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Emerging Technologies for Optimizing Efficiency and Minimising GHG Emission in Existing and Upcoming Coal Fired Plants in India

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ABSTRACT : This time where margin between demand and supply of electrical power is increasing utilities are facing the difficult task how to solve the problem. One option is that go for new generating units with high efficiency, eco-friendly but this takes time and huge amount so to overcome this problem, it is realized that why not go for possible ways to maximize the efficiency of the existing power plants. To utilize the full available potential of existing plant equipments, it is not adequate to optimize components on an individual basis, rather it is necessary to take systematic approach and look at the complex interaction between the components and asses how best its potential is to be utilized.

This paper gives the few ideas through which the available potential at every possible aspect to maximize the efficiency of the system. An increase in efficiency has an impact on the level of emissions a plant releases. Since less fuel is required to generate a given kWh, fewer emissions are released for that given kWh.

Keywords : FBC, GHG, ISB, Super Critical, Ultra Super Critical.

I. INTRODUCTION

This paper gives the information to maximize the utility of coal use in power generation, plant efficiency is an important performance parameter. Efficiency improvements have several benefits.

- Prolonging the life of coal reserves and resources by reducing consumption.
- Reducing emissions of carbon dioxide (CO_2) and conventional pollutants.
- Increasing the power output from a given size of unit and
- Potentially reducing operating costs.

Also focused on upcoming new technologies for improvement in efficiency of the thermal power plant.

II. IN INDIAN SCENARIO POWER GENERATION BY COAL FIRED POWER PLANTS

As on 29 Feb. 2012., in India the total power generation is 190592.55 mW and coal is the most abundant fossil fuel in the India and is predominately used for Electrical power generation. 105437.38 mW i.e., 55.32 % power generated in the India was produced by coal, electric utilities have burned solid coal in steam generating units.

This section gives a summary overview of the types or ranks of coal that are typically burned in Indian power plants, the most commonly used combustion processes, and the resulting emissions of greenhouse gases.

In India, coals are ranked based on the geological age of the coal and the conditions under which the coal formed, coals are divided into four major categories called “ranks:” anthracite, bituminous coal, sub-bituminous coal, and lignite. Most coal-fired power plant in the India burn either bituminous, sub-bituminous or lignite coals having grade *E* and *F*. For the purpose of prices, the grades of coal on the basis of UHV (Useful Heating Value) being considered are as under in Table1 and Table 2.

Table 1. Classification of coal on UHV.

Coal Grade	UHV (Kcal / Kg)
A	> 6200
B	> 5600 – 6200
C	> 4940 – 5600
D	>4200 – 4900
E	> 3360 – 4200
F	>2400 – 3600
G	>1300 – 2400

Source : Anthropogenic emission from energy activities in India.

Table 2. Characteristics of major coal used for electricity generation in India.

Coal Grade	C % Carbon	H % Hydrogen	S % Sulfur	N_2 % Nitrogen	O_2 % Oxygen	A % Ash	M % Mositure	NCV (kcal/ kg) Net Calorific Value	UHV (kcal/ kg) Useful Heat Value
D	33.1	2.46	0.44	0.83	NA	25.9	7.2	4999.0	4332.0
D	30	2.48	0.57	0.69	NA	27.1	2.9	5555.0	4760.0
D	32.31	2.12	0.4	0.78	NA	25	7.3	5068.0	4442.0
E	37.9	2.4	0.53	0.8	6	30.4	7.5	4529.0	3670.0
F1	41.87	3.33	0.56	0.94	6	34.07	7.8	4137.0	3122.0
F2	44.47	3.37	0..35	0.99	6	36.3	8.4	3833.0	2731.0

Source : Anthropogenic Emission from energy activities in India.

III. COAL UTILIZATION IN INDIAN THERMAL POWER PLANTS

Steam turbine power plants operate on the Rankine thermodynamic cycle. In India Coal-fired power plants use one of these basic coal utilization processes (see Table 3).

Table 3.

Coal-firing Configuration	Coal Combustion Process Description	Operating Characteristics	
Pulverized-Coal	Coal is ground to a fine powder that is pneumatically fed to a burner where it is mixed with combustion air and then blown into the furnace. The pulverized coal particles burn in suspension in the furnace. Unburned and partially burned coal particles are carried off with the flue gas.	Wall-fired	An array of burners fire into the furnace horizontally, and can be positioned on one wall or opposing walls depending on the furnace design.
		Tangential fired (Corner fired)	Multiple burners are positioned in opposite corners of the furnace producing a fireball that moves in a cyclonic motion and expands to fill the furnace.
Fluidized-bed combustion	Coal is crushed into fine particles. The coal particles are suspended in a fluidized bed by upward-blowing jets of air. The result is a turbulent mixing of combustion air with the coal particles. Typically, the coal is mixed with a sorbent such as limestone (for SO_2 emission control). The unit can be designed for combustion within the bed to occur at atmospheric or elevated pressures. Operating temperatures for FBC are in the range of 1,500 to 800 to 900 ºC.	Bubbling fluidized bed (BFB)	Operates at relatively low gas stream velocities and with coarse bed size particles. Air in excess of that required to fluidize the bed passes through the bed in the form of bubbles.
		Circulating fluized bed (CFB)	Operates at higher gas stream velocities and with finer-bed size particles. No defined bed surface. Must use high-volume, hot cyclone separators to recirculate entrained solid particles in flue gas to maintain the bed and achieve high combustion efficiency.

IV. CO_2 EMISSIONS FACTORS IMPACTING COAL-FIRED POWER PLANT

The level of CO_2 emissions that can potentially be released from a coal-fired Power Plant depends on the type of coal burned, the overall efficiency of the power generation process, and use of air pollution control devices.

V. IMPACT OF COAL GRADE ON CO_2 EMISSIONS FROM POWER PLANT

The amount of CO_2 that potentially can be emitted from a coal-fired power plant varies depending on the coal grade burned. The amount of heat released by coal combustion depends on the amounts of carbon, hydrogen, and oxygen present in the coal and, to a lesser extent, on the sulfur content. Hence, the ratio of carbon to heat content depends on these heat-producing components of coal, and these components vary by coal grade. Table 4 presents grades of Indian coal with Elemental analysis. Comparison of the CO_2 emissions for the average heating values of Indian coals Table 5. The values presented in the table are assuming complete combustion. However, for a given coal grade there is variation in the CO_2 emission depending on the carbon and coal bed from which the coal is mined. Therefore, switching from a low to a high grade coal will tend to lower GHG emissions.

Table 4. Grades of Indian Coal with Elemental Analysis and Moisture Content.

Coal Grade	C % Carbon	H % Hydrogen	S % Sulfur	N_2 % Nitrogen	O_2 % Oxygen	A % Ash	M % Mositure	UHV (kcal/ kg) Useful Heat Value
D	33.1	2.46	0.44	0.83	NA	25.9	7.2	4332
D	30.0	2.48	0.57	0.69	NA	27.1	2.9	4760
D	32.31	2.12	0.4	0.78	NA	25	7.3	4442
E	37.90	2.4	0.53	0.8	6	30.4	7.5	3670
F1	41.87	3.33	0.56	0.94	6	34.07	7.8	3122
F2	44.47	3.34	0.35	0.99	6	36.3	8.4	2731

Table 5. Elemental analysis and moisture content of the coal used at some power plants in India.

Coal	C % Carbon	H % Hydrogen	S % Sulfur	N_2 % Nitrogen	O_2 % Oxygen	A % Ash	M % Mositure	NCV (kcal/ kg) Net Calorific Value	CO_2 (kg/ kwhr) Carbon di-oxide
Dadri	40.3	4.16	0.5	0.9	15.92	38.22	NA	NA	0.865
Rihand	37.74	3.26	0.39	0.73	14.65	43.23	NA	NA	0.879
Singrauli	50.22	4.78	0.33	1.09	17.25	26.33	NA	NA	0.812
Chandrapur	37.69	2.66	0.8	1.07	5.78	47.0	5.0	3649.9	1.052
Dahanu	42.39	3.73	0.39	0.82	14.21	38.46	5.93	3986.37	0.8258
Nevyeli Lignite	26.09	2.33	1.5	0.24	13.33	7.0	47.0	2229.0	1.017
Kutch Lignite	28.33	3.03	2.25	0.88	13.94	15.0	36.0	2900.0	0.977

VI. CO_2 CONTROL TECHNOLOGIES IN COAL-FIRED POWER PLANTS AND APPROACHES

Effective and commercially viable CO_2 control technologies for coal fired Power plant are available and Some are still in the research and development phase and are not yet ready for commercial application. The basic approaches to reduce the amount of CO_2 released to the atmosphere either by reducing the amount of fuel used so that amount of CO_2 formed by improving the energy efficiency of the electrical generation process, or by separating the CO_2 for long-term storage using carbon capture technology[4] which is still in the research and development.

VII. EFFICIENCY IMPROVEMENTS FOR EXISTING COAL-FIRED POWER PROJECTS

Many improvements measures are applied to coal-fired power plant to increase thermal efficiency of power plant. A summary of the findings from the different case studies, research papers and published articles identifying potential efficiency improvement techniques applicable to existing coal-fired power is presented in table 6. all of these improvements could not necessarily be implemented at each coal-fired power plant.

Table 6. Summary of findings for Improvement of Efficiency of Existing Coal-fired Power plants.

Efficiency Improvement Technolog	Description	Reported Efficiency Increase
Combustion Manage-ment and Flue Gas Exhaust Temperature Optimization	Proper preparation of input coal, accurate assessment and distribution of combustion air, fine tuning of the draught system control the combustion [5]. Water/steam quantity and quality control in economizer, evaporator, super-heater, re-heater and combustion parameters dictate the boiler outlet parameters inclusive of flue gas exhaust temperature.	1% a
Cooling System Heat Loss Recovery	In general, the impact of cooling-water temperature on condenser pressure is about 2 mbar per 1ºC changes in inlet temperature6, and the associated impact on heat rate is in the order of 0.1% of station heat consumption per 1 mbar. Thus a difference of 5ºC in cooling water inlet temperature might change unit heat consumption by around 1% [7].	0.2 to 1% b

condt.

Efficiency Improvement Technolog	Description	Reported Efficiency Increase
Flue Gas Heat Recovery	Flue gas exit temperature from the air pre heater can range from 135 ºC to 190 ºC depending on the acid dew point temperature of the flue gas, which is dependent on the concentration of vapor phase sulfuric acid and moisture. For power plants equipped with wet FGD systems, the flue gas is further cooled to approximately 69°C as it is sprayed with the FGD reagent slurry. However, it may be possible to recover some of this lost energy in the flue gas to preheat boiler feed water via use of a condensing heat exchanger.	0.3 to 1.5%
Low-Grade Coal Drying	Sub bituminous and lignite coals contain relatively large amounts of moisture (15 to 40%) compared to bituminous coal (less than 10%). A significant amount of the heat released during combustion of low-grade coals is used to evaporate this moisture, rather than generate steam for the turbine. As a result, boiler efficiency is typically lower for plants burning low-grade coal. The using waste heat from the flue gas dry low-rank coal prior to combustion or provide space in CHP to dried out.	0.1 to 1.7%
Intelligent Soot Blowers Optimization	Soot blowers intermittently inject high velocity jets of steam or air to clean coal ash deposits from boiler tube surfaces in order to maintain adequate heat transfer. Proper control of the timing and intensity of individual soot blowers is important to maintain steam temperature and boiler efficiency. The ISB system functions by monitoring both furnace exhaust gas temperatures and steam temperatures	0.3 to 1.5%a

Source : (*a*) Data from Gandhinagar and Ukai Thermal Power Station. (*b*) The International Energy Agency (IEA), NETL, Reported efficiency improvement metrics adjusted to common basis by conversion methodology assuming individual component efficiencies for a reference plant as follows : 8 7% boiler efficiency, 40 % turbine efficiency, 98 % generator efficiency, and 6 % auxiliary load. Based on these assumptions, the reference power plant has an overall efficiency of 32 %.

VIII. EFFICIENCY IMPROVEMENTS FOR NEW COAL-FIRED POWER PROJECTS STEAM CYCLE

The theoretically maximum achievable thermal efficiency that can be achievable by an power plant by using the Rankine cycle regardless of the technologies used is approximately 63 % but due to thermodynamic limitations and energy losses that cannot be recovered. Existing coal-fired Power plant using the Rankine cycle operates well below this limit. If the energy input to the cycle is kept constant, increasing the pressures and temperatures for the water-steam cycle will increase the output and the overall efficiency. However, a practical limitation to the higher pressure and temperatures that can be achieved in a boiler is the availability of boiler materials that can withstand these increased conditions over an acceptable service life. The majority of existing PCfired power plant have subcritical boilers and now Subcritical boilers typically operate at pressures of 17 MPa and at temperatures between 540 to 570 ºC with maximum efficiency of 37 % in 330MW and super critical boilers are designed to operate at steam pressures as high 22 MPa and steam temperatures as high as 570 ºC with efficiency of up to 41% in 660 mW. Now latest highest capacity power generation plant in India is 800MW super critical technology is yet to come in operation. The parameters for supercritical technology is SHO Pressure at outlet (kg/cm^2) -258 (25.4 MPa)

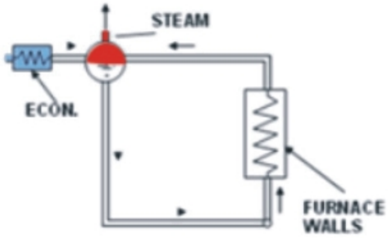
SHO temperature ºC - 571

RH outlet temperature ºC -569

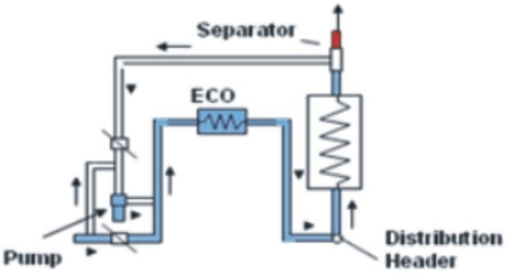
SHO Steam flow for 800MW (T/hr) - 2550

SHO Steam flow for 660MW (T/hr) - 2115

The materials that can withstand the high-temperature and pressure of supercritical steam conditions allows for substantial improvements in efficiency for power plant. “Supercritical” is a thermodynamic term describing the state of a substance where there is no clear distinction between the liquid and the gaseous phase (i.e., they are a homogenous fluid). Technically, the Supercritical power plant typically use steam pressures of 24 MPa and steam temperatures of 580ºC. However, supercritical boilers can be designed to operate at steam pressures as high as 25 MPa and steam temperatures as high 590 ºC. Above this temperature and pressure the steam is called “ultra-supercritical”. For a supercritical boiler, the feed water enters the boiler, is converted to steam, and is passed directly to the steam turbine. A supercritical boiler does not have a steam drum as shown in Fig 1.



(i) Sub critical boiler with “Drum”



(ii) Super critical boiler with “separator”

Fig. 1.

Because the water-steam cycle medium is a single phase fluid with homogeneous properties, there is no need to separate steam from water in a drum. Supercritical boilers operate as once-through boilers in which the water and steam generated in the furnace water walls passes through only once. This eliminates the need for water/steam separation in drums during operation, and allows a simpler separator to be employed during start-up conditions. Because these units do not have thick-walled steam drums, their start-up times are quicker, further enhancing efficiency and plant economics.

All power plants have a single reheat cycle where the steam is first passed through the high pressure steam turbine and then send to reheat in the boiler before passing to the low pressure turbine. This process increases the efficiency of the power plant without increasing the maximum temperature of the steam. An additional efficiency may be increases by the use of a double reheat cycle, which reduces fuel use by approximately 1.5% compared to a similar power plant using a single reheat cycle (Retzlaff, 1996). It is recognized since the 1960s but due to additional cost not used.

Continuing research and advances in metallurgy have allowed the development of supercritical and ultra-supercritical (USC) boilers. USC boilers designed to operate at steam conditions of 310 kg/cm^2 and temperature of 600 ºC operate at efficiencies approaching more than 42 % as shown in Fig. 2.

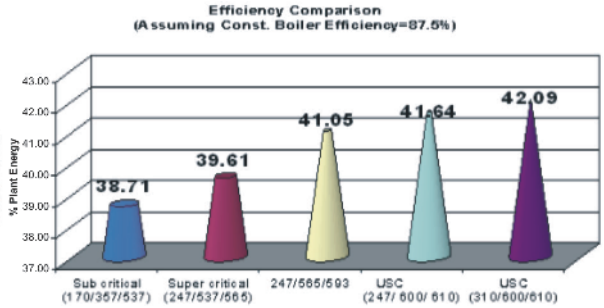


Fig. 2 Sub critical to Ultra Super Critical Plants- Efficiency a/ b / c , USC = Ultra Super Critical; a = MS Pressure kg/cm^2, b = MS Steam Temp ºC, c = RH Steam Temp ºC

Source: Adoption of Supercritical Technology an Affirmative Step by NTPC Limited, S Mahajan.

IX. COAL DRYING

Low-grade coals are often utilized because the low cost per unit of heat input. However, a major disadvantage of low grade coals is their high moisture content, typically 25 to 40%. When this coal is burned, considerable energy is required to vaporize and heat the moisture, thus raising the heat rate of the power plant and lowering its efficiency. As fuel moisture decreases, the heating value of the fuel increases so that less coal needs to be fired to produce the same amount of electric power. So the pre-combustion drying[10] of low-grade coals can improve the overall efficiency and several advanced coal drying technologies are or nearly are commercial available.

X. OXYGEN COMBUSTION

Oxygen combustion (oxy-combustion, oxy-firing or oxy-fuel) is an emerging technology applicable to either new or existing power plants. The advantage offered by this technology is its potential for CO_2 emissions control because it produces a concentrated (nearly pure) CO_2 exhaust gas stream that requires minimal post-combustion clean-up prior to compression, transportation, and injection for long term storage. The basic concept of oxy-combustion is to use a mixture of oxygen (or oxygen-enriched air) and recycled flue gas (containing mostly CO_2) in place of ambient air for coal combustion. The resulting flue gas contains primarily CO_2 and water vapor with smaller amounts of oxygen, nitrogen, SO_2, and NO_X. Consequently, the flue gas can be processed relatively easily to further purify the CO_2 (if necessary) for use in enhanced oil or gas recovery or for geological storage.

XI. CONCLUSION

To improve the operating efficiency of the coal-fired power plants and thereby significantly reduce CO_2 emissions above mentioned recommendations are require to be focused and also adopt the technology for upcoming new coal-fired power plants having max.efficiency. The development and demonstration of those technologies that target higher efficiency at coal-fired power plants should be accelerated. For example, advanced materials, coal cleaning and drying, co-generation of heat and power, and more efficient CO_2 capture technologies all need to be deployed. In addition to these efficiency improvements, the deployment of CO_2 capture and storage (CCS) technology is vital.

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