Understanding Heat Rate of Thermal Power Plant & Improving Efficiency

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Heat Rate & Efficiency

- Heat Rate of a Thermal Power Plant indicates How much fuel energy is consumed for generation of one unit of Useful Work. Useful Work means

  1. Electric power supplied to Grid
  2. Steam Supplied to Industries for heating and process
  3. Used for household or other heating or other purpose.

Energy Efficiency is how much useful energy is produced from one unit of fuel energy consumed. Therefore, Heat Rate and Efficiency are two opposite terms to measure the performance of a Thermal Power Plant.

The objective is to reduce Heat Rate to increase the performance of a power plant, measured in term of Efficiency.

Heat rate in relation to Global Warming

- Reduced Heat Rate does not save the cost in terms of fuel cost but also
  1. Reduces CO_2 emission and Global Warming thereby.
  2. Reduces Environment Pollution, by less emission of

     SOX, NOX & Environment Pollution.

Global warming is the most threatening issue on the planet today. It disturbs the ecological balance, causing flood, draught, sea level rise, cyclones and many catastrophic conditions. International organizations like UNFCC, COPs have put restriction on coal burning because of highest emission of CO_2 out of all other fossils.

Environmental pollution kills 6.5 millions people every year globally, that includes 2 million in China and India alone.

Restriction on Coal Combution

- International Organizations UNFCC/COP have imposed restriction on combustion of coal as it is, because of highest emission of CO2 out of all other fossil fuels. Coal combustion must be made more efficient and environment friendly for use.
- India holds 9.8% of global coal reserve, which can sustain for more than 150 years @ of present production, and therefore promising energy security. But we are not being able to use it to its full potential because of restriction.
- Coal contributes around 56% of total power production in India, and 90% of thermal power plants in India are fed with coal.
- Though Renewables, particularly solar and wind are growing much faster @ more than 12% in India, but these are intermittent and not sustainable in different weather conditions, unless huge storage capacity is developed.

Global emission of CO_2 from fossil combustion is in order of 38 billion tons per annum, mostly from fossil fuel-based power plants. India shares 6.3% of global emission.

In a road map to achieve net zero emission of carbon by 2070, India has declared to install 50% of its power generation capacity from non fossil fuel and reduce the carbon intensity by 45% to its GDP by 2030.

As per the report from European Environment Agency (EEA) report

“EU achieved its three 2020 climate and energy targets of reducing greenhouse gas emissions by 20% compared to 1990 levels, increasing the share of renewable energy use to 20%, and improving energy efficiency by 20 %.”

- This indicates that, carbon emission can be reduced to the extent of 20%, by improving combustion efficiency and other energy saving measures.

Efficiency components of Power Plant

- Overall efficiency of a thermal power plant consists of three components, which are
  - The efficiency of steam boiler, that converts fuel chemical energy to heat energy in form of latent heat. The typical efficiency of a boiler is 85%.
  - The efficiency of power turbine, that converts heat energy to mechanical motion, called work energy. The typical efficiency of a power turbine is 54% for ultra super critical steam run closed cycle power plant, 50% for super critical steam, and 46% for sub critical steam.
  - The efficiency of power generator, that converts mechanical energy to electric energy. The efficiency of a typical generator is more than 98%.
- Overall efficiency of a typical closed cycle power plant works out to be 0.85x0.5x0.98 = 0.4165 or 41.65%. This implies that balance, 100-41.65= 58.35 efficiency is lost mainly through flue gas, both of boiler as well as power turbine.
- The lost heat through flue gas is recovered by Heat Recovery Steam Generator (HRSG), called a Cogeneration Power Plant that produces electric as well was steam. The produced steam can either be used by industries or household heating or any other purpose like vapor absorption machine or preheating of a process steam.
- The Performance of a power plant is determined by how much heat produced from fuel combustion is recovered.

Improvement in Heat Rate

- Thermal Efficiency of a power plant can be improved through
  - **Maximum recovery of heat from flue gas** –

    NTPC, at Ramagundam and Talchar has set up 100 TR FGHR-AC, that recovers heat from low temperature flue gas to heat water, that runs **vapor absorption machine** for Air Conditioning. These are in operation since 2013 and 2017 respectively as reported.
  - **Design of boiler and power turbine** -

    Bucket tip and **packing leakage** of power turbine contribute as high as 40% of total loss. Strong burner design of boiler can avoid **incomplete combustion** and **insulation** (Refractory) design can reduce sensible heat loss.
  - **Operation and Maintenance** –

    Steam leakages and loss of insulation constitute major portion of heat loss to atmosphere. High moisture content of fuel leads to latent heat loss and large **difference of temperature** between air supply and flue gas in boiler leads higher sensible loss.

Heat Recovery from Flue Gas in Gas Turbine

The Thermal Efficiency of a typical cogeneration power plant is 70%. This can be improved further, if low temperature flue gas after HRSG, is utilized for some useful work.

It has been reported that as high as a thermal efficiency of 80% can be obtained by recovering heat from low temperature flue gas.

Central Heat and Power (CHP) - In CHP system, the gas burns in a combined cycle gas turbine (CCGT) power plant for electricity, using exhaust gas to heat steam boilers to make more electricity, and finally using "the exhaust stream to heat buildings or other purposes. Thermodynamic efficiencies of 80% for this type have been reported.

By using low temperature flue gas heat for useful work, such as **pre heating of a process** stream or **vapor absorption machine** for Air Conditioning or other purpose, can substantially increase the thermal efficiency of a power plant.

Improvement in Heat Rate from O&M – A rule of Thumb.

As a rule of Thumb

Reducing temperature gap between feed air and flue gas by 22 degree C, the boiler efficiency can be increased by 1%.

One degree C change in cooling water temperature leads to deviation of condense pressure by 0.59 kPa, thereby deviation in cycle heat rate of 0.36%.

Switching from conventional to Frequency Drive motors in cooling water fans can improve heat rate more than 0.5%.

It is stated, as rule of thumb, that boiler efficiency can be raised by 1% by reducing 15% of excess air or reducing 40-degree F temperature in the flue gas. This applicable to any boiler irrespective of the fuel type.

Improvement in Heat Rate with actions & Quantification.

Every power plant has unique opportunities for, and challenges to, improving its heat rate. The values show in this table are only general ones based on research from energy efficiency studies. *Source: Una Nowling*

Improvement	Range of heat rate benefit	Payback period
Improving combustion controls and monitoring	0.25%–1.00%	<1 year
Increased condenser cleaning and repair of air leaks	0.30%–2.00%	<1 year
Turbine seal improvements	0.50%–2.30%	1–3 years
Increased feedwater heater monitoring, maintenance, and repair	0.20%–1.00%	1–3 years
Air heater seal repair or upgrade	0.10%–0.50%	2–3 years
Preheating combustion air with waste heat	0.10%–0.30%	2–3 years
Increased cleaning of turbine deposits	0.25%–3.50%	2–4 years
Low-pressure turbine blade upgrade	1.00%–2.00%	2–4 years
Replacement of main fan motors with variable frequency drives	0.20%–0.50%	3–5 years
Solar combustion air heating	0.25%–0.75%	>5 years
Solar feed water heating	3.00%–7.00%	>5 years

Growth of coal fired Power Plant

- As per the draft National Electricity Plan (NEP), released by Central Electricity Authority in Sept 22, total installed capacity of power plants has to grow to 866 GW by 2031-32, out of which 592 GW has to come from non fossil fuel power plants. In order to achieve this, solar power alone has to grow @28 GW annually against @8 GW average in last five years. This requires 300% growth by 2031-32, which appears to be very difficult task.
- In such situation Govt has to **fall back on coal-based power plants**, either through upgradation of existing or additional with advanced technology with higher thermal efficiency and environment friendliness.
- Therefore, power demands from coal fired plants are bound to grow in next more than decade.

Steps taken for Heat Rate enhancement

- Super Critical Technology has been adopted for thermal power generation. The design efficiency of supercritical is about 5% higher than sub critical. All Ultra Mega Power Projects are required to use super critical technology.
- Old and in efficient units are being either abandoned or modified or upgraded. 7.75 Gw of capacity have retired so far.
- To facilitate the replacement of old and inefficient units, Ministry has granted automatic transfer of coal linkage to new super critical units.
- Under National Mission on Enhanced Energy Efficiency, a scheme PAT (Perform Achieve and Trade), being implemented by Bureau of Energy Efficiency, individual target of improving efficiency by 154 power stations have been fixed.
- Indigenous Research is being pursued for developing Advanced Ultra Supercritical technology, with target efficiency of 10% over super critical. Steam pressure 310 kg/cm2 and temperature 720 deg C.
- High Efficiency Electrostatic Precipitator (ESP), Low Nox Burner, Desulphurization or dispersion of flue gas through tall stack (275 meter) are the steps to protect environment.

Integrated Coal Gasification combined Cycle (IGCC) Power Plant

- Coal can be gasified to produce Synthetic gas which fuels the power turbine like a gas turbine.
- Like a natural gas combined cycle (NGCC) power plant, IGCC uses a gas and steam turbine to generate electricity, but in the case of IGCC power plant, syngas, a mixture of hydrogen and carbon monoxide is used.
- In South Africa, Eskom, with technology provided by Ergo Exergy, is operating a demonstration plant, to supply syngas, produced from UCG, for electricity generation on a commercial basis.
- It is reported that Linc energy produces one million M^3 of syngas from UCG, in Uzbekistan to fuel Angren power station.

- Power generation from gasification is predicted to be one of the dominant markets. The mandate from Paris convention on climate change, to reduce the greenhouse gas emission has given impetus to IGCC power plant application, because the **removal of CO_2 from syngas due to its high partial pressure is easier** than from conventional NGCC.

- Some important challenges in widespread adoption of IGCC are cost, availability, and complexity. Cost is the greatest barrier to IGCC acceptance. It is much costlier than natural gas combined cycle, due to addition of gasification plants. Its financial viabilities depend upon subsidies and tax benefit.

- Most of the challenges are attributable to gasification technology. To make IGCC economically viable, less complex, and more available, the technology will play an especially important role. R&D works all over the world are at full swing in this direction.

Conclusion

- To use our vast reserve of coal to fullest , it is essential to improve the thermal efficiency of coal power plants and make it more environment friendly. There is huge fuel saving potential that can be achieved by improving heat rate.
- Gasification and carbon capture technology are the ways through which coal can be optimally utilized and fully absorbed in industries. Though these will significantly add to the cost but will pay to environment and energy import.
- IGCC power plant can improve the thermal efficiency as well as facilitate carbon capture for environmental protection.

Thank You