Performance Assessment of 2500 TCD Cogeneration Plant

Sangamesh Y G, Suchitra G, Jangamshetti S H

Abstract – In this paper an energy balance has been carried out for an actual 2500 TCD plant. The turbine hardware model is used to predict the optimum amount of power that can be cogenerated from the system for different generation temperatures at a pressure of 45 bar. The optimum superheat temperature is found to be 5000C for a backpressure turbine with single extraction. Selected actual operating data are employed for analysis and performance assessment. The cogeneration plant performance test is to determine the power output and plant heat rate. It is a cost effective method of supplying the steam and electric needs of the organization. Excess electricity generation is sold to the utility company. The continuous need for steam combined with the savings on electricity purchases made the cogeneration technology well suited for the company energy needs. The results demonstrate that analysis is a useful tool in performance assessments of cogeneration systems. Such results can allow the efficiency of cogeneration systems to be increased and the applications of cogeneration in larger energy systems to be configured more beneficially, leading to reductions in fuel use and environmental emissions.

Index Terms— Cogen, Distributed Cogeneration System, Plant factor, Tons crushing per day, Utilisation Factor.

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1 INTRODUCTION

India faces a peak electric generating shortage of over 20% and an energy shortage of 12%. India is the world's largest producer of sugar, with over 430 sugar mills [1] producing an estimated 12 million tons of sugar annually. The rapidly changing markets for sugar and energy provide an excellent opportunity to develop innovative methods to optimize the cogenerated power from the sugar plants that can reduce the energy shortage faced by the country. Market studies [1] have indicated that an additional power of 3500 MW can be generated through the use of cogeneration in the sugar industry. This paper builds up an energy balance for an operating plant and estimates the magnitude of the optimum power that can be cogenerated from the plant. A Bilagi sugar mill has a licensed capacity of total 2500 TCD and produces export quality crystal white sugar. The process technology is of latest technology and design resulting in low power and steam consumption and high operating efficiency. The factory is one of the most advanced integrated sugar complexes in Karnataka having adapted latest steam and electrical energy conservation systems .The main feature of this sugar complex is cogeneration unit of 1 No. 8 MW steam turbine [4]. Apart from captive consumption of about 4 MW, the remaining power is to be export to the main grid during season and some power has to be import from the KPTCL during off-season. There are two types of turbine in Sugar Industry. One is back pressure and another one is condensing. In back pressure turbine process steam requirement (to manufacture Sugar) is met from back pressure which gives quantity of steam depending load on turbine at constant exhaust pressure. This steam contains high heat energy and has to be used to the extent the steam requirement for process. In condensing turbine this is not the case. Steam required for process is given in extraction mode and balance in condensing mode (steam is condensed in condenser and condensed water is sent to Boiler). Therefore when there is no demand or less demand of steam for process even then turbine can be run on full load all the time during season or off season depending upon availability of fuel. This turbine consumes less steam to produce per KW of power hence more efficient and used for cogeneration.

The main objective of the present study to survey the complete plant across which overview of the every department of the plant and the energy assessment of cogeneration plant. To examine the characteristics of the generating unit in terms of input-output steam curve, incremental heat rate curve, unit heat rate curve. To identify the main energy consuming areas/plant items to be surveyed during the training. To collect macro data on plant energy resources, plant equipment details.

2 COGENERATION

Energy system sequentially generating electrical power and thermal energy and System common in cane sugar industry for a very long time. Co-generation is the combined production of two forms of useful energy from the same fuel. Co-generation systems are sequential in nature because the exhaust from producing one form of energy is used as input for producing the next form of energy. It is often used in industrial units requiring significant amounts of thermal energy and electricity and where the ratio of the two forms of energy are favorable toward the combined production of thermal and mechanical energy. There are two types of cogeneration systems as topping and bottoming cycle. In topping cycle shaft power is first developed and the exhaust is used for the supplying thermal energy. Whereas, in bottoming cycle, the sequence is reversed [2]. Topping cycle is often used when temperature and pressure for given industrial processes are relatively low. Bottoming cycle is a typical feasible when the temperature of the processes waste steam is relatively high. The important benefits of cogeneration are reduction in the overall energy cost. These savings, combined with the benefits of minimum operating and maintenance cost and high reliability of the components can lead to an overall positive cash flow. When steam (in the case of steam turbine) or gas (in the case of gas turbine) expands through the turbine, nearly 60 to 70% of the input energy escapes with the steam or gas [6]. If this energy in the exhaust steam or gas is utilized for meeting the less heat requirements, the efficiency of utilization of the fuel increases. Such a location, where the electrical power and process heat requirements are met from the fuel, is termed Regeneration. Most of the industries need both heat and electrical energy. Hence, cogeneration can be a good investment for industries. Cogeneration system may be based on any type of fuel or heat source and with commercially available technology as shown in fig.1.

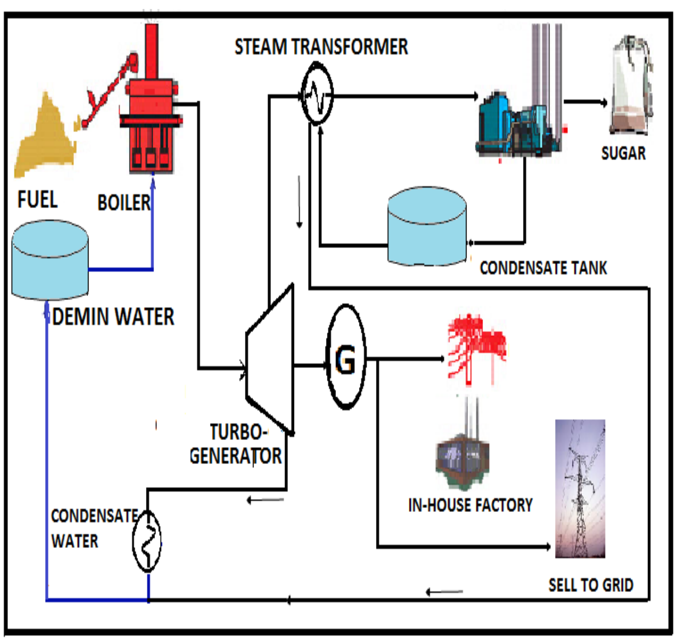

Fig.1. Process flow diagram of cogeneration [3]

While dwelling on Energy audit, it will be relevant to highlight the importance of improving productivity of bagasse. The foregoing discussions and case study have established the fact that how moisture % in bagasse is a critical factor in enhancing the productivity of bagasse in addition to efficient boiler conditions. Modern high efficiency boilers of high pressure designs i.e. pressures upwards of 45kg/cm2 aim at an efficiency of 70% plus for bagasse firing, and with these boilers productivity of bagasse is further increased with the increase operating pressures. Adopting higher pressure power cycle will increase the power output from the same bagasse.

3 ENERGY ASSESSMENT

The principal technical advantage of cogeneration systems is their ability to improve the efficiency of fuel use in the production of electrical and thermal energy. Less fuel is required to produce a given amount of electrical and thermal energy in a single cogeneration unit than is needed to generate the same quantities of both types of energy with separate, conventional technologies [5]. This is because heat from the turbine-generator set, which uses a substantial quantity of fuel to run the turbine, becomes useful thermal energy in a cogeneration system rather waste heat. Different types of cogenerators have different fuel-use characteristics and produce different proportions of electricity and steam. The electricity to heat ratio refers to the relative proportions of electrical and thermal energy produced by a cogeneration unit. Cogeneration systems in many situations have economic advantages relative to separate processes for thermal and electrical energy production. In other situations, the costs for cogeneration and non-cogeneration options are similar, but the other advantages can still allow the cogeneration option to be preferred. Cogeneration, based on fuel, plant size and specific application, can be classified broadly under the following categories: Based on energy source, i.e. conventional solid, liquid gas fuels, renewable fuels, Process gas etc.

TABLE -1

STATEMENTS OF POWER GENERATED, EXPORT & IMPORT FROM 01-04-2010 TO 28-02-2011 [4]

Parameters	Units in KWH
Total Units Generated	27872000
Total Units Imported	13576800
Total Units Exported	127200
Plant Consumption	14295200

Plant Load Factor (PLF):

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Plant load factor can be defined as the ratio of energy actually produced to maximum energy that could have been installed [4].

$$PLF=\frac{(\text{Total Units Generated/TG Running hrs}) \text{ in the season}}{\text{Capacity of the Plant}} * 100 \quad (1)$$

Utilization factor (UF):
Utilization factor is defined as the ratio of maximum power developed to total power that could have been generated [4].

$$UF = \frac{\text{Maximum power generated}}{\text{Total power that can be generated}} * 100 \quad (2)$$

Average Load on TG:

$$\frac{\text{Total units generated in the season/ TG Running hrs}}{1000} \quad (3)$$

$$\text{Average Export} = \frac{\text{Total Units Exported/ TG Running hrs}}{1000} \quad (4)$$

Alternator Efficiency:
Total heat of a steam at turbine inlet at 42 kg/cm2, 485 ^{0}C and steam outlet at 12.3 kg/cm2, 230^{0}C (5)
Heat energy input to turbine per kg of inlet steam = 29.87 kCal/kg [4].
Power generation efficiency of the turbo alternator

$$\eta = \frac{\text{Energy output}}{\text{Energy input}} * 100 \quad (6)$$

TABLE -2

ECONOMICS OF COGNERATION [4]

Parameters	Range
Plant Load Factor(PLF)	80.35%
Utilization Factor(UF)	80.25%
Average load on TG	6.4MW
Cogen Consumption	48.71%
Alternator efficiency	34%

4 CHARACTERISTIC OF POWER GENERATION UNIT

For the controlled operation of power systems there are many possible parameters of interest. Fundamental to the economic operating problem is the set of input-output characteristics of a thermal power generation unit. The unit consists of single boiler that generates steam to drive single turbine-generator unit. The electrical output of this set is connected not only to the electrical power system, but also to the auxiliary power system in the power plant. Gross input to the plant represents the total input measured in terms of tons of fuel per hr, the net output of the plant is the electrical power output available to the electric utility system [3]. Fig.2 shows the input-output curve of a steam unit in idealized form it is presented as a smooth linear curve. These data may be obtained from design calculations. Steam turbine generating unit have several critical operating constraints. Generally, the minimum load at which a unit can operate is influenced more by the steam generator and the regenerative cycle than by the turbine. Minimum load limitations are generally caused by fuel combustion stability and inherent steam generator design constraints.

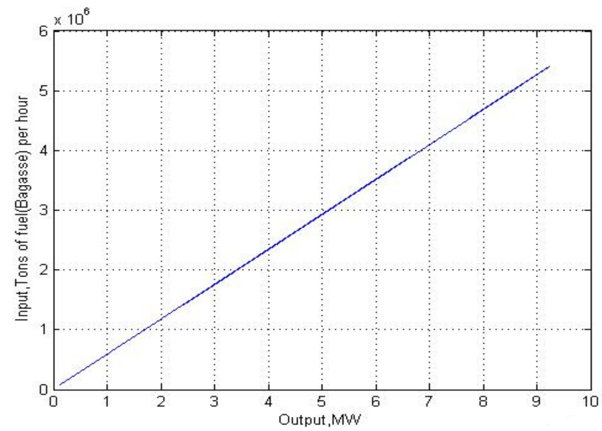

Fig.2. Input-Output Curve of a Steam Generator

The incremental heat rate characteristic for a unit of this type is shown in fig. 3. This incremental heat rate characteristic is the slope of the input-output characteristic. The data shown on this curve are in terms of R per kilowatt hr versus the net power output of the unit in megawatts. This characteristic is widely used in economic dispatching of the unit. The last important characteristic of a steam unit is the unit heat rate characteristic shown in fig. 4. It is proportional to the reciprocal of the usual efficiency characteristic developed for machinery. The unit heat rate characteristic shows the heat input per kilowatt hr of output versus the megawatt output of the unit. The data obtained from heat rate tests or from the plant design engineers may be fitted by a polynomial curve [3].

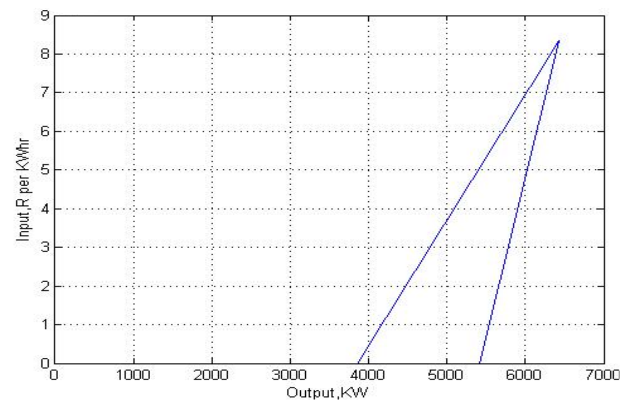

Fig.3. Incremental Heat Rate Curve of a Steam Generator

The different representations result in different incremental heat rate characteristics. The use of these different representations may require that different scheduling methods be used for establishing the optimum economic operation of a power system.

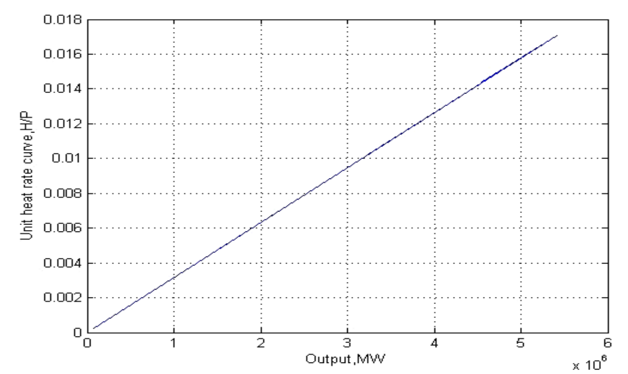

Fig.4. Net-Heat Rate Curve of a Steam Generator

5 TARIFF FOR GENERATED UNIT

The method of billing of the energy transaction will be as per the guidelines issued by the electricity board for the interstate exchange of energy. The same procedure will apply during the period when the meter or the allied equipments of either party are defective or cease to register the quantity. Cost to sell to the grid/ board is Rs. 4.51 per unit.

6 NEED FOR COGENERATION

Cogeneration involving simultaneous generation of multiple useful energy sources viz. power, heat, refrigeration / cooling, water recycling, Evaporation and Drying. Industries go for Captive Cogeneration due to following principle reasons[5]. To reduce power and other energy costs. To improve productivity and reduce costs of production through reliable uninterrupted availability of quality power from Cogeneration plant. Cogeneration system helps to locate manufacturing facility in remote low cost areas. Improves energy efficiency, and reduces CO2 emissions. Therefore it supports sustainable development initiatives. The system collects carbon credits, which can be traded to earn revenue. Due to uninterrupted power supply it improves working conditions of employees raising their motivation. This indirectly benefits in higher and better quality production. Cogeneration system saves water consumption & water costs. Improves brand image and social standing.

7 DISTRIBUTED GENERATIONS

It is now worldwide trend to take recourse to Distributed Generation in preference to the large interconnected networks. This concept called Distributed Cogeneration Systems (DCS) has gained tremendous importance worldwide and particularly in North America and Europe due to following reasons. DCS enables multiple sources of revenue earnings e.g. in addition to power the project can sell steam, refrigeration, recycled water, desalinated water etc. Multiple sources of revenue are vitally important for power projects particularly operating on costly petroleum fuels. In DCS cost of fuel gets distributed on all these energies making the tariff of each of these energies more reasonable and therefore attractive for the purchaser [6]. Biomass based cogeneration systems reduce Nox emissions due to reduce flame temperatures in boilers. All cogeneration projects are classified under sustainable development initiatives, as they help reduce CO2 emissions and earn carbon credits. Trading of carbon credit is going to be a real phenomenon in very near future. These projects being clean energy initiatives, help restore already off balanced ecological equilibrium. Cogeneration projects are also water saving projects. This is because heat from exhaust steam of steam turbine is not directly rejected in cooling tower but it is either sold to consumers or used for driving Ammonia Absorption Refrigeration Plant (AARP) which in turn can drive Cold Storages, Ice plants, AARP has one unique feature that it can be air-cooled and therefore the feasibility and location of the project doesn't critically depend on availability of water.

8 POWER GENERATED UNITS

Statements of power generated, export & import from 01-04-2010 to 28-02-2011. Monthwise units generated, Export and Import [4].

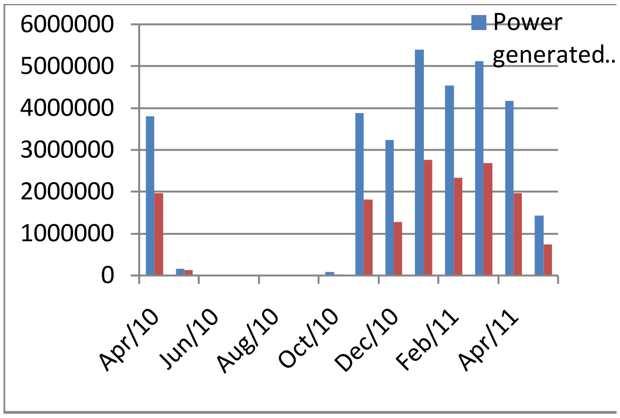

Fig.5. Monthwise Power Generated with Exported units

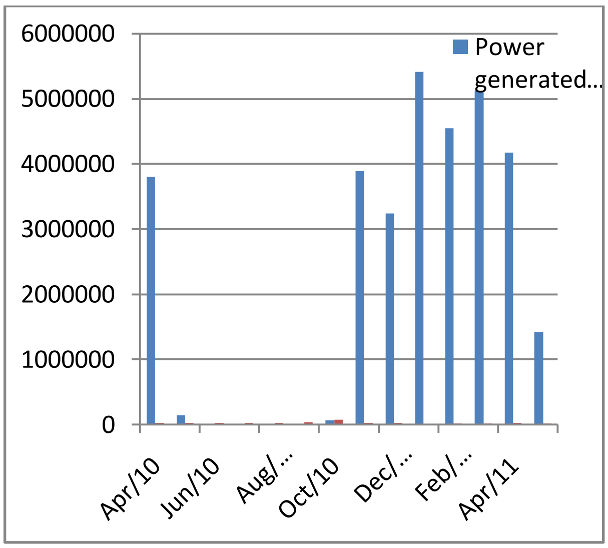

Fig.6. Monthwise Power Generated with Imported

9 ENERGY CONSERVATION OPPORTUNITIES

Findings & recommendation: In cooling tower fan power consumption, energy saving potential by installing Automatic Temperature Controller (ATC), which will switch ON/OFF cooling tower fan is about 15%.

- In fin-fan cooler, there is significant energy saving potential by replacement of existing fin-fan coolers by water-cooled plate heat energy. These savings are due to low pumping power requirement of water based cooling.
- At low Pressure Boiler Feed Pump significant energy saving are possible by reduction of stages in multistage pump or by installing VFD or by installing new pump of proposed specification. This saving potential is primarily due to difference in design duty point (head & flow) of the existing pump as compared to the operating head & flow; which is causing the pump the operate at far off point than the design duty point; thus causing reduction in operating efficiency.
- High Pressure Boiler Feed Pump significant energy saving are possible by reduction of stages in multistage pump or by installing new pump of proposed specification. This saving potential is primarily due to difference in design duty point (head & flow) of the existing pump as compared to the operating head & flow; which is causing the pump the operate at far off point than the design duty point; thus causing reduction in operating efficiency.
- Osmotic filtration is practiced on fairly large scale at gas turbine plants. Reverse osmosis requires high pressure pumping. Even in the best-practiced system in the last effect (stage) of separation there is a reject stream to be maintained at 10 Kg/cm^2 artificially to have significant permeate rate. Normally this resistance is created by control valve. Finally, reject stream leaves to drain or to other point of use. Modern day trend is to replace artificial throttling by pressure recovery turbine. Gravity Feeding of Cooling Tower Makeup Water, Water can be made flow through gravity from source to cooling tower basin.

10 CONCLUSION

As by analyzing the characteristics of the generating plant, the input-output steam curve shows how much tons of coal required to produce the required output. Calculations require for the assessment is stated clearly in report. Apart from the captive consumption of about 4MW remaining 4MW is exported to the grid during season. In cogeneration, Plant is running manually hence losses, labour charge were increased, For better energy conservation suggestion has to be given that to adopt automation to control the entire cogeneration. During training program at Bilagi Sugar Mill, running of cogeneration plant with parallel to the 110V grid with reliable generator and the line relay protections in such a way that for any grid failure or disturbance in the grid islanding takes place so that in house sugar productions is not hampered.

11 APPENDIX

TABLE -3
PARTICULARS OF TG

Sl.No	Particulars	Units	TG
1	Make		BHEL, Bangalore
2	Type		Synchronous
3	Capacity	KVA	10000
4	Rated Voltage	Volt	11000
5	Full load current	Amps	525
6	Frequency	Hz	50
7	Power factor	PF	0.8(lag)
8	Speed	RPM	1500
9	Excitation Method		Brushless
10	Winding		Star Connection
11	Type		Extraction cum back pressure

11 ACKNOWLEDGEMENT

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13 BIOGRAPHY

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