Cogeneration with steam turbines: Powering chemical plants & communities

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Chemical industry – India & the world

The chemical industry constitutes manufacture of basic chemicals (fertilizers, plastics, synthetic rubbers), pesticides & agrochemicals, paints & coatings, soaps & detergents, explosives & pyrotechnic products, glues & essential oils, man-made fibers, etc. About 10% of all fossil fuels produced, globally, are consumed by the chemical industry, resulting in 2-Gt (gigatonnes) of greenhouse gas (GHG) emissions per annum. In this context, the industry offers enormous potential in terms of adoption of sustainable technology alternatives. The industry has also widened its focus to include climate actions, in addition to emissions reduction & safety.

The chemical industry invests heavily in innovation and research & development (R&D). China, USA & India are among the top-ten chemical R&D spenders & the countries have policy frameworks for adoption of sustainable energy solutions by the industry. Green hydrogen & energy efficiency themes are central to chemical industry's efforts to reduce emissions, in consonance with COP-26 (26th Conference of Parties), held in Glasgow.

Energy efficiency improvements

Energy efficiency improvement is central in the path towards a low carbon future. Energy efficiency improvements lead to enhanced energy security, reduce pressure on national budgets, increase competitiveness and improve operations, besides reducing emissions. An analysis, by Deloitte, also lists energy efficiency improvement as a solution with high maturity & scalability, in comparison to solutions with renewables or blue/green hydrogen.

According to an International Energy Agency (IEA) report, approximately $450-bn continues to be invested annually, globally, for energy efficiency improvement & other end uses.

Adoption of cogeneration

One of the energy efficiency improvement solutions is adoption of cogeneration, also referred to combined heat & power (CHP). Cogeneration is simultaneous generation of heat for process utilisation and power as per demand. When the heat for industrial process/district heating is generated separately and power is produced separately, the systems are less efficient. However, when heat production & power generation are combined into a single system, efficiencies up to 80% can be achieved.

Cogeneration can consist of gas turbines, steam turbines, reciprocating engines & thermal energy storage as technologies and equipment. Gas turbines (GT) & steam turbines (ST) are more common equipment among CHP installations.

Gas turbine CHP installations are seen in large combined cycle power plants. In the chemical industry, the CHP installations typically include steam turbines and, more commonly, in a combined cycle arrangement.

Steam turbines used in CHP applications can be back-pressure or condensing type with extraction, as per the demands of the chemical plant. Intermittency of heat/steam availability and need to dump steam as required by process constraints in chemical industries can also be managed through adoption of steam turbines with injection capability. Steam turbines can also be a driver for pumps and compressors in cogeneration plants.

Design of cogeneration systems

Cogeneration systems can be designed as Electrical Load Matching or Thermal Load Matching systems – depending on the priorities of the plant. The deficit/excess of electrical/thermal load can be managed with the external supply/demand.

Typical power-to-heat (PtH) ratios for cogeneration systems with combined cycle [GT- Heat Recovery Steam Generator (HRSG)-ST] arrangement can range between 0.5-1, with overall plant efficiency ranging between 70-80%.

When steam turbines alone is used for cogeneration, the PtH ratio can be low, ranging between 0.05-0.3.

It is observed that the nature of the plant (i.e., petroleum refining, chemical, fertiliser) can determine the PtH ratio & can influence the overall efficiency. For fertiliser industry, the ratio averages 0.3, whereas for breweries, the ratio is below 0.2. Other factors that influence the applied technology (GT/ST/Reciprocating Engines) include the load patterns, fuel availability, island mode vs. parallel mode operation of plant, and local environmental regulations.

Economics of CHP technology

One of the hurdles to improved adoption of CHP technology is the significantly high initial capital cost of the plant and higher Operation & Maintenance (O&M) costs due to a more complex assembly of systems, compared to simple power generation & heat generation systems. A simplified cost analysis of different cogeneration configurations can be done with existing installations, as a source of data.

Specific installation cost (cost/kW) for gas turbine based CHP plants are 50-75% higher compared to that of steam turbines based CHP plants, with consideration of 15-MW power capacity. From an O&M cost perspective, gas turbine based CHP systems can be, roughly, 50% more expensive.

Specific production cost (SPC) of CHP plants, measured in US$/MWh, based on 17-MW power capacity and with certain defined plant parameters, with simple cycle gas turbines is lower, as compared to the combined cycle or steam turbine based CHP installations. However, combined cycle CHP power SPC is lower, as compared to steam turbine based CHP power SPC.

CHP markets

Few OEM manufacturers from the developing world have taken the lead to work collaboratively with leading energy-intensive chemical companies & install CHP solutions at scale, driving benchmark efficiencies for the plants.

Cogeneration market, globally, is estimated to be US$26.6-bn, as per 2021 figures, and is expected to grow to $35.2-bn by 2026.

The Asia-Pacific market is expected to lead in terms of CHP installations, over the next few years. Germany is the largest CHP market in Europe. Policy measures from national governments are key to accelerated adoption of CHP plant systems. Policy measures in Germany, for example, provide tax incentives for biomass-based CHP systems. A similar policy environment exists in USA, where tax incentives & rebates are promoting cogeneration installations. Both are targeting around 20% share for power generation from CHP plants.

In India, approximately 500-MW of waste heat recovery power & 10.2-GW of biomass based cogeneration capacity exists, as on March 2022. Indian policy makers also estimate a potential of 28-GW addition from biomass-based CHP plants & 14-GW addition through bagasse-based cogeneration.

Concluding remarks

Policy makers, energy-intensive industries, energy agencies, Engineering, Procurement, and Construction (EPC), contractors, process licensors and original equipment manufacturers (OEMs) have to work in consonance to improve the global energy infrastructure and assist nations walk the path towards energy efficiency & net zero emissions.

ABOUT TRIVENI TURBINES

Triveni Turbines is a leader in the sub-100 MW steam turbine market, catering to sugar, distillery, cement, steel, food processing, pulp & paper, pharmaceuticals, petroleum refineries, chemicals, petrochemicals and fertiliser industries. Over the past 60 years, the company has installed 6,000+ turbines in 80 countries, with over 16-GW capacity in total.

Triveni Turbines has steam turbine portfolio customised to the needs of the chemical industry and has reference units, operating successfully in chemical plants in India & worldwide.