Re utilization of Gland Steam for Optimized Efficiency in Cogeneration Power Plants

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***Abstract*— Energy audit is an important tool in transforming the fortunes of any organization. This is highly relevant to the sugar industry as it deals with a renewable energy source and looked upon as rural power house. The scope for conservation is immense and if properly harnessed can take the organization to the path of prosperity. In this paper, a gland steam system has been studied and a proposed system is provided for the enhancement of the gland steam system. Also, in actual cogeneration process, it is observed from the gland leak steam condensate of 8.0 lit/min from steam turbine with temperature of 75 deg. C on an average, going as waste in drains. The reutilization of this steam is carried over by the enhanced gland steam system.**

Key words — Cogeneration, Gland steam, Recovery system.

I. INTRODUCTION

Cogeneration is simply the simultaneous production of electrical and thermal energy from a single source of fuel. Two basic operating cycles depending on whether mechanical / electrical power is produced before or after heat is extracted for thermal application.

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 exhaust steam or gas. [1] If this energy in the exhaust steam or gas is utilized for meeting the process heat requirements, the efficiency of utilization of the fuel increases.

Such an application, where the electrical power and process heat requirements are met from the fuel, is termed "Cogeneration". 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. [2] An ideal cogeneration scheme will be such that, the fuel heat input is exactly equal to the sum of electrical energy and thermal energy requirement of the process plant.

II. COGENERATION TECHNOLOGY METHODS

A. Options for cogeneration

- Gas turbine with waste heat recovery boiler (WHRB) and extraction / back pressure turbines.
- Steam boiler with extraction / back pressure steam turbines.

In both the cases, the combustion of fuel releases heat energy. [5] A portion of the heat energy is used for electric power generation, while another portion is used for meeting the process thermal energy requirements through steam.

An ideal cogeneration scheme will be such that, the fuel heat input is exactly equal to the sum of electrical energy and thermal energy requirement of the process plant. [3] In such a case, since all the fuel heat will be fully utilized, the system efficiency will be 100% except for any practical heat release and heat utilization losses. [8] This however is nearly impossible to implement in practice, because of the in-compatibility of the ratio of the electrical and thermal energy requirements of the process plant. Thus, it becomes evident that any cogeneration scheme adopted would meet only one of the two (thermal and electric) energy needs of the plant fully.

Since electricity needs can be supplemented with the power from grid also, it follows that the cogeneration scheme should strive to meet the thermal energy requirements fully and generating whatever feasible electricity in the system.

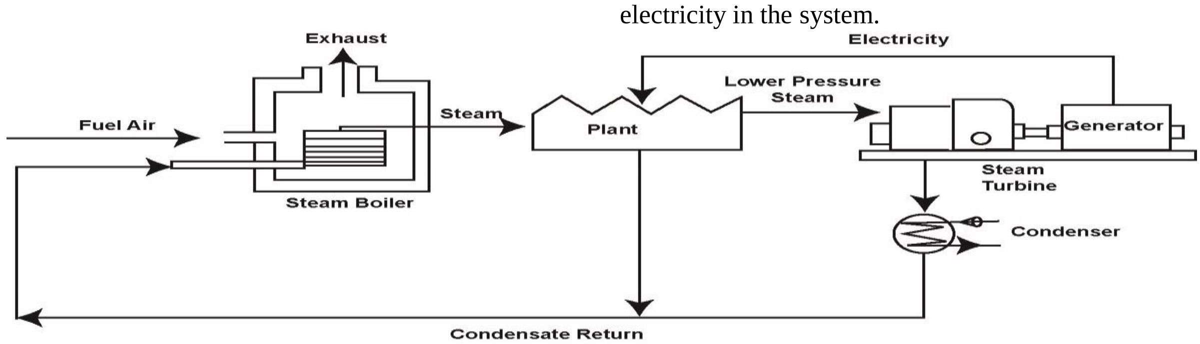

Fig.1. Steam turbine topping cycle

Such a system is called as a thermal balanced cogeneration system. In addition, some process plants (like sugar industry) generate fuel in the energy generation process. [9] The heat energy content of the fuel so generated would be much in excess of the sum of electrical and thermal energy needs of the plant.

In such cases, the cogeneration scheme adopted would produce excess electric power (while exactly catering to the thermal energy needs of the process plant through low pressure steam) and the excess electricity can be pumped into the utility grid, which is ever starving for additional electrical power. [5] Having identified thermal energy balanced system as the best alternative for adoption, there would be still two options possible under this system, viz.,

- Generate excess electricity and send the excess to the utility grid.
- Generate less electricity and buy the balance electricity requirement from the grid.

When the combustion of fuel takes place in a gas turbine (GT) or an internal combustion engine, the exhaust gases from them (which contain the thermal energy for process use) are passed through Waste Heat Recovery Boilers (WHRB) for producing the steam required. It must be noted that, such cases would result in either auxiliary firing (when the energy at GT exhaust is short) or bypassing of some gas to atmosphere, when the energy at GT exhaust is more than the requirement [6].

III. COGENERATION SCHEMES

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.
- Based on primary equipment. i.e. gas turbine, fired boilers / heaters, waste heat boilers, steam turbines etc.

A. Types of cogeneration

There are two broad categories of Cogeneration [7]. They are:

- Topping cycle
- Bottoming cycle

B. Topping Cycle

Power is produced first followed by extraction of heat. [17] This is most common type of cogeneration system. Prime movers in topping cycle are reciprocating engine (gas and diesel) and gas turbine. Fig.1 shows a backpressure steam turbine topping cycle, which is self-explanatory.

C. Bottoming cycle

Here high temperature steam or hot water is first produced in a boiler primarily for thermal application. [15] The residual steam or hot water is then used to drive a steam turbine to generate electricity as shown in Fig.2.

It is called combined cycle system and is a highly efficient method of producing mechanical/ electrical energy. [10] This is only for large industrial application. More specialized cogeneration system can be built using Rankine cycle engines, sterling engines, and fluidized bed combustion systems.

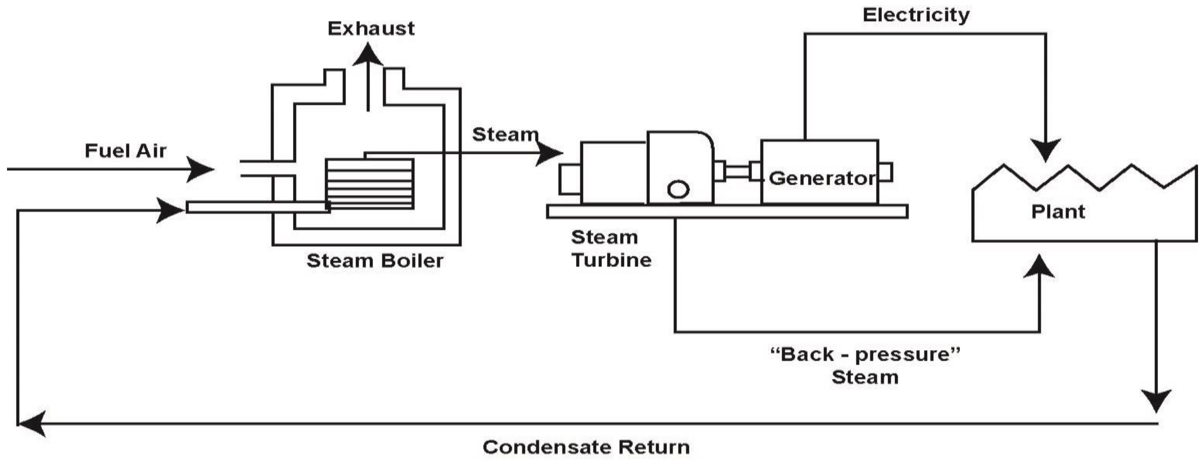

Fig.2. Steam turbine bottoming cycle

IV. BENEFITS OF CO-GENERATION

The cogeneration process has the following benefits such as:

1. The fuel, bagasse is renewable source of energy.
2. The sugar industry gives additional power with bagasse used for generation of steam.
3. Reduced emission levels and therefore environment friendly.
4. Ensure fuel security.
5. Co-generation project leads to reduction in transmission losses considerably and thus helps in stabilizing the grid voltage.

V. HEAT TRANSFER

The purpose of boiler is to generate either hot water or steam. The heat released by burning fuels (or the waste heat in the gases) is to be transferred efficiently to the incoming water. In the boiler practice, the heat is transferred in two modes: (a) by radiation and (b) by convection. The radiation heat transfer occurs because of both flame radiation and non luminous gas radiation. [14] The radiation heat transfer is governed by the 'inverse square law' and also the emissivity and temperature of the radiation source and the boiler heating surface. The convection heat transfer can be either due to natural convection or forced convection. Various dimensionless numbers, characterizing the flow of fluids, like Reymolds, Nusselt, Grasshoff, and Prandtl etc. Density, viscosity and wetted perimeter of the flow channels are used to compute these dimensionless numbers.

VI. GLAND STEAM SYSTEM

A high pressure steam turbine is having a sealing gland, where, the turbine rotor penetrates the casing of the turbine. Under certain conditions the gland is sealed by an auxiliary steam supply, and under other conditions the gland is self sealed by turbine inlet steam. [13] A control system is provided to modify the temperature of the auxiliary steam to be more compatible with the self sealing steam, so as to eliminate thermal shock to the turbine rotor as shown in Fig.3.

Most steam turbines have a shaft-sealing system which uses carbon rings to isolate the rotor assemblies on both ends with steam injected to prevent air in-leakage into the turbine. This leakage would reduce turbine efficiency and flow into the condenser downstream of the turbine further reducing system efficiency. [16] This “gland steam” must be removed by an ejector or other vacuum producing device to prevent it from flowing back to the turbine.

The purpose of the gland steam system is to reduce steam leakage to a minimum and to prevent air ingress. Steam leakage leads to the requirement for increased make up; this increases the load on the feed and boiler water treatment chemicals and to a deterioration of the working environment surrounding the power plant. Air ingress leads to a loss of vacuum and hence reduction in plant efficiency, and causes problems of thermal stressing around the gland as well as increases oxygen content of the exhaust steam.

VII. ENHANCED GLAND STEAM SYSTEM

In actual cogeneration process, the gland leak steam condensate from steam turbine has been going as waste in drains. According to the proposed gland steam system as shown in Fig.4, the gland steam, instead of going as waste in drains, it is reutilized by giving it back to the CRT and then to the boiling feed water (BFW) through heat pump for better energy conservation in the present cogeneration power plant. So that, the waste heat will be recovered and reused by this proposed gland steam system thereby helps in energy consumption.

	UNIT	NOTE A	NOTE B	NOTE C	NOTE D
PRESSURE	ata	3.06	1.02	1.02	0.98
TEMP.	Deg.c	422.53	180	421.16	285.54
FLOW	TPH	2.175	0.099	0.02	0.05
ENTHALPY	KCal/Kg	793.5	677.36	793.56	727.4

X - Gland steam supply control station
Y - Gland steam dump control station
RGT - Real Gland Temperature

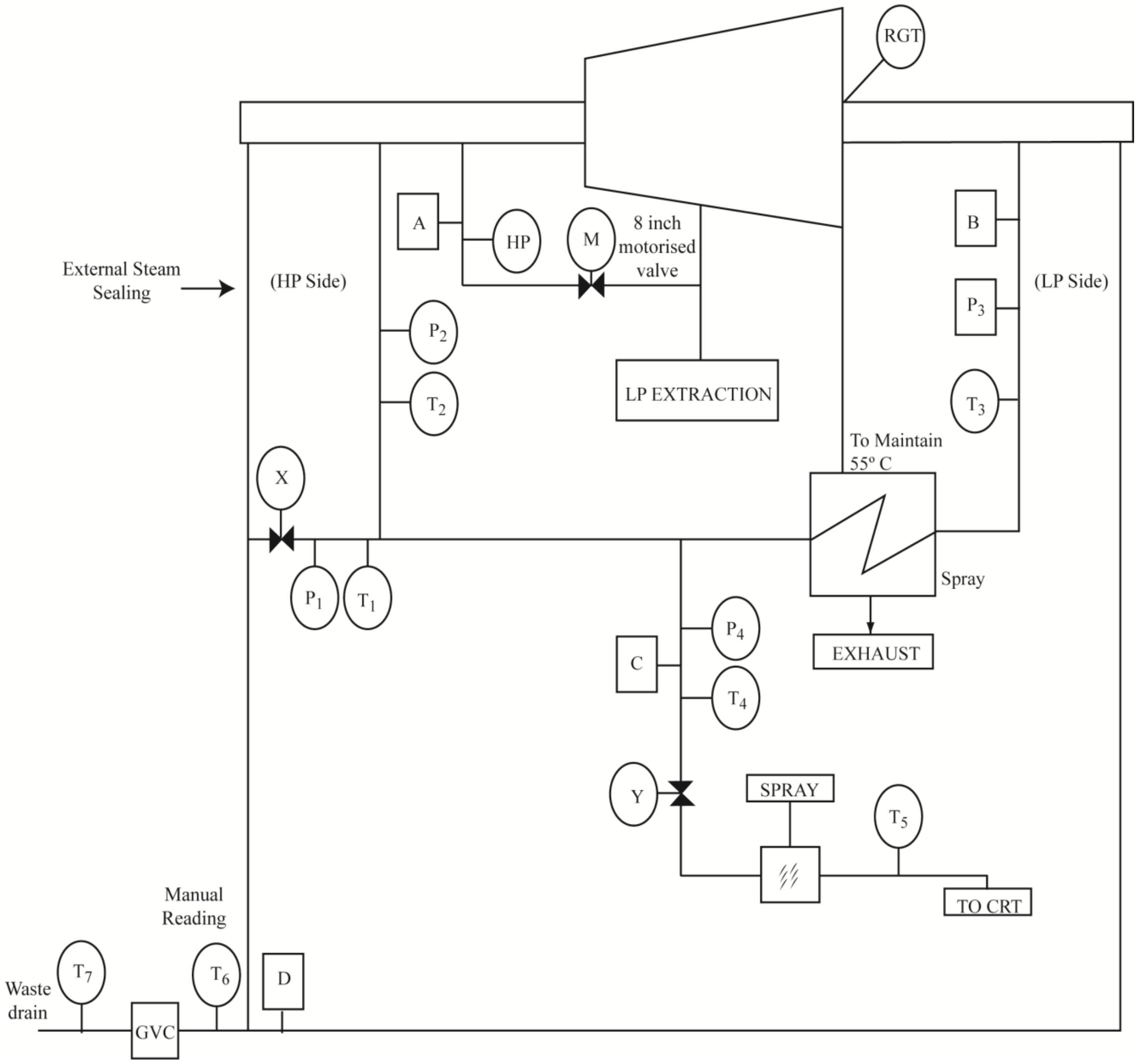

Fig.3. Gland Steam System flowchart in Cogen Power plant

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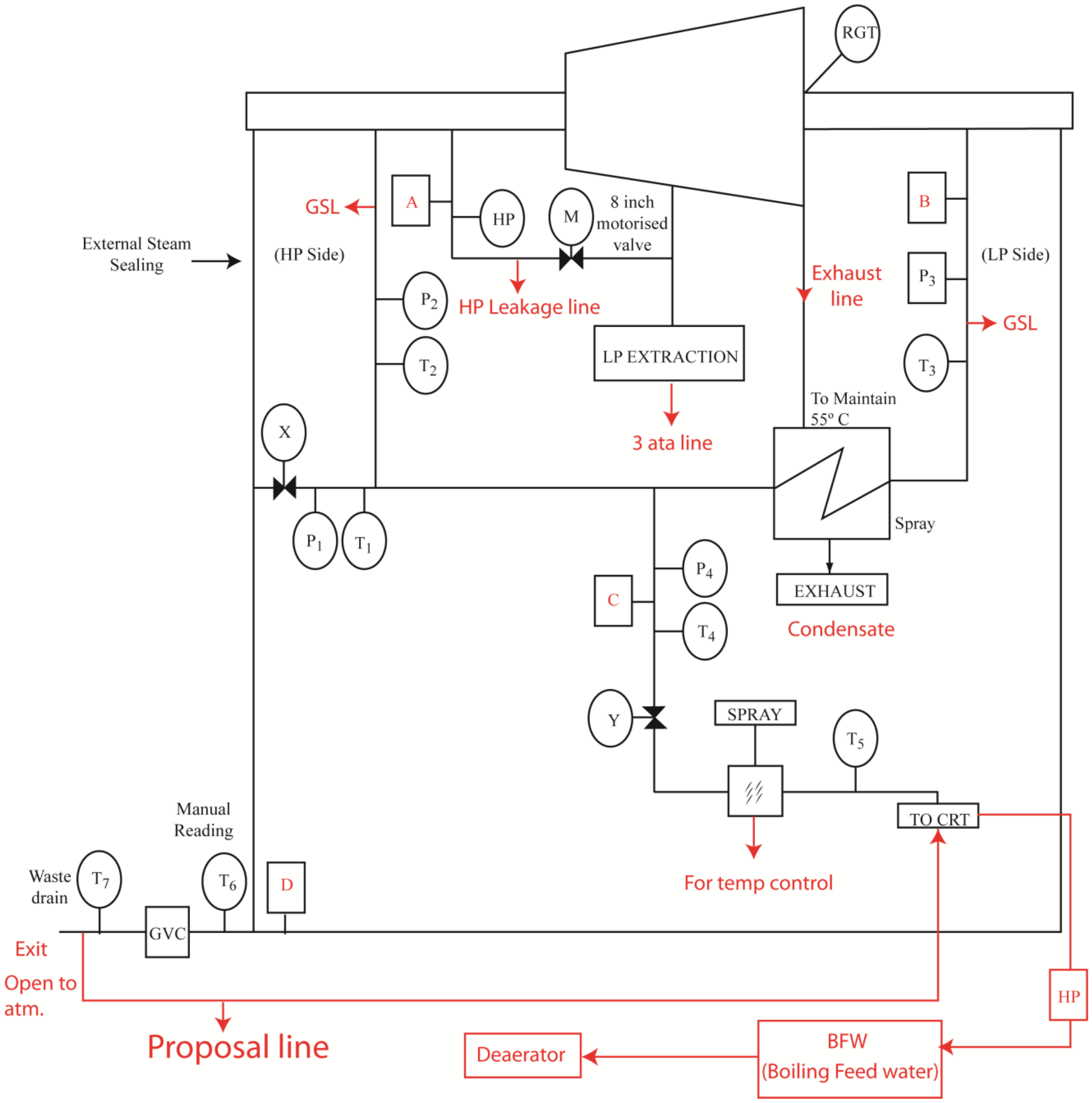

Fig.4. Enhanced Gland Steam System flowchart in Cogen Power plant

VIII. PAYBACK PERIOD CALCULATION

Recovery of Gland Leak Steam Condensate

We are getting gland leak steam condensate of 8.0 lit/ min from our steam turbine with a temperature of 75 deg.C on an average. Presently this has been going as waste in drains.

We have to lay a pipeline from GVC (Gland Vent Condensate) drain to Condensate Receiving Tank to conserve DM water and heat energy in the condensate.

a) Quantity of Gland Leak Steam Condensate : 8.0 lit/min

: 8.0 x 60 = 480 lit/hour

: 480 x 24 = 11520 lit/day

= 11.52 tonnes / day (savings)

Cost savings @ Rs. 45 / Ton of DM Water = 11.52 tonnes / day x Rs. 45 / ton = Rs. 518.40 / Day

b) Enthalpy of Gland Steam Leak Condensate @ 75 deg.C : 75 Kcal/Kg

Enthalpy of DM water @ 30 deg.C : 30 Kcal/Kg

Net increase in Enthalpy : 45 Kcal/Kg

For 11520 Kgs of Gland steam condensate : 11520 Kgs x 45 Kcal/Kg

: 518400 Kcal

Equivalent Bagasse Quantity @ 2272 Kcal/Kg : 518400 / 2272

: 228 Kgs of Bagasse / day (Savings)

Cost Savings @ Rs. 675 /Ton of Bagasse = 0.228 x 675 = Rs. 153.90 / Day

Total Cost savings (a+b) = Rs. 518.40 + Rs. 153.90 = Rs. 672.30 / Day

Implementation Cost:

Pipeline Cost : Rs. 65000/-

Erection Cost : Rs. 10000/-

Total Cost : Rs. 75000/-

Other running maintenance cost is NIL.

Hence the simple Payback Period is = 75000/672.30 = 111.55 days

= 112 days (say)

IX. CONCLUSION

In actual cogeneration process, it is observed from the gland leak steam condensate of 8.0 lit/min from steam turbine with temperature of 75 deg. C on an average. Presently this has been going as waste in drains. According to this paper the gland steam system is enhanced to reutilize the gland leak steam by giving it back to the CRT and then to the boiling feed water (BFW) through heat pump for better energy conservation in the present cogeneration power plant.

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