A DEVELOPMENT ON PROCESS INTEGRATION IN A THERMAL POWER PLANT FOR ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

Generation of power needs comparatively more amount of coal in comparison to other fossil fuel used in industries. Present study is limited to minimization of consumption of coal within ergonomically safer limit for human health capturing the Carbon Dioxide .The study is based on the generation of power in a thermal power plant located at Northen India. The unit is having2x110 mw and 3x11O mw with rated capacity 1050 mw power.Anthropogenic discharge of CO2 increasing % of greenhouse gases considerably in biosphere and the sustainability proposed to be maintained by capturing both precombustion and post combustion discharge gases. The plant also deployed H2 as cooling agent. The possibility of an integrated system with H2 based gas turbine generation considered also in this paper for the project. Productivity of such integrated system is an important factor as the efficiency of the plant is going down in the process of minimization of greenhouse qases ,cost involvement in installing such system cannot bring the project to its original efficiency unless the H2 is considered for improvement of the turbine system.T he project is also reliable from the viewpoint of limited energy resources for the future generations to come.

Keywords : Sustainability ,greenhouse gas,CO2 capture, IGCC

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1.0INTRODUCTION

United Nations in its World Commission Report ,' Our Common Future' published in 1987regarding the Environment and Development explained the term sustainable development clearly.This report also known as Brundtland Report (02)implied the crucial need for new economic patterns and products that are sustainable,which is compatible with both ongoing technological development and perfections of the environment. In our common future sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. However American Society of Civil Engineers(ASCE) defines(01) sustainable development as process of change in which the direction of investment,the orientation of technology, the allocation of resources, and the development and functioning of institutions to meet present needs and aspirations without endangering the capacity of natural systems to absorb the effects of human activities and without compromising the ability of future generations to meet their needs.

Increasing level of green house gases(GHGS) is posing a threat on the atmosphere of the earth by absorbing infra red radiations which earth receives and trap heat that results in increased temperarure of the environment.

These gases are categorised into (a) naturally occurring gases e.g. water vapour,CO2,methane and nitrous oxides and (b) anthropogenic gases which are the industrial gases like CFC+ ,emission of CO2 etc; however if the concentration of GHG's remain stable then the amount of energy radiated back by earth's atmosphere ,which would maintain the temperature of earth's surface roughly constant. With rapid industrialization in the past century , the use of fossil fuels increased with time and due to the same reason the level of CO2, has been continuously increased in the atmosphere. During 2007 the global emission of carbon di oxide was 7 billion tons which is expected to increase to 14 giga tons per year by 2050 assuming the demand of fossil fuel keeps increasing because of the growing economies around the world. Among all the green house gases produced CO2 is the largest emitted gas with a contribution of 84% of the total gas emitted on fossil fuel combustion primarily in U.S.A.(03)

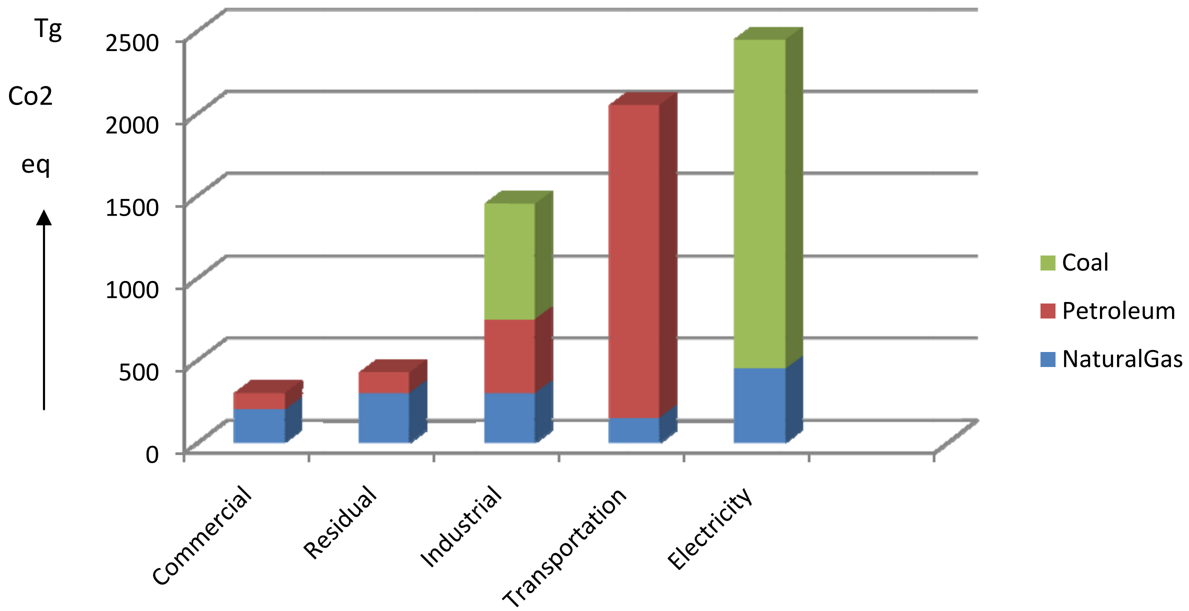

Figure 1 : Comparative Bar chart showing consumtpion of fossil fuels upto 2006;(Environmental Protection Agency,USA)

Carbon di oxide capture and storage (CCS) is a process consisting of separation of CO2 from industrial and energy related sources ,transport to storage ,locations and long term isolation from atmosphere. A Massachusets Institute of Technology energy initiative symposium held on March23,2009 on retrofitting of coal fired power plants in CO2 emmission mitigation have consensus opinion that 80% of the CO2 emmission is from thermal power plants and the removal of CO2 after capturing is the best solution to protect the earth from global warming problems.

1.1Project Background : Present power project is built over an area of 250 acres, with the facility of disposal of ash from the water supplied by the nearby barrage of Chambal River.The ash is disposed off in slurry forms through ash and slurry disposal unit. The requirement of coal is being met up from the supply of coal by Coal India Limited from its coal mines located at an average distance of 1000 km from the project.

Basic cycle of operations is Rankine Cycle and steam generated from boiler is being passed through prime mover which is condensed in condenser to be fed into the boiler again.The plant may be divided into the following areas of operations : 1Boiler and Turbine 2.Condensing Unit 3. Electric Generator 4 Cooling System 5 Control and instrumentation. The design is effected on the basis of appropriate size and selection of different sections so as to have optimum heat economy and to increase the thermal efficiency. From the effective operational criterion the plant is again divided into the following sections : a Fuel and ash section b Air and Gas Section c .Feed water and steam section d Cooling Water Section.

A Fuel and Ash Section: Pulverised Coal is the primary fuel here which is being supplied to the boiler through feed water handling device. Ash content is around 35—40% ash is collected from the back of the boiler and remove to the ash storage tank through the disposal equipment. **In Air** from the atmosphere is supplied to the combustion chamber of boiler through the action of forced draft fan and induced draft fan. The flue gases initially pass around the boiler tubes in the boiler housing, next through the dust collector(electro static precipitator) and then economizer. Finally they are exhausted to the atmosphere through fans. **The steam** extracted from turbine are being used in the plant through condenser where the condensate leaving the condenser is first heated in Low Pressure (LP)heaters through extracted steam from the LP extraction of the turbine. Then it goes to the deareator where extra and non condensable gases are removed from the hot water to avoid pitting/oxidation. From deareat or it goes to the boiler feed pump, which increases the pressure of the water..From the BFP it passes through the high pressure heaters.A small part of water and steam is lost while passing through different components, Therefrom the water is added in hot well. This water is called the make up water.T hereafter **feed water** enters into the boiler drum through economizer.I n boiler tube water circulated due to the density difference in lower and higher section of the boiler.The wet steam passes through the super heater. From superheater it goes into HP turbine after expanding in the HP turbine side.The low pressure steam called cold reheat steam(CRH)goes to the reheater.From the reheater it moves to the Intermediate Pressure (IP)turbine and then to the LP turbine and then exhausted through the condenser into hotwell.**Cooling Water Section**: A large quantity of cooling water is required to condense the steam in condenser and maintaining low pressure in it.The steam which has given up its heat energy is charged back into condenser so that it is ready for use. The cold water is pumped continuously into condenser. The steam passing around tubes looses heat and rapidly charged back into water. But these two types of water should not mix with each other as the process water needs more purity.

Besides the nature of cooling system is hydrogen based. Hydrogen is used for cooling medium primarily because of its superior cooling properties and low density. Thermal conductivity of hydrogen is 7.3 times more than air.It has also higher transfer coefficients. Its ability to transfer heat through forced convections is about 75% better than air. Density of hydrogen is approximately .50 times of air at a given temperature and pressure. This reduces the windage loss in high speed machines like turbo generator .Increasing the hydrogen pressure the machine improve its capacity to absorb and remove heat. Relative cooling properties of air and hydrogen is given below:

1Elimination of fire risk because hydrogen will not support combustion.

2 Corona discharge is not harmful to insulation since oxidation is not possible.

3 Smooth operation of machine in view of vertical elimination of wind age noise and the use of heavygas light enclosures and dirty proby casting.

Hydrogen Coolers: Three hydrogen coolers each comprising of two individual units are mounted inside the stator frame.The inlet and outlet of cooling water from both of machine i.e. from non driving side as well turbine side.The cleaning of the individual cooler element can be carried out from both ends of the generator even during the operation.The assembly of individual cooler elements in stator frame is however carried out only from non driving side.

Hydrogen Driers: Two nos of driers are provided to absorb the hydrogen in the generator.Moisture in this gas is absorbed by silica gel as indicated by its change in colour from blue to pink. The silica gel is reactivated by heating.By suitable change over from drier to other on un interrupted drying is achievement .

1.0 Research Methodology :

In the present paper the problem and improvement considered in the following areas **:**

A ; The flue gas being exhausted into the air causing atmospheric pollution by 3-15% CO_2 for which appropriate methods suggested to reduce the % of CO_2 **.**

B : Applicability of hydrogen gas as gas turbine gas from ergonomic intervention for improvement in capacity

C Limitation of the possibility due to cost involvement and criticality of the physical factors

1.1 CO_2 Capturing methods :

The various technologies invented to reduce the CO_2 emission may be categorized in the four areas which are 1 Post Combustion capture involves separation of the CO_2 from flue gas and would be applied to subscribed pulverized coal(PC),supercritical pulverized coal(SCPC),or ultra super critical pulverized coal (USCPC) 2Pre Combustion separation ,a physical solvent is used to separate the CO_2 from syngas via pressure decrease. Integrated gasification combined cycle(IGCC) Power Plant use this approach for carbon capture which is easier and thus much less expensive 3Oxy fuel combustion is a third emerging option, which uses oxygen instead of air for combustion and produces a concentrated CO2 exhaust stream. Finally 4 CO2 can also be captured in limited quantities from industrial origin as a consequence of natural gas purification which does not involve full consumption(4). Following table provided a comparative picture of various methods :

Comparison of Power Station with and without CO2(International Energy Agency Greenhouse gas programme,2006a): **Table 1**

Technology Coal fired system	**Thermal efficiency %**	**Capital Cost** In dollar	**Electricity Ciost/unit** In dollar	**Cost of Co2**
No Capture	44	1410	5.4	---------
Post Combustion	34.8	1980	7.5	34
Pre Combustion	31.5	1820	6.9	23
Oxy Fuel Combustion	35.4	2210	7.8	36

From the comparative study of different capturing system it is apparent that the both the capturing cost and the unit cost of stored CO2 is minimum for precombustion system of capturing. Besides the Hydrogen generated from the synthetic gas can be gainfully deployed for generation of power from turbine and simultaneously processed for utiluisation in generator cooling .From this viewpoint though the process of absorption with solvent, absorption and membrane separations are being utilized in post combustion method to get CO2 of 15% the process cost incurred are on the average 20 to 25% higher the no capture cost.In the precombustion system efficiency is much less but cost incurred is also less for capturing CO2..

In the power industry the H2 can be proposed as fuel depending on its source of generation. Hydrogen can be generated from renewable energy or from the nuclear energy by electrolysis or by thermal conversion ,in our project the source has been considered as fossil fuels by thermal conversion processes including CO2 sequestration.The supply of hydrogen from the processing of green house gases for reducing CO_2 in atmosphere can be done by the process 1 The process of gasification and separation from CO_2 by coal conversion and then transporting the same to the power house through pipe line 2 integrated hydrogen and electricity generation from coal or natural gas and supplying the same to the remote users 3 generation of electricity from combined cycles by combustion of coke and capturing CO_2.These processes involved CO_2 sequestration and removal of NOx emission. Regarding NOx emission the emission can be reduced in power plants vide1 proximised combustion including catalytic condensation 2 fuel dilution mostly by steam, water or nitrogen 3 removal of exhaust gases.The cost of electricity is comparatively much higher in selective catalytic reduction(SCR) by means of ammonia injections ,the Sconox process recently proposed for extremely elevated rates using adsorption –absorption on potassium carbonate beds. The premixing strategies may become critical due to larger flammability limits and the lower ignition temperature of H_2 with respect to natural gas particularly when the syngas is being used as proposed in our case.In such case stochiometric flame temperature in relation to NOx generation studied by Todal and Batista for various level of emissions of different fuels as gas turbine fuels. As already stated SFT may be greatly reduced due to utilization of undiluted H_2.

3,0 PRECOMBUSTION PROCESS :

Synthetic gas produced for the precombustion is actually a combination of hydrogen and carbon monoxide which bis produced by gasification.Among a wide variety of CO_2 capturing technologies,absorption method,which has two types of processes is the popularized system adopted in power plants.In chemical absorption,solvent reacts with CO_2 chemically and the solution is separated back in generator.CO_2 and solvent reacts physically with some pressure increase. The cost may go up to 25% due to this system.Unlike post combustion method the concentration of CO_2 and pressure of flue gas is typically high.,there is no need to pressurize the feed which allows significant energy savings **.**The precombustion method can only be applied to fossil fuels.

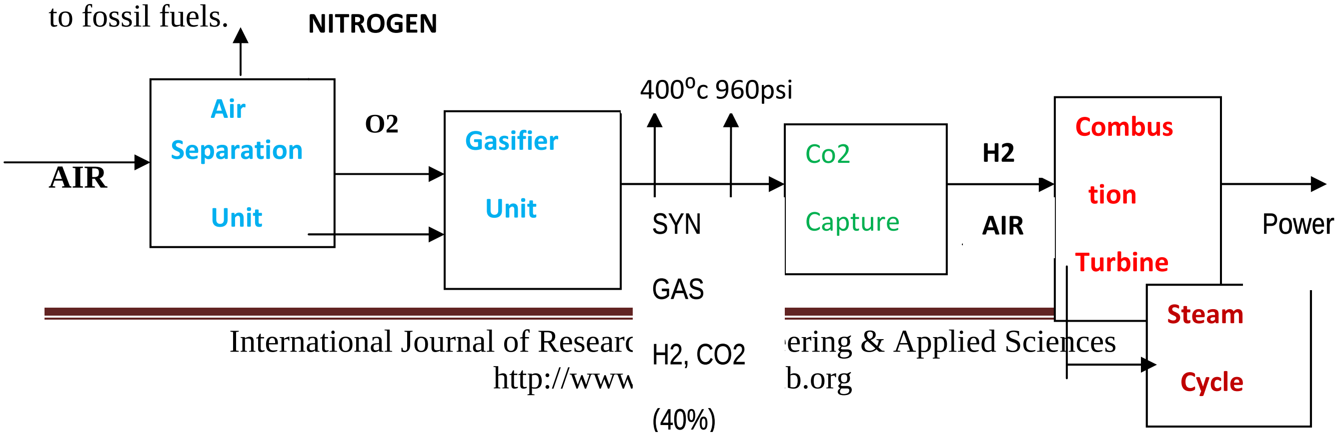

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Fig 2 : Precombustion Process

Precombustion is particularly applicable to new power plants as we have alredy seen that the system has got advantage of capturing high pressure CO_2 and the involvement of cost is also very low. Some more technologies are also available in this system .However the system constraints like availability of components,spare parts and improvements of efficiency of the system are of regular nature.In the appropriate application of CO_2 capture method some issues may cause problem to the system.Monoethanolamine (MEA)is a widely used solvent in CO_2capturing.But CO_2 capturing process with amine is the most reliable one(07,11). Hazardous wastes lying at the bottom of the plant may cause environmental problem.Ammonia gas is produced at the plant by degradation of ammonium solvent.Some other dangerous solid wastes may also produce in this connection which may be closely monitored.Chemical and thermal degradation of solvent affect the efficiency of CO_2 capture process by reducing the amine fraction of the solvent..Recently in the laboratory CO_2/H_2 separation by a pressure swing adsorption process is investigated (6).The development of a H_2/CO_2 separation process for an IGCC plant with precombustion CO_2 capture needsa fundamental material evaluation as well as rigorous process development including modeling.The higher adsorption of CO_2 on the activated carbon at the same process condition is for an effective process.

Thereafter carbon sequestration research activities encompasses all activities of sequestration and is composed of(1)Geologic srquestration of CO_2 and (2)terrestrial sequestration.

3.1 Probable sequestration of co2: Geologic sequestration involves the capture and disposal of anthropogenic CO_2 in geologic sites.Various geologic sites identified so far includes producing or abandoned unmineable coal seams,oil and natural gas reservoirs,deep saline aquifers and deep ocean injections .During the storage the gas stream is compressed to its critical condition so that the maximum amount of gas can be stored in the geologic sites.Since CO_2 dissolved in water and forms carbonic acid, which is corrosive, minimizing the water content in the CO_2 stream is essential for safe operation of the compressor.For oil recovery operations in U.S.A substantial amount of CO_2 already supplied.Rejected coal seams located around central and eastern coal fields are the possible areas where our industry can carry out storage operations.The rejected coal seams filled with water for prevention of firing.The project is located around 700 km from such unutilized coal seams,oil basins ,underground depth of 800metres and sea bed to store atleast more than a few billions of space to accommodate CO_2. This need additional transportation cost if carried by long haulage gas tanker. Regarding pipe line transportation booster compressor is required after every distance of 300km to cover the total distance. This transportation distance may vary from 700 to 1800 kmto reach the selected oil basins,saline aquifiers or ocean basin. The capacity of such storage should be more than 100 billion tones to store CO_2 jointly or by a single company. As alredy observed that efficiency of plant come down by average 12 % of the existing free capacity.efforts may be made to utilize the CO_2 as far as possible .From this view point a few of the practice may be exercised **1**While storing in a depleted gas or oil reservoir both of which are having enormous capacity, gas reservoirs seems to be better.Oil/Gas reservoir are being used globally for 140 giga billion tones annually .Presence of pure and coal bed methane and the reaction between the CO_2 and pure methane are to be considered for safe3 storage.**2.** In India CO_2 is being used substantially with ammonia for producing $(NH_4)_2CO_3$ which is an useful fertilizer and for this purpose accumulated CO_2 is being passed over ammonia solution .**3** Sequestration of CO_2 is required for mineral carbonation by mixingCO_2 with solid minerals like olivine to form $CaCO_3$,a chemical being used substantially. For this purpose a 3 tier method is being followed ☹a)Preparing the reactant minerals mining, crushing and milling—and transporting them to processing unit(b)Reaching the concentrated CO_2 stream with the prepared mineral and (xc)separate the carbonate products and storing them in suitable repository.4CO_2 can be used as enhanced oil recovery(EOR)fluid which is capable of enhancing oil recovery(5)after the pressure is no longer supporting the recovery of hydrocarbons. Typically oil fields produce 20—40% of its resources using conventional method presence in the reservoir and the implementation of EOR system to supply the balance 30—60% after recovering from oil basin

3.**2 Sustainability of the system by utlising H_2 :** From the system discussed so far as it appears that plant efficiency sacrificed by applying syngas which reduces the efficiency to 31.8% in comparison to post combustion system efficiency 34.8%.In the plant hydrogen can be used which burns at a higher temperature than methane and other hydrocarbons.But the cost of hydrogen is more than any fossil fuel(8).So the advantage of ignition to be gainfully utilized. The higher temperature of combustion process increases the levels of undesirable NO_x which puts blockade in orogress of the process as already discussed in CO_2 capturing system. The higher temperature of H2 may be the cause of melting and deforming of metals. Similarly ignition commences at a lower temperature. Turbine blades are also vulnerable to extreme temperatures which is 2300 º k or more.To avoid the catastrophie hydrogen is mixed with nitrogen or steam before combustion to reduce hydrogen concentration.When CO2 is used as the oxidizer in a gasification process,the nitrogen that is separated to produce oxygen may be added to the hydrogen after separation.Turbine modifications may also be necessary to accommodate the difference in density of the hydrogen combustion gas mix compared to a normal methane or air mix.

3.3 Integrated gasification combined cycle(IGCC): Integrated gasification combined cycle power plants are relatively new coal power plant deswign where the coal is gasified before combustion.This design has several advantage over ordinary pulverized coal power plants.The gasification of coal makes it possible to use a gas or steam turbine combined cycle which is considerably more efficient than the single steam cycle available in pulverized coal concepts.In IGCC existing plant design,coal is reformed to the syngas in a gasification process ,and the syngas is used directly in gas turbine. As carbon is removed from the fuel as carbon di oxide in the gasification process,CO2 emission from the power generation are considerably lower than with coal fired cases directly.But even in IGCC plants CO2 emissions are discharged directly to the atmosphere and thus without any practical solutions to our problem.As emission of CO2 is almost in pure stream the capturing of CO2 is much easier even when capture is retro fitted in the existing plant. .Present IGCC plants are not fully capable of operating on precombustion designs, as they are fired with syngas which produces same emissions as combustions of natural gas.The modification is required in the present system so that it can produce H2 directly and a water gas shift reactor can also be developed conveniently with it.

4.0 RESULT AND ANALYSIS :

Use of the combined cycle increases the efficiency level of the power plant by 20% which means the original capacity of the thermal power plant with precombustion system of capturing reduced to 800mw will be enhanced by another 200 mw approximately. However the application of H2 gas is a very special one for which a reasonable value of 2300°k stochiometric flame temperature to be maintained in the gas turbine to meet the standard of operation(09,12).Regarding the application of Hydrogen the combustion leads to a lower mass flow rate and a different component of product gases wlth an higher water content that in turn lnfluences the molecular weight and the specific heat of the mixture. These effects are observed as follows:

1Variation of enthalpy drop in the expansion of gas

2.A variation of the flow rate at the turbine inlet which in turn affects the turbine and compressor matching

3 A variation of heat transfer coefficients on the outside of the turbine blades affecting the cooling system performance .

Blade cooling and pressure ratio are the two important constraints in utilising such combined cycles of hydrogen gas, suitably diluted with steam or nitrogen. The varied composition of the hot steam enhances convective heat transfer coefficients on the outer side of the blades increasing the thermal flux with negative consequences on the performances of the cooling unit. The highest pressure ratio increases the convective heat transfer coefficients on both blade sides and the temperature of the air used in cooling unit whose performances decays

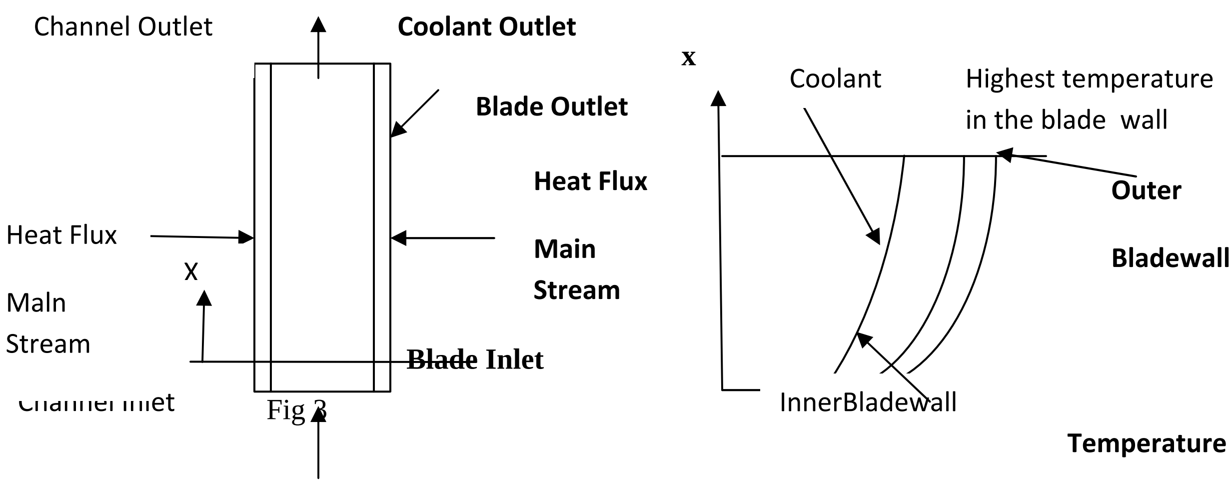

Fig 3

nitrogen which has been cycled in gas turbine compressor, cycle can be reused for the purpose of cooling in the generator.As hydrogen is 7.5 times better convectivity and much less density than air it can gainfully cooled the existing generator system as already pointed out generator cooling system.

The present power plant is running with 1050 MW installed power level have to contribute another 200 MW for installation of such CO2 capturing plant which has very effective CO2 capturing system.But such increase of capital cost for anew plant upto 45% and the cost of electricity by 30%(EPA 2008) should be offset by effective utilization of H_2 gas to generate the additional range of electricity by a margin of another 200 MW. But the system constraint as discussed so far are too many to be taken care of. Besides the commercial applications of CO_2 in fertiliser particularly inn ammonium carbonate and utilization in soft drinks in case commercially viable can reduce the financial bottleneck .Regarding CO_2 sequestration the technology is available but the impact of cost is very high(Xina Xie).The target set by Keoto Protocol in reducing the CO_2 level emission in Intragovernmental Panel to keep the radiation level 5% below the 1990 level assuming average CO_2 generation 4 billion tons each year is difficult..

5.0 CONCLUSION :

Environmental study and sustainability of power plant generation maintaining the balance in biosphere and ecosystem is an important aspect in intragovernmental issues.Looking at the nature of consumption the carbon deposits which is still huge and its consumptions in the current decade are enormous .The situation arrived when government of each country think seriously about the environmental pollution level and the alternative to gradual depletion of fossil fuels which may be huge but limited in view of our consumption trends for the period upto 2050..Intragovernmental Panel on climate change (IPCC)observed that average global temperature increased 0.13 °Cper decade from 1956 to 2005 and 0.2°C per decade from 1990—2007.Setting of emission by Kyoto Protocol is the primary step taken by the international body keeping in view of increase of emission level upto 2050.From this project development study for reducing CO_2 in a thermal power plant where emission level is very low per capita in India but very high at macro level, the importance of collective sequestration of CO_2 is predominant as the joint initiative with other thermal power plants are not immediately forthcoming. Besides the transportation cost of such CO_2 or its liquefied form is not easily feasible. The application of hydrogen in such cases need more deatailed work to avoid accidents and explosions .Ergonomical study of design and modifications of the design and process to set the product standard particularly the ratio of $N_2$and steam with nitrogen to be fixed up after model testing Similarly from the turbine side the material of turbine to be carefully selected to operate at 2300°K for successful operation of the plant at 51.8% efficiency. The waste disposal system in the plant regarding solvent should be monitored and the collection of pure CO_2 to be processed from business angle which is either to send directly to the customer at very cheaper cost or to store in such place from where the material can be salvaged safely .The environmental sustainability and economic sustainability cannot be separated from social sustainability. The executives and the workers to be properly trained about implementation of a new system and they should interact themselves along with the plant control to avoid breakdown.T he work life style should be improved to match the new technology so the success of that technology should be better understood at the project.

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