PERFORMANCE ANALYSIS OF SUBCRITICAL, SUPERCRITICAL AND ULTRA-SUPERCRITICAL COAL FIRED POWER PLANTS

[1]Mohamed Said Mohamed, [2]Mundlapati Swarnakanth, [3]R.Kumar

[1]B. Tech Student, [2]B. Tech Student, [3]Associate Professor,
[1]School of Mechanical Engineering,
Lovely Professional University, Phagwara, Punjab, India.

Abstract: Numerous scholars have examined a systematic literature review of electricity, exergy, exergy-economic, and economic 4-E study of thermal power plants over the years. In this study, a significant amount of work has been done in coal-fired power plants on the thermodynamic study of the Rankine period of subcritical, supercritical, and ultra-supercritical coal-fired power plants. Further, energy, exergy and economic analysis of these three power plants of different capacities were clearly examined. This paper is intended for researchers who are working on 4-E analysis in a variety of thermal power plants. The scope of future research in thermal power plants is also indicated in this study.

Keywords **- Coal fired power plant, Subcritical power plant, Supercritical power plant, Ultra-supercritical power plant.**

1. INTRODUCTION

Energy proficiency of high energy-devouring businesses assumes a critical part in social manageability, monetary execution and natural assurance of any country. To assess the energy productivity and guide the maintainability advancement, different strategies have been suggested for energy request the executives and to gauge the energy effectiveness execution precisely in the past decades with abapical demonstrating and procedures are created to use of the energy proficiency assessments the connected polices and recommendations dependent on the energy proficiency assessments are provided [1]. The Energy productivity, Certain types of macro-level energy efficiency metrics, particularly for high-energy industries, can be used to assess the assessment framework and the conflict between alternatives[2]. Major science, however, photovoltaic energy hybrid cycles need to be done in order to attain. Indeed, due to solar instability, these systems suffer greatly from non-design activity. Therefore, it is important to establish unique control methods that can enhance the system's efficiency under all working conditions [3] .A lot of research work on thermo-economic analysis of coal-fired power plants have been done by various researchers [4]–[21] .

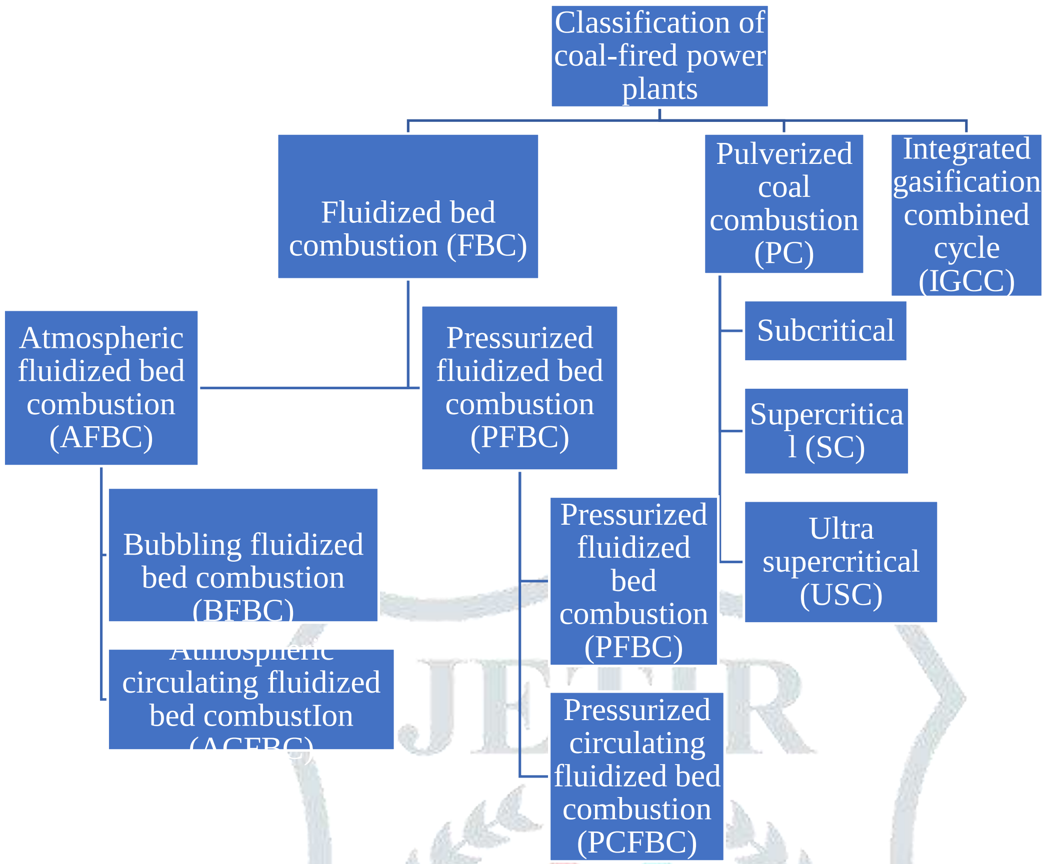

figure 1: classification of coal-fired power plants [22]**.**

table 1: classification of pc power plant (efficiencies for steam coal)

Category	Efficiency (%)	Temperature (°C)	Pressure (bar)	Reference
Subcritical	38	374	165-221.2	[22]
Supercritical	43	540 – 570	221.2-250	[22]
Ultra-Supercritical	47	600	300	[22]

2.TYPES OF COAL-FIRED POWER PLANTS

2.1 Subcritical

Subcritical power plants are the least productive coal-fired power plants, but they account for the vast majority of output. Temperatures are below 374°C and steam pressure is below 221.2 bars. The steam that passes through the turbine is normally not reheated, but instead is released into the atmosphere. Subcritical power plants in the modern era have performance levels of about 38%.

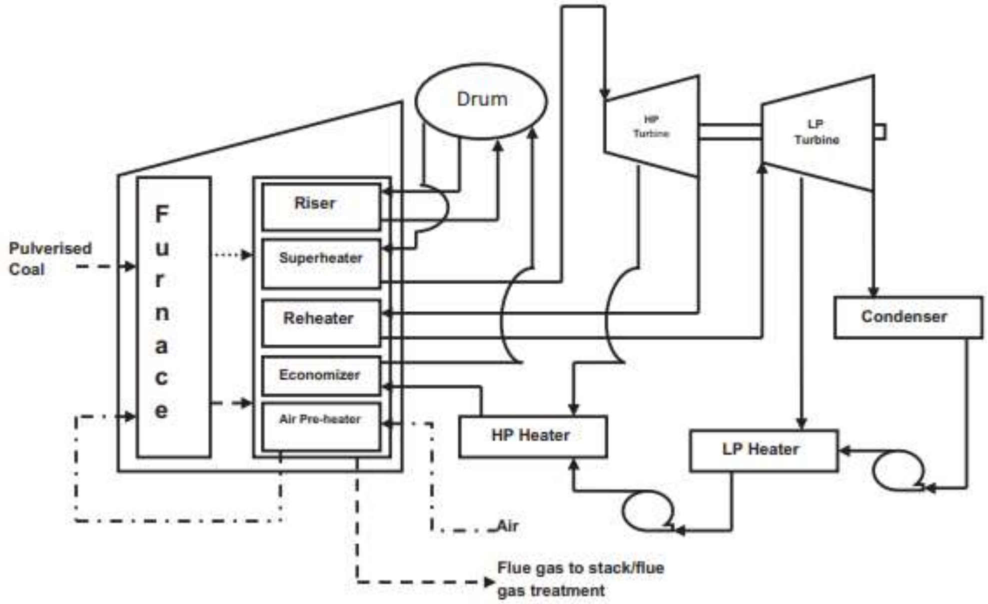

fig. 2. Schema of coal-fired subcritical power plant [23].

2.2 Supercritical (SC)

The first supercritical steam generating units were built in the United States in the 1950s. Increased temperatures and pressures necessitated the development of new, highly resistant stesel varieties, which material science had yet to provide. Fatigue fractures triggered power plant outages, rendering supercritical power plants obsolete at the time. Material that permitted working with supercritical steam conditions did not become available for another twenty years. Steam pressures of 221.2 to 250 bar and temperatures of 540 to 570°C are used in modern supercritical power plants. Since the steam is reheated after passing through the turbine, such power plants can achieve efficiency levels of up to 43%.

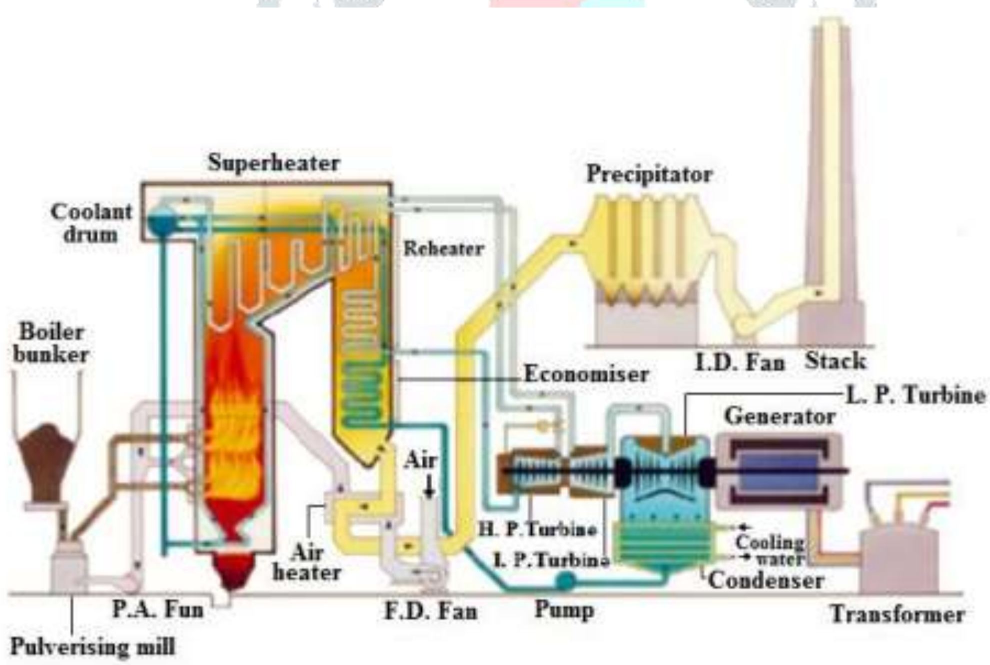

figure :3 schema of supercritical coal fired power plants [24].

2.3 Ultra supercritical (USC)

During the 1990s, material research advanced quickly towards steel forms that were much more heat and pressure resistant than those used in supercritical power plants. Plant builders were able to deal with temperatures well above 600°C and pressures well above 300bar as a result of this. Approximately 60 generating units have been constructed, are under construction, or are currently planned since the first ultra-supercritical power station was built. The majorities of these units were built around the year 2000 and are used as demonstration projects. Ultra-supercritical power plants also have a wide range of performance levels. The least efficient plant is in Japan (Matsuura EDP 1), which achieves 40.5 percent efficiency, whereas the most efficient unit is in Germany Niederaussem (K), which achieves 45 percent efficiency. Nonetheless, power plants with efficiencies of more than 47% are already in the works.

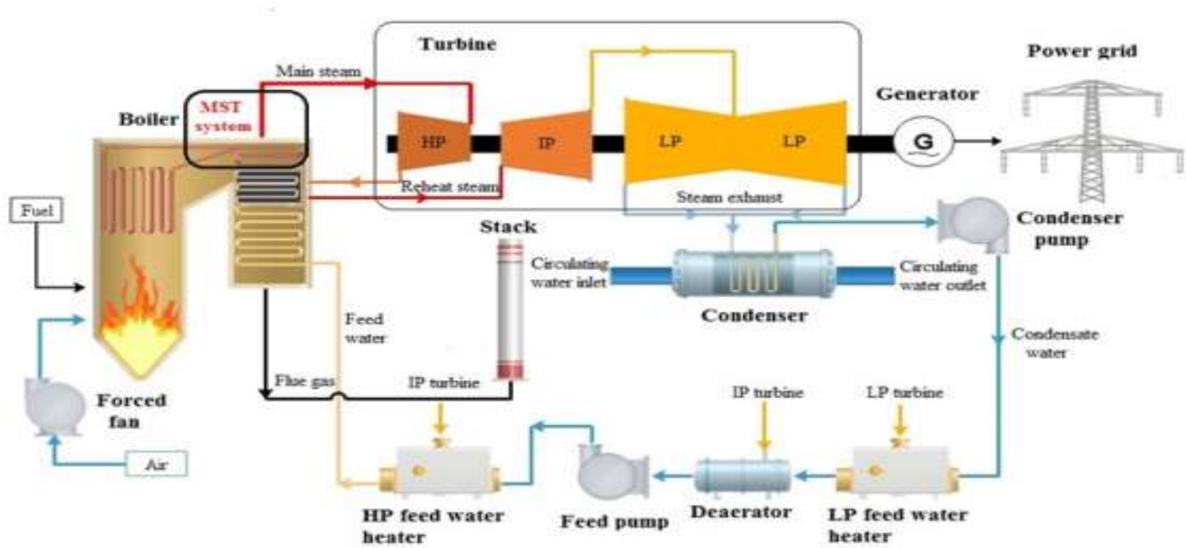

figure 4. simplified layout of a 1000 mw coal-fired ultra-supercritical power plant [25].

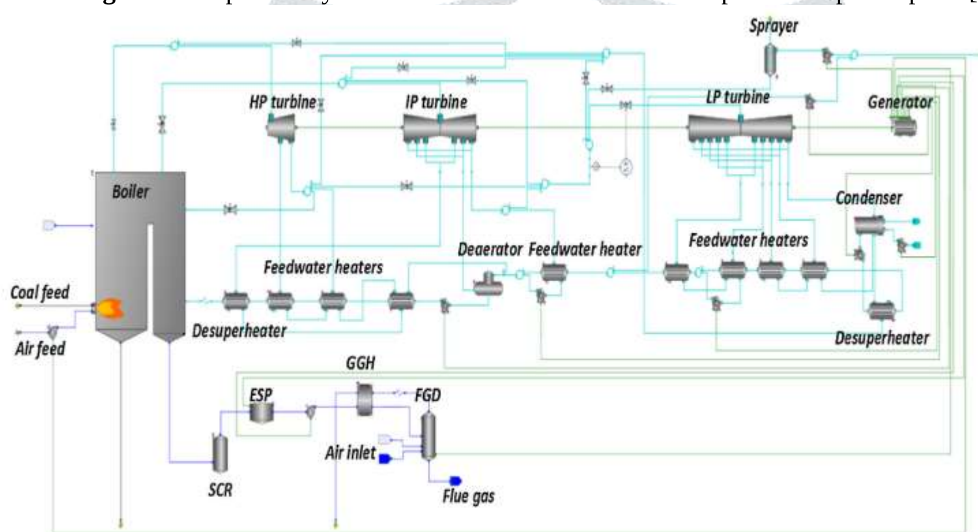

fig. 5. supercritical pulverized coal reference flow sheet.[26]

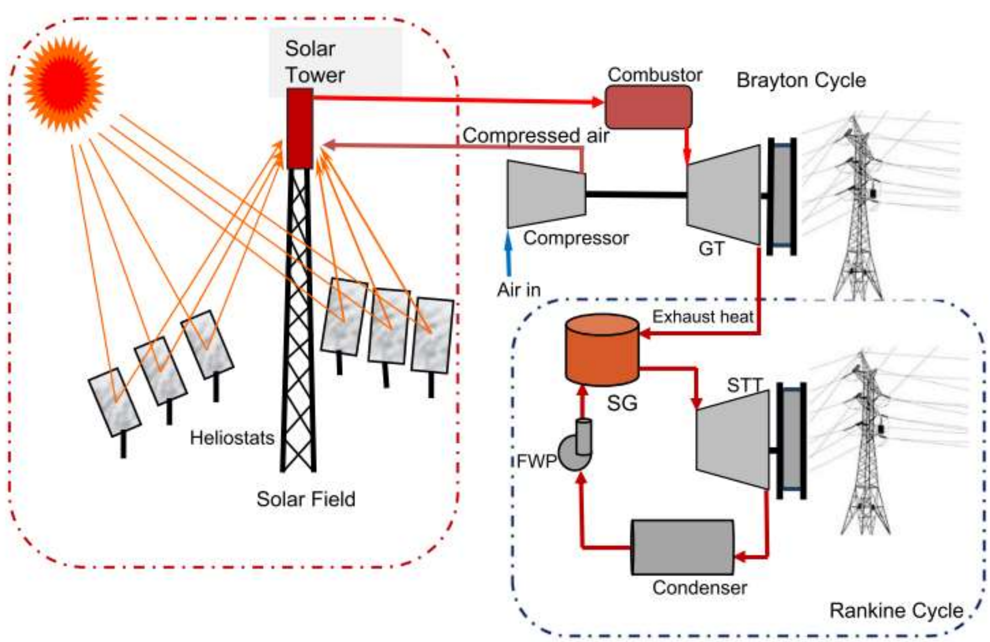

fig. 6. the solar field, brayton cycle, and rankine cycle are all represented in this schematic of an st-isccs power plant. stt ¼ steam turbine, fwp ¼ feed water pump, gt ¼ gas turbine, sg ¼ steam generator [27].

table 2 subcritical coal-fired power plant energy, exergy and economic analysis

			Subcritical Coal-fired power plant		
References	Capacity (MW)	Energy analysis	Exergy Analysis	Economic analysis	Findings
[28]	210, 150, 160, 150, 157, 210, 165, 160.9	√	√	×	Engineers and scientists may use a comparison of 9 power plants to improve the productivity of both individual plant components and the entire plant.
[29]	232.6	×	√	√	Exergy destruction can be reduced by lowering the temperature variations of the net heaters and improving the thermodynamic parameters of the working fluid supplied to the turbine.

table 3 supercritical coal-fired power plant energy, exergy and economic analysis

			Super critical Coal-fired power plant		
References	Capacity (MW)	Energy analysis	Exergy Analysis	Economic analysis	Findings
[30]	600	×	√	×	The boiler system's exergy loss was discovered to be the biggest.
[31]	422	×	√	×	The furnace is the source of the most exergy damage, followed by the turbine.

table 4 ultra supercritical coal-fired power plant energy, exergy and economic analysis

			Ultra-Supercritical Coal-fired power plant		
References	Capacity (MW)	Energy analysis	Exergy Analysis	Economic analysis	Findings
[32]	1100	×	√	√	Thermodynamics and economics were combined to optimize a large-scale coal-fired power plant.
[33]	1000	√	√	×	Coal-fired power generation can help with CO2 reduction, particularly in countries where coal is the primary source of electricity.

3. CONCLUSION

The energy loss occurring at the boiler and turbines is discovered to be greater than the loss at other components of the plant. Besides, considering the carbon emission due to the direct combustion of coal, thermodynamic and technological improvements are becoming increasingly important. Performances of sub-critical, super-critical and ultra-super-critical power are brought together and conclude that running the power plant under supercritical conditions will improve its performance. Both combined-cycle heavy-duty gas turbines, including easy and large-scale supercritical coal-fired power plants, as well as small and medium-scale subcritical coal-fired power plants, use aero-derivative gas turbines. It is an effective solution to close the gap between power and supply needs by using traditional thermal power plants to achieve the highest level (or recharge cycle).

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