Abstract

With the growing trend of increases in fuel prices over the past decades as well the rising concern regarding global warming, many industrial establishments have switch over to their own generating plants, and this method of generation is known as captive power generation. Further this method of power generation reduces grid dependability, reduces waste, lower carbon emission etc. Seeing the importance of captive power generation, two power plants i.e. naphtha based combined cycle power plant (116 MW) and coal based steam power plant (120 MW) have been taken up as case study, and their performance has been compared through energy, exergy and water footprint assessment. It may further be noted that so far analysis has been considered mostly for utility power plants operating on natural gas (for CCPP) as the fuel; power plants using other fuels such as naphtha or fuel mixes have been considered. Apart from naphtha, which is kept as feedstock in a petrochemical complex, residual fuel gas (rfg) and carbon black fluid stock (cbfs) are also used.

To start with, both energy and exergy analyses of the entire naphtha based combined cycle power plant (CCPP) has been carried out. Various parameters, such as cogeneration efficiency, efficiency standard and heat to power ratio have been introduced to judge the thermodynamic aspect of CCPP. Further, particular attention has been paid to assessing this CCPP separately as a cogeneration unit and a combined cycle power plant unit. However, we know that energy analysis is a quantitative analysis which can provide only a partial assessment of the energy transfer. While another indicator called exergy analysis can be employed to augment the assessment and this has been adopted. Exergy analysis also enables us to assess the performance of the components. The result shows that cogeneration efficiency and "efficiency standard" are found as 57.87% and 41%, while exergy efficiency is found to be 30%, with combustion chambers and auxiliary boilers as the most inefficient units. Using the relation between exergy and sustainability the result shows that combustion chambers appears to have the highest improvement potential.

Further for performance comparison, a coal based steam power plant (CSPP) of 120 MW unit capacity has been taken up. The total power output of the plant is 121.8 MW, which is close to the real value of 120 MW, with energy and exergy efficiency as 34.7% and 32% respectively. Further, energy analysis introduces the condenser as a major source of heat loss where 97.90 MW is lost to the environment while exergy analysis introduces boiler as a major source of exergy destruction, where 120 MW of exergy is destroyed. In CSPP, boiler has a high improvement potential.

Of course, the result from energy and exergy shows that CCPP has higher efficiency and; thus, a smaller heat rate. Thus, the smaller the heat rate, the smaller is the waste heat that needs to be rejected, and therefore less cooling water is required. Hence, to show a correlation between power plant efficiency and water consumption pattern, the present study conducts the water footprint assessment (WF) of CCPP and CSPP. Two methods have been adopted to investigate the WF of both power plants: - water balance mass diagram (direct WF) and water supply chain (indirect WF). From the first method, evaporation loss appears to have a major contributing factor for direct WF, whereas from the second method operational WF appears to have major

contributing factor for indirect WF. The result shows that specific water consumption in CSPP is 3.54 m^3/hr, whereas in CCPP it is 0.9 m^3/hr. Water loss in CSPP is not only higher in different stages, it also needs a good amount of water for ash handling. This makes CSPP less favourable compared to CCPP as per as WF is concerned.

This dissertation aims to present some methodologies for energy, exergy and environment analyses as well as an assessment of water footprint. The methodologies have been effectively demonstrated using two captive power plants. This also gave scope to compare two plants of almost the same unit capacity. Based on these analyses one may also take up an economic assessment of these two plants.

Keywords: combined cycle power plant, energy, exergy, naphtha, steam power plant, captive power generation, water footprint