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Case Study about High Pressure Heater Utilization ina Local Power Generation Plant in Saudi Arabia

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ABSTRACT: *In this paper, there are two High Pressure Heaters (HPH) were out of service due to lake of maintenance. According to this issue, the unit efficiency decreased which consumed more fuel to compensate the temperature drop. During water circulating in a condensate water system there are heat waste, temperature drop, low performance and poor quantity of heat transfer which will cause an insufficient efficiency due to High Pressure Heaters (HPH) are not working properly.*

To remedy this issue, we study and focused on how efficiency can be improved when high pressure heaters in service and compare the results between the two situations in and out of service by calculate different parameters; TGHR, TNHR, Boiler efficiency and NUHR. Fuel cost effectiveness studied in this paper at maximum heat rate difference 11.8 kJ/ kWh.

KEYWORDS*: Heatrecovery; heat exchanger; power generation plant; fuel cost; unit efficiency; boiler efficiency.*

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I. INTRODUCTION

Viklund, S. B. [1] Waste heat recovery inventions their usage in several industries applications. Enhancing method heat recovery efficiency delivers important and instant cost savings. Waste heat recovery systems are used in several industries such as a power generation system, petroleum refining, heavy metal production, cement, chemical refining and other industries. Additional heat can be used in several ways which it is internally and externally.

Cao, L. & Zhang [2] Enthalpy discriminant relation between fresh air and exhaust air studied the economic efficiency of the fresh air exchange the impact on public buildings using exhaust air total heat recovery in hot summer and cold winter area. The results showed that using the exhaust air total heat recovery unit, the total cooling load of the entire building could be reduced by more than 45% and the total heat load is reduced by more than 20%.

Heo, H. S.Organic [3] Rankine cycle was applied to an excavator to recover waste heat, replicate it into electrical energy, and subsequently reduce the fuel consumption. The varieties for the major design parameters were determined to satisfy the target of the heat recovery.

Lu, Y. Roskilly [4] Engine coolant and exhaust heat recovery used an organic Rankine cycle (ORC). The case study selected a small engine as the heat source to initiative the ORC system using a scroll expander for power production. the combined engine waste heat recovery system can improve the overall system efficiency.

Loni, R. Kasaeian [5] Solar dish collector performance studied within different Parameters, the cavity receiver was used as the heat source of the organic Rankine cycle (ORC). The main objective is the calculation total thermal efficiency of the system.

Manfrida, G. Secchi [6] Robust mathematical intensive on model of a Latent Heat Storage (LHS) system constituted by a storage tank comprising Phase Change Material spheres. The operation of a solar power plant connected with a latent heat thermal storage and an ORC unit was simulated under dynamic (time-varying) solar radiation conditions.

Punov, P. Lacour. [7] Analysis of the possibilities of exhaust gas heat recovery for a tractor engine discussed. Rankine cycle simulation with four working fluids were carried out at the most characteristic operating point of the engine. The simulation results exposed that the output power of the engine and the efficiency of the engine increased which paralleled to a Rankine cycle efficiency.

Schimpf, S. & Span [8] Net electricity demand reduced of the system by 1–9% over a period of 20 years Simulated and optimized by different solar thermal and ground source heat pump system with additional heat of the collectors during summer.

Vélez, F. Chejne [9] Thermodynamic study comprehended on the use of a low temperature heat source for power generation through a subcritical Rankine power cycle with R134a as working fluid. The outcome of adding an internal heat exchanger to the cycle was examined, giving as a result a maximum efficiency of basic cycle and with an internal heat exchange.

Ashouri, M. Astaraei [10] ORC is being studied thermodynamically and economically for small-scale electricity generation. Result of superheating and recuperating was studied on the thermal efficiency and costs of the system. Results show the addiction of the system efficiency and system costs on the effective pressure of heat exchanger.

Calise, F. Capuozzo [11] Improvement of the performance for an organic Rankine cycle (ORC) powered by medium-temperature heat sources for different operating conditions and design criteria in two simulations. The first simulation aimed at selecting a design optimization criterion of some geometrical parameters, the second simulation evaluates the off-design performance of the ORC power plant.

1. Overview of The Research

This study discusses a case study of heat recovery system in a local power generation plant. Principle of heat recovery can applicable even in solar or traditional power generation plant. Heat exchanger is a major component for heat recovery system in this paper. Improvement in efficiency and fuel cost effectiveness introduced in this paper by case study in local power generation plant.

Figure 1 represent the schematic diagram for feed water system inside the power generation plant;

There are two High Pressure Heaters (HPH) installed in the system, the water exiting from feed water tank to HPH 6 with pressure of 182 bar and temperature of 168 °C by using feed water pump. In HPH 6 the water is heating by steam extraction from intermediate pressure turbine (IPT) with 435 °C and 13.3 bar. Then, the water exiting from HPH 6 to HPH 7 with temperature of 191 °C. While, In HPH 7 the water is heating by steam extraction from cold reheat line with 281 °C and 25 bar. Then, the water exiting from HPH 7 to Economizer with temperature of 218 °C as shown in temperature distribution table1 and Fig. 1

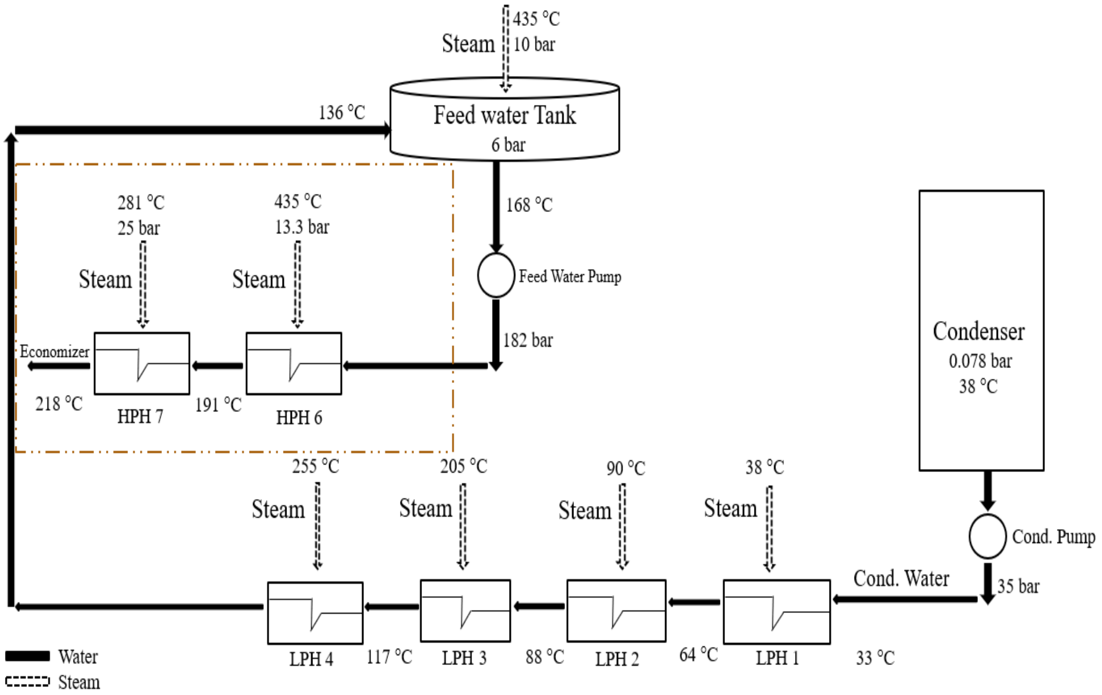

Fig.1. Feed Water System Schematic Diagram

Table 1 High Pressure Heaters (HPH) Temperature Distribution

Heater No.	Steam Temp. in°C	Water Temp. in°C	Water Temp. out°C
HPH6	435	168	191
HPH7	281	191	218

There are two type of heaters used in a power plant as shown in Fig2:

1- Four Low Pressure Heaters (LPH)
2- Tow High Pressure Heaters (HPH) placed before boiler

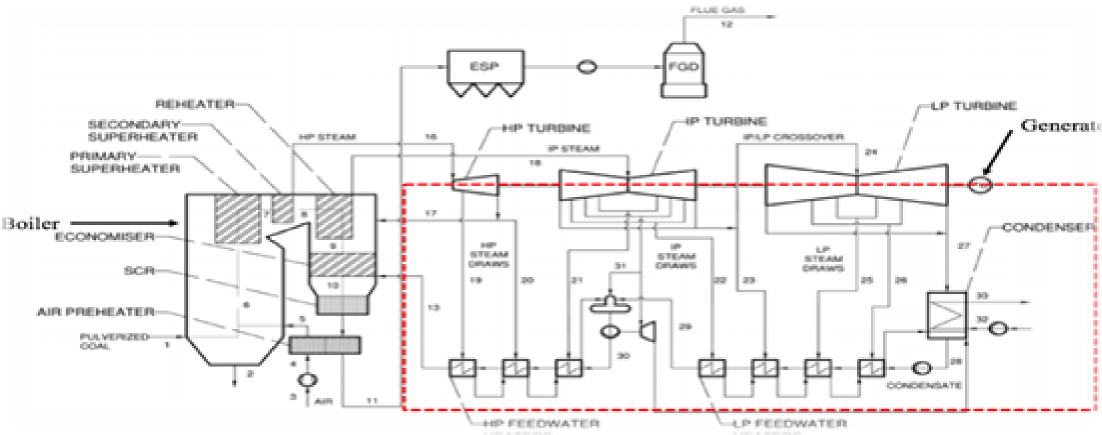

Fig.2.Heating Condensate Water System in Power Plant

Also, there is a failure exist in High Pressure Heaters (HPH), according to this failure, some problems occurred frequently such as:

1. Decreasing of temperature roughly by 74°C as shown in Fig.2
2. Increasing of fuel consumption
3. Decreasing unit and boiler efficiency
4. Boiler’s tubes fouling

II. METHODOLGY

The method of this study was based on theoretical modeling to determine the performance of the different parameters are presented in this section; TGHR, TNHR, GUHR, NUHR, $\eta_B$and $\eta_{U.}$

*The parameters for calculation methods are obtained from the shift operator's logbooks from control rooms of the power plant.

Table 2 HPH In and Out of Service Data Input

Symptom	**HPH In Service**	**HPH Out of Service**
	Value	**Value**
$\dot{m}_{LS}$	337	337 kg/ s
h_{LS}	3401.02	3401.02 kJ/ kW
h_{FW}	939.25	1076.4 kJ/ kW
$\dot{m}_{HRH}$	313.18	313.18 kg/ s
h_{HRH}	3535.2	3535.2 kJ/ kW
h_{CRH}	3056.27	3056.27 kJ/ kW
$\dot{m}_{F}$	93.8	96.3 kg/ s
P_{G}	397000	397000 kW
P_{N}	367200	367200 kW

So, in order to find GUHR, we calculate next parameters in sequence; TGHR, TNHR and η_B after these parameters, NUHR can be calculated and all of these parameters are calculated in two situations of High Pressure Heater (HPH); in service and out of service.

$$TGHR= (\dot{m}_{LS}) * (h_{LS} - h_{FW}) + (\dot{m}_{HRH}) *(h_{HRH} - h_{CRH})/(P_G) \quad [12]$$

$$TNHR= TGHR*(P_G/P_N) \quad [13]$$

$$\eta_B = (\dot{m}_{LS}) * (h_{LS} - h_{FW}) +(\dot{m}_{HRH}) * (h_{HRH} - h_{CRH})/ (\dot{m}_F *\text{Calorific Value of Fuel*Density ofFuel*1000}) \quad [14]$$

$$GUHR = (TGHR/ \eta_B) \quad [15]$$

$$NUHR = \text{Mass Flow Rate * Calorific Value * Density}/P_N \quad [16]$$

$$E_{net}=1/NUHR \quad [17]$$

These governing equations arranged by sequence in recompence from equation 1 until equation 6.

III. RESULT AND DISCUSSION

This section presents following results obtained from mathematical modeling in case of HPH in service and out of service. HPH implementation in power generation unit shown the different parameter values for HPH in service and out of service.

Table 3 HPH In and Out of Service Data Output

Symptom	**HPH In Service**	**HPH Out of Service**
	Value	**Value**
TGHR	2.46 kJ/ kWh	2.35 kJ/ kWh
TNHR	2.66 kJ/ kWh	2.54 kJ/ kWh
GUHR	2.60 kJ/ kWh	2.67 kJ/ kWh
NUHR	10158.34 kJ/ kWh	10429.09 kJ/ kWh
η_B	94 %	87 %
η_U	35.43 %	34.51 %

As shown in figure 3, TGHR, TNHR and GUHR has an improvement when HPH in service by average of 0.1 KJ/ kWh, this will make a difference on NUHR by 429.04 KJ/ kWh as shown in Fig. 4

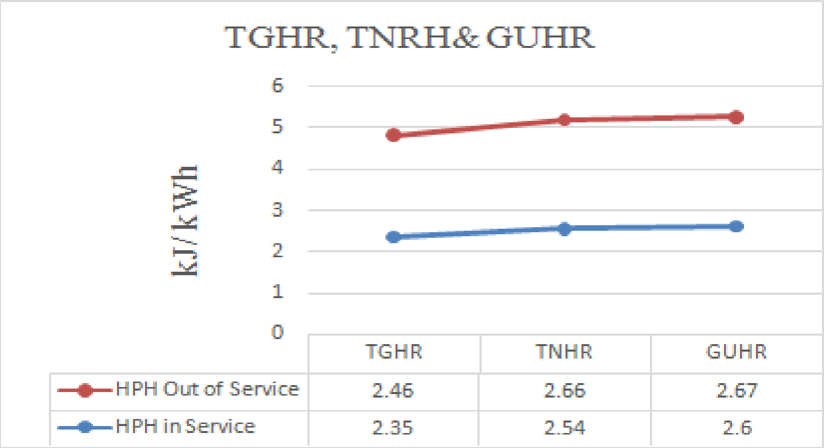

Fig.3. HPH in and Out of Service Parameters; TGHR, TNHR and GUHR

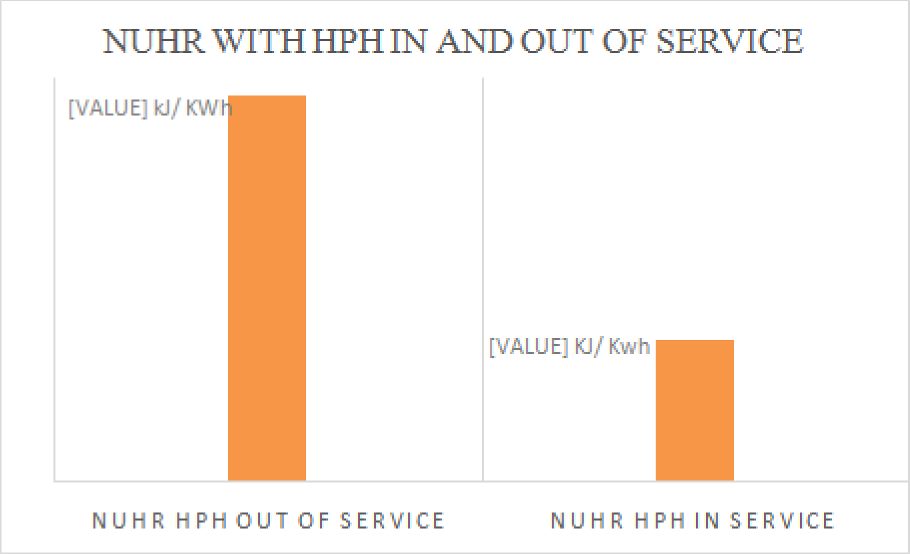

Fig.4. HPH in and Out of Service NUHR Parameter

Boiler efficiency has a visualize improvement when HPH in service which conduct to 6 % and this will be save the heat gained from the generation unit from waste also to improve the unit efficiency from 34 % to 35 %.

That's means heat exchanger effect on boiler efficiency duet to reducing the amount of fuel combustion and utilize the heat gain. The difference between two situations are 271 kJ/ kWh, this amount being heat recovery from feed water system also it saves the money during operation time.

3.2Fuel Cost Effectiveness: Annual Fuel Cost is based on known operating information:

Table4 Fuel Cost Data Input

Symptom	Definition	Value
(FC)	Fuel Cost	32.614 SR/MBTU
(CF)	Capacity Factor	0.8 %
(GUC)	Gross Unit Capacity	397000 kW
(T)	Time in (hours/Year)	8760 hours/Year
Boiler Efficiency	(η_B)	0.87 %

Table 5 Heat Rate Data Input and Cost Analyses

Parameter	Variance	Heat Rate difference	Cost of Fuel
Main Steam P	-2.8	9.5	237,015
Main Steam T	-2.8	6.6	164,663
Hot Reheat T	-69	2.7	67,362
Condenser P	0.7	20.2	503,969
Final Feed Water T	-2.8	11.8	294,398

After calculating those parameters in below equation, the annual fuel cost is= 28,855 SR/Year

Annual Fuel Cost (SR/Year) = (THRD/η_B) *FC*CF*GUC*T [18]

3.3 Controllable Parameters Calculations

- Main Steam Pressure
- Main Steam Temperature
- Hot Reheat Temperature
- Condenser Pressure
- Final Feed Water Temperature

Note: Variances and heat rate difference supplied by a power plant.

In table 5; the major parameters are temperature heat rate and annual fuel cost per year (1$=3.75SR). It's clearly shows that; the temperature is inversely proportional with cost of fuel. Cost of fuel per year can be calculated by multiplied it to temperature heat rate and its summarized in table 5.

IV. CONCLUSION

This paper presents a mathematical modeling for typical case study in local power generation plant is also presented.

There are two situations for applied governing equation; HPH in service and out of service.

These parameters; TGHR, TNHR, GUHR, boiler efficiency and NUHR are calculated. Boiler efficiency it should be increased 7 % by when HPH in service and unit efficiency from 34.5 % to 35.4 % as shown in data output in table 2.

unit lose -2.8◦C which needs 11.8 kJ/kWh to reoccurrence these losses. Annual fuel cost per heat rate is 28,855 and its reached to 340,489 SR with maximum heat rate losses 11.8 as shown before in table 3.

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