cycle

The maximum Carnot efficiencies are higher for higher temperature

For $T_1$ = 2600K; $T_2$ = 420K; $\eta$ =85%

For $T_1$ = 850K; $T_2$ = 300K; $\eta$ =65%

The net thermal efficiency in practical Rankin cycle is much less than ideal maximum Carnot efficiency. The practical thermal efficiencies are $\eta_1$ =25%, $\eta_2$ =40% which gives $\eta$ =55%.

With statistics showing a coal reserve for next 80 years in Bangladesh, MHD-steam combined cycle can be used for coal conservation. One reason to promote MHD-steam combined cycle than gas-steam combined cycle is due to its higher efficiency. MHD system causes less environmental chemical and thermal pollution. On the other hand MHD generator is without any rotating parts. Hence maintenance requirements are expected to be modest. But the advantage of MHD are offset by difficulties of high temperature requirement (2500-3000K) and high magnetic flux densities (5 to 6 Tesla) involving costly superconducting magnet technologies.

High temperature combustion process requires sophisticated process devices and components those may not be feasible for a country like Bangladesh. The cost comparison of gas-steam and MHD-steam plant can yield the correct analysis which is beyond the scope of this paper. But from fig.2 we can see that for a certain range of capacity factor MHD can be more cost effective than coal fired thermal plant. Yet nuclear plant can be more economic than MHD plant but there again rises the question of availability of nuclear fuel due to so many international laws and regulations as Bangladesh do not have any easy access to the nuclear fuel. MHD retrofit would offer several benefits. It can be readily installed in a topping plant since it operates in a temperature regime that extends past that of any existing plant and offer high efficiency and improved environmental impact. It is important to assess whether the benefits and other factors raised above make it worthwhile to consider firstly retaining the old plant and secondly attaching a new plant to it instead of possibly going to a freestanding new plant. Many of the power plants commissioned in Bangladesh are very old (almost 25-30 years) and as result the thermal efficiencies are way below the normal reference value. This can be upgraded by using a retrofitted MHD over those plants which would result in lowering the operating cost and any poor performance of the old plant may be reduced. Sometimes if the existing system can cope up, then a retrofit can become more cost effective than building a new plant.

Recent studies have revealed that gas reserve of Bangladesh will come to an end around 2021. Then coal will be the primary fuel used in the power plants. For using coal as fuel in Gas-Steam combined cycle plant, then gasification of coal will be necessary. From this point of view MHD-Steam combined cycle plant could be a choice rather than former one. On the other hand no pre-cleaning of coal is required for MHD.

Reliability is another factor that can be important, since improved reliability can reduce the need for new plant. Reliability must be such that the plant can compete economically with conventional plant. For base load operation the overall availability should be 70-80%. This means that MHD plant subsystems must have a higher availability, i.e. the generator availability should be higher that 80%. Harmonics in a power system are to be kept within specified limits which are of the order of 1.5%. This requires very effective filtering of the harmonics associated with the inversion of the DC output from the generator. Special demands are therefore imposed on the power conditioning circuits. MHD produces DC voltage which makes it unsuitable for Bangladesh as there is no DC transmission system existed. On the other hand to design an inverter with high power handling capability is complex and less reliable. Harmonics is another problem for an inverter as it would require costly filter components. The operating life cycle of inverters are less compared to ac generators. Overall an inverter meeting up all the desired requirements may not be cost effective considering all the factors and aspects.

## VI. CONCLUSION

MHD has the potential and prospect to find a place in the power industry. With its attractive and lucrative features it may pose a competition for the conventional technologies. But with the conventional steam thermal power plant technology being well established and continued to be in the main stream MHD plants are yet to gain commercial acceptance. In future, with advanced technologies like coal gasification, nuclear fusion and hydrogen technology etc MHD may gain acceptance as a topping unit for steam power plant and gas turbine power plant. However technological problems related with design, material, high temperatures, reliability and long service life etc are under investigation in several countries and the prospects are favorable. For Bangladesh more detailed studies are needed to be carried out. The feasibility study of the comparison combined cycle gas-steam plant and combined cycle MHD/steam plant can propose a solution. MHD plants are more feasible because these can be used for both the base and peaking plant. The feasibility of MHD was established in the 1950s and 1960s when large scale engineering facilities emerged in many of the leading industrialized countries. In the 1970s and 1980s large engineering tests dealing with support and auxiliary systems were carried out and system studies demonstrated that combined cycles using both open and closed cycle MHD processes should be economically competitive. Now we have reached the stage when the feasibility of retrofit demonstration plants is considered by several countries including the USA, Japan, Russia, Italy, China, India and Australia. The 1990s are likely to see several demonstration plants in several countries competing to get MHD power plant into the market place.

## REFERENCES


[1] Messerle, H.K., Fang, Y., Simpson, S.W., Marty, S.M. Sub-atmospheric disk-generators for coal-fired MHD/steam combined cycle plant, *Energy Conversion and Management*, 1989, Vol.29, No.4, PP.273-278

[2] W.D. Jackson, Critique of MHD Electrical Power Generation, Proc. Third Beer-Shuva International Seminar on MHD Flows and Turbulence, PP.193-214, Ben Gurion University of Neger, Beer-Shuva, Israel

[3] Jackson, William D., Ferro William E., Seinel, George R., Gish, William B., Integration of MHD plants into Electricity Utility Systems, *IEEE Transactions on Energy Conversion*, Vol. EC-1, No.3, September, 1986

[4] Messerle, H.K., Integration of MHD plants into utility grids, Proc. Us-Australia Workshop, Sydney, Australia, 1986, P.P 1-10

[5] Womack, G.J., MHD Power Generation, Chapman and Hall, London, 1969

[6] Rosa, R.J., Magnetohydrodynamic Energy Conversion (Hemisphere Publishing Corp., Washington, DC, 1987)

[7] S. Rao, Dr. B.B. Parulekar, Energy Technology (Nonconventional, Renewable and Conventional), Khanna Publishers, Third Edition, 1999, August

[8] Shioda, S., Results of feasibility studies on closed cycle MHD power plants, Proc. Plasma Technology Conf., 1991, Sydney, Australia, PP.189-200



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