Review on Performance evaluation of co-firing MSW with coal at coal-fired power plant

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Abstract - **As of now, the problem of MSW processing and disposal is a globally pressing one. The main components of MSW are paper and cardboard (25–30% of total wastes volume); organic wastes (including food, 26–35%); metal and glass (5–12%); plastic (7–10%); wood, textiles, and rubber (2–4% of each). Thus, the content of energy-yielding fractions (cardboard, paper, wood, textile, polymer wastes) is about 82% of the total volume of MSW. Annually, 1.3–1.6 billion tons of such wastes are generated globally. About 75% of municipal wastes are not reclaimed or processed. Instead, they are stockpiled at landfill sites where they undergo slow thermal decomposition thus polluting the environment. According to experts, the impact of such wastes on the environment is comparable to that of coal-fired thermal power plants and automotive vehicles for some indicators.**

Thus, the aim of this review paper "to evaluate a power plant's performance when co-firing using various percentage of replacement with Municipal Solid Waste" on the basis of previous study.

Index Terms - **Municipal Solid Waste, Coal Fired Power Plant, Calorific Value, Plant Efficiency, Power Generation**

1.INTRODUCTION

A power plant is assembly of systems or subsystems to generate electricity, i.e., power with economy and requirements. The power plant itself must be useful economically and environmentally friendly to the society.

The history of power development in India dates back to 1897 when a 200-kW hydro-station was first commissioned at Darjeeling. The first steam station was set up in Calcutta in 1899. By the end of 1920, the total capacity was 130 MW, comprising. Hydro 74 MW, thermal 50 MW and diesel 6 MW. In 1940, the total capacity goes to 1208 MW. There was very slow development during 1935-1945 due to Second World War. The total generation capacity was 1710 MW by the end of 1951. The development really started only after 1951 with the launching of the first five-year plan.

1.1 Power plant historical development

In a search for reduced operating costs, plant design has moved on from generating units based on the Rankine cycle, which typically achieved thermal efficiencies in the range 30--40 per cent. Now combined cycle gas turbine (CCGT) units utilizing the latest heat recovery steam generator (HRSG) plant can achieve efficiencies of 50-60 per cent. The removal of European Community restrictions on burning gas for power generation, coupled with other factors, has resulted in increased deployment of CCGT units. However different current plant may now appear, the underlying principles of generation and distribution had been mastered by the end of the nineteenth century. Since then, the evolution of power plant design has been largely incremental, driven mainly by new technology. The past three decades have witnessed the integration of microprocessor equipment into every aspect of generation and distribution. The next 20 years should see this technology develop further, bringing with its pseudo-intelligent applications which truly harness the rapidly expanding computational power available. New computer-based systems will increase plant automation, improve unit control, and permit more flexible plant operation, while at the same time maximizing unit efficiency and reducing harmful emissions.

New developments in plant design are continually being sought and investigated to improve unit performance. Currently integrated gasification combined cycle (IGCC) and advanced pressurized fluidized bed combustion (PFBC) are emerging technologies that are showing great potential for yielding high efficiency and low emissions.

1.2Traditional coal-fired power generation technology

The traditional method of producing electricity from coal is to burn the fuel in air and capture the heat released during the combustion in a boiler where it is used to raise steam, the latter driving a steam turbine generator. This type of power plant has been evolving since the modern steam turbine was invented by Charles Parsons in 1884. His first unit drove a dynamo that produced 7.5 kW of electrical power. A power plant of this type is made up of several key components (Figure 1.1). There will be a fuel handling system designed to receive the bulk coal deliveries from the mine and convert the mined coal into a form that can be readily burned. In most modern coal-fired power plants this involves crushing the fuel to produce a powder. This pulverized coal is then fed into a combustion system where it is mixed with air and ignited under controlled conditions, releasing chemical energy as heat. This heat is captured by water within tubes in the boiler, the heat energy converting the water into steam. The combustion system and boiler must be closely integrated for highest efficiency and will normally be considered a single unit in modern plants. Once combustion is complete most of the ash residue falls to the bottom of the combustion chamber and is removed as slag. However, some ash forms into fine particles that are carried away with the hot combustion gases. These particles must be removed at a later stage.

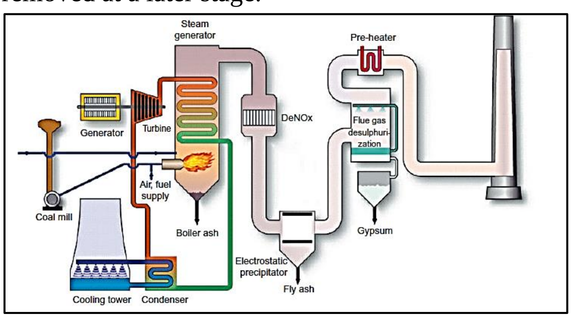

Figure 1.1 Schematic of a pulverized coal-fired power station

Steam generated in the boiler is carried to a steam turbine that is designed to extract as much heat energy as possible from the gas. In a large coal-fired power station the steam turbine is likely to be composed of at least three elements: a high-pressure (HP) turbine, an intermediate-pressure (IP) turbine, and one or more low-pressure (LP) turbines. Steam passes from one to the next in sequence. Higher efficiency can often be achieved by reheating the steam between the HP and IP turbines by returning it through a special stage of the boiler called a re-heater.

To extract the maximum amount of energy from the steam, a condenser is fitted to the output of the LP turbine(s) to condense the steam back into water. The colder the cooling water used in the condenser, the higher the efficiency will be. The water is then returned to the boiler and passes around the cycle again.

1.3 Boiler Technology

The boiler in a coal-fired power plant converts chemical energy contained within the coal into heat energy that is captured and carried away in hot, high-pressure steam (Figure 1.2). Coal-burning technology has a long history and has seen many plant configurations, but the most important type of plant in modern use is the pulverized coal-fired power plant, often abbreviated as PC plant. PC plants probably account for more than 90% of all operating coal-fired power stations in general use and this type of plant is the main plant design for future high-efficiency coal-fired plants. A PC plant burns coal that has first been ground to a fine powder using large grinding mills.

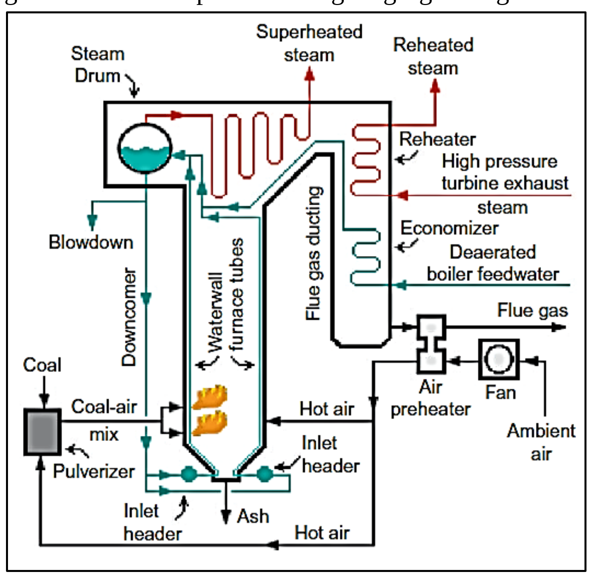

Figure 1.2 Cross-section of a pulverized coal plant boiler

II- LITERATURE REVIEW

2.1 General

Some researchers have been carried out the research for find out the effect of various different supplementary fuel on the power plant efficiency and working conditions. Some of them are as:

2.2 Previous Research

"Thermodynamic analysis on the transient cycling of coal-fired power plants: Simulation study of a 660 MW supercritical unit"

Chaoyang Wang, Ming Liu, Bingxin Li, Yiwen Liu, Junjie Yan

The flexibility of coal-fired power plants must be improved to satisfy load fluctuations in power grids caused by the rapid spread of power generation capacity from unpredictable renewable energy sources. Startups, shutdowns and large amplitude load cycling have become normal operational states for coal fired power plants in recent years. The extremely high thermal inertia of a power plant influences the energy consumption of the power plant in load fluctuation processes. To obtain the energy consumption characteristics of power units during transient cycling processes, dynamic models of a 660 MW supercritical unit were established with the GSE software. The heat storage and control systems of the unit were considered. The energy consumption of the power plant was obtained at different cycling rates and compared with the results calculated with steady-state models. Results show that compared with those obtained with steady-state models, the standard coal consumption rate (SCCR) of the power plant increased by 3.57 g (kW h)-1, which accounts for 1.3% of SCCR at most during the load-up process and decreased by 2.96 g (kW h) -1, which accounts for 1.0% of SCCR at most during the load-down process. The average SCCRs of these dynamic and steady-state models differed when the load cycling rates were different. When the load varied between 50% THA and 75% THA, the maximum difference of standard coal consumption rate variation (SCCRV) was 1.2 and 0.26 g (kW h) -1 during the load-up and load-down transient processes, respectively. The maximum differences in SCCRV were 0.85 and 0.34 g (kW h) -1 during load-up and load-down transient processes, respectively, with the load ranging from 75% THA to 100% THA.

"Performance evaluation of co-firing various kinds of biomass with low rank coals in a 500 MWe coal-fired power plant"

Tae-Young Mun, Tefera Zelalem Tumsa, Uendo Lee, Won Yang

Recently in Korea, the co-firing of biomass in existing pulverized coal power plants has become an important mean to comply with the nation's renewable portfolio standard (RPS). This study investigated boiler efficiency, net plant efficiency, and combustion characteristics from co-firing various biomasses along with two coal blends and the combustion of low rank coals through process simulation based on an existing 500 MWe coal fired power plant using a commercial process simulator (gCCS). Five sources of biomass - wood pellet, empty fruit bunch pellet, palm kernel shell, walnut shell, and torrefied biomass were selected as renewable fuels for co-firing. In addition, hard grove grind ability index tests were conducted for a blend of coal (90%) and each selected biomass (10%) based on thermal share input to investigate the milling power consumption of each blended fuel for a more rigorous simulation. The results show quantitatively that when biomass is co-fired the plant efficiency is decreased due to its lower heating value and more power consumption in mills. The plant efficiency of torrefied biomass co-firing was the highest among all biomass co-firing and combustion of low rank coals due to higher energy density and enhanced grind-ability of torrefied biomass after torrefaction.

"Analysis of Increasing Efficiency of Modern Combined Cycle Power Plant: A Case Studies"

Janusz Kotowicz, Mateusz Brzęczek

The paper presents a comprehensive thermodynamic analysis of various gas turbine improvements in a modern combined cycle power plant designed to increase its electrical efficiency. The power plant was analyzed for use in open air (convection, film, and transpiration) cooling without and with cooling air cooler, closed air cooling, closed steam cooling and sequential combustion. The combined cycle power plant is equipped with a 200 MW gas turbine and a subcritical heat recovery steam generator with steam reheating. This article presents the effect of coolant cooling (air) and its use in the steam cycle of the combined cycle power plant. The influence of the higher permissible metal blade temperature in gas turbine on the electric efficiency of the gas turbine as well as the entire combined cycle power plant was also shown. It has also been proven that using industry - known solutions such as steam cooling and sequential combustion, the net electric efficiency of a combined cycle power plant can reach 0.63 - 0.65.

"Effect of Operating Parameters on the Performance of Combined Cycle Power Plant"

A K Tiwari, M M Hasan and Mohd Islam

This paper is intended to review the literature on research, development and projects related to gas turbine combined cycle. It focuses on summarizing several research investigations carried out by the author and associates, during the past years, in the field of gas turbine combined system. The performance of gas-steam combined cycle power plant depends on various operating parameters. The power output and efficiency both depends on operation of topping as well bottoming cycle but mainly depends on topping cycle which is Brayton cycle in this study. Besides the power output and efficiency there are different losses which occur in different components of plant. These are based on first and second law of thermodynamics. The second law approach (exergy analysis) gives better understanding of different losses and optimization of system for higher power output and efficiency. Hence the effect of different parameters on the performance of combined cycle is reviewed in this paper.

"The effect of ambient temperature on electric power generation in natural gas combined cycle power plant—A case study"

Günnur Şen, Mustafa Nil, Hayati Mamur

Natural gas combined cycle power plants (CCPPs) are widely used to meet peak loads in electric energy production. Continuous monitoring of the output electrical power of CCPPs is a requirement for power performance. In this study, the role of ambient temperature change having the greatest effect on electric production is experimentally investigated for a natural gas CCPP. The plant has generated electricity for fourteen years and setup at 240 MW in Aliağa, İzmir, Turkey. Depending on the seasonal temperature changes, the study data were obtained from each gas turbine (GT), steam turbine (ST) and combined cycle blocks (CCBs) in the ambient temperature range of 8–23 ◦C. In electric energy production, an important decrease was in the GTs because of the temperature increase. This decrease indirectly affected the electric energy production of the STs. As a result, the efficiency of each GT, ST and CCB decreased, although the quantity of fuel consumed by the controllers in the plant was reduced. As a result of this data, it has been recommended and applied that additional precautions have been taken in the power plant to bring the air entering the combustion chamber to ideal conditions and necessary air-cooling systems have been installed.

"Adaptation of Thermal Power Plants: the (Ir)relevance of Climate (Change) Information"

Christian W.J. Bogmans, Gerard P.J. Dijkema, Michelle T.H. van Vliet

When does climate change information lead to adaptation? We analyze thermal power plant adaptation by means of investing in water-saving (cooling) technology to prevent a decrease in plant efficiency and load reduction. A comprehensive power plant investment model, forced with downscaled climate and hydrological projections, is then numerically solved to analyze the adaptation decisions of a selection of real power plants. We find that operators that base their decisions on current climatic conditions are likely to make identical choices and perform just as well as operators that are fully 'informed' about climate change. Where electricity supply is mainly generated by thermal power plants, heat waves, droughts and low river flow may impact electricity supply for decades to come.

"Statistical modeling of an integrated boiler for coal fired thermal power plant"

Sreepradha Chandrasekharan, Rames Chandra Panda, Bhuvaneswari Natrajan Swaminathan

The coal fired thermal power plants plays major role in the power production in the world as they are available in abundance. Many of the existing power plants are based on the subcritical technology which can produce power with the efficiency of around 33%. But the newer plants are built on either supercritical or ultra-supercritical technology whose efficiency can be up to 50%. Main objective of the work is to enhance the efficiency of the existing subcritical power plants to compensate for the increasing demand. For achieving the objective, the statistical modeling of the boiler units such as economizer, drum and the superheater are initially carried out. The effectiveness of the developed models is tested using analysis methods like R2 analysis and ANOVA (Analysis of Variance). The dependability of the process variable (temperature) on different manipulated variables is analyzed in the paper. Validations of the model are provided with their error analysis. Response surface methodology (RSM) supported by DOE (design of experiments) are implemented to optimize the operating parameters. Individual models along with the integrated model are used to study and design the predictive control of the coal-fired thermal power plant.

III-CONCLUSION

The facts for the energy potential of MSW on the basis of previous research are as

1. About 50 billion tons of municipal solid waste have already been accumulated in the world by 2018 and are now stored in landfills; and about 24.60-hectare landfill area is utilized as landfill in Jabalpur available for next 10 years only.
2. the annual amount of the world production of MSW is about 1.5 billion tons (nomenclature GMSW); and about 421 mt/day in 2009 and about 1500 mt/day in 2018 MSW are generated in Jabalpur city which is near the power plant and facing problem for MSW management.
3. About 60% of MSW is not recycled and is stockpiled at landfill sites.
4. About 80% of non-processed MSW is combustible

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