SUST Journal of Engineering and Computer Sciences (JECS), Vol. 20, No. 3, 2019

Study of High Pressure Heaters and Its Influence on Operation Cost in Power Plants: Case Study Garri -4

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Received: 15/10/2019
Accepted: 17/11/2019

ABSTRACT-Electricity is one of the most important achievements that modern sciences have given to mankind. It became a part of modern life and one cannot think of a world without it. It has many uses in our daily life. Recently, in Sudan, there are some problems related to its continuity and availability of electrical and thermal power generation. This paper presents a part of the solution for the generation of thermal power for Garri-4. The characteristics of electrical energy are sustainability, easy transmission, and easy utilization. All these factors make electrical energy desirable. The main problem of electrical power is the high cost of production due to the high cost of fuel. Through the centuries, there is a lot of work done to reduce the energy cost, by rising up the efficiency and increase the performance of the systems. This paper shows the effect of high-pressure (HP) heaters out of service in the Garri-4 power plant. It aims to investigate the influence of HP heaters on the power plant's overall performance. The mathematical modeling is used through thermodynamic and heat transfer equations to study the efficiency and the operation cost for the power plant. The paper concludes that HP heaters have a clear influence on the power plant performance by increasing the overall power plant efficiency and reduce the operation cost. It also makes it less harmful to the environment through less emission due to less fuel consumption. There is an increase the overall power plant efficiency by 3.78% , 1.03%., and 2.56%, from 27.67%, for different cases studied in this paper.

Keywords: *Thermal Power, High-Pressure (HP) Heaters, Heat Transfer, Heat Exchanger, Efficiency.*

المُسْتَخْلَص– تعتبر الكهرباء من أهم منجزات العلوم الحديثة للبشر، ولا يمكن التفكير فى الحياة الحديثة بدونها بسبب الأستخدامات المتعددة لها فى الأنشطة اليومية. برزت فى الاونة الأخيرة مشاكل تتعلق بإستمرارية وإستدامة توليد الطاقة الكهربائية فى السودان تتعلق بالتوليد المائى والحرارى. هذه الدراسة تطرح جزء من الحلول المتعلقة بالتوليد الحرارى لمحطة قرى الكهربائية. من مميزات الطاقة الكهربائية الإستدامة, سهولة النقل وسهولة التعامل معها. كل هذه العوامل جعلت منها الطاقة الاكثر طلبا. تكمن مشكلة الدراسة في ارتفاع تكلفة انتاج الكهرباء من خلال ارتفاع تكلفة الوقود. سعي الانسان علي مر العصور لتقليل تكاليف الطاقة من خلال رفع كفاءة الانظمة وتحسين أدائها. في هذه الدراسة تم التطرق الي سخانات الضغط العالي في محطة كهرباء قري الخارجة من الخدمة بهدف التحقق من تاثير سخانات الضغط العالي في رفع الاداء الكلي للمحطة. أستخدم في هذه الدراسة النموزج الرياضي من خلال أستخدام معادلات الديناميكا الحرارية وانتقال الحرارة لدراسة تأثير كفاءة وتكاليف تشغيل المحطة. .خلصت الدراسة الي ان سخانات الضغط العالي لها تأثير وأضح علي الأداء الكلي للمحطة من خلال رفع الكفاءة الكلية للمحطة، وتقليل تكاليف التشغيل. وأيضا تقلل من الاضرار المترتبة علي البيئة عن طريق تقليل الإنبعاثات من خلال تقليل إستهلاك الوقود.

1. INTRODUCTION

Throughout the century the man tried to reduce the energy cost, by rising up the efficiency of the systems. Steam power plants generate most of the electric power in the world, to save fuel. Efforts are constantly made to improve the efficiency of the cycle on which steam power plants operate. The general idea is to increase the fluid average temperature during heat addition and decrease the fluid temperature during heat rejection [1].

Investigations on the increase of efficiency of the Steam Turbine cycle and turbine production concerns have been carried out by many Research Centers for a few years.

The objectives of this paper are as follow; to increase the efficiency of generation, to reduce the quantity of the fuel in order to increase the operational life of a plant, to economically study the cost related to influence of high pressure heater, and to decrease (reduction) vibration in the shaft of the turbine.

The importance of the study lies in increasing the generation efficiency (output increase from the turbine to the electric generator) is a cheap and safe manner. Also, it can supply the national grid power capacity for sustained, stable electricity. It is also significant in reducing the DC-stop from factories, homes, and hospitals which leads to the progress and development of Sudan [3].

The Garri-4 power plant is a steam power plant. It uses the CFB boiler to generate steam. It also uses high-pressure heaters to improve the plant overall efficiency.

Recently, the high-pressure heaters are out of service which led to erode the power plant efficiency and increase fuel consumption. Other related problems happened such as increase the turbine vibration.

2. Studies that consider the influence of HP heater in the operating cost

The HP heater is found to reduce the power plant cost through increasing the fuel utilization, by rising up the feedwater temperature before entering the boiler. In the 210MWe coal-fired power plant which is situated in North India; Analysis is used to predict coal consumption rate, overall thermal efficiency, the mass flow rate of steam through the boiler, and Net present value (NPV) of plant for a given load. The thermodynamic analysis was carried out using mass and energy equations followed by empirical correlations, predicted mass flow rate of steam, coal consumption rate. The economic analysis included operational activities such as equipment cost, fuel cost, operations and maintenance cost, revenue, and plant net present value[1].

The study concluded that the effect of employing redundancy (excessive) units to boiler feed pumps and condensate extraction pumps on the annual cost of the plant. Net present value reflects equipment, maintenance, insurance, operating, coal, and revenue increase with an increase in pump redundancy in various subsystems. The Net present value decreases with any addition of boiler feed pump redundancy in the water circulation subsystem. It also shows marginally increasing trend with condensate extraction pump redundancy in the condenser unit. The effect of condensate extraction pump redundancy on Net present value is comparatively higher as compared with the case of the boiler feed pump. It is expected to lower the initial cost of the condensate extraction pump as compared with the cost of the boiler feed pump.

The usage of the high-pressure heater allows the low temperature of condensate water to be pumped by the feedwater pump. It increases the lifetime of the feed water and maintains the power plant efficiency.

Another study conducted by Devandiran in 2016. It shows the effects of the feedwater heaters on the performance of coal-fired power plants. By adding the feedwater heaters in the power plant cycle, the overall efficiency of the power plant is increased by 2.4 %. Improving power plant efficiency could alleviate the negative effect of coal consumption on CO2 emission. By means of thermodynamic optimization.

It was proposed to include the feedwater heaters in the power plant cycle, achieving optimum power plant efficiency. Simulations had been carried out using HMBD software. Results showed a feasible improvement of the overall power plant efficiency. This implied a direct reduction of Co_2 emission of about 1.3 %. Moreover, the financial analysis confirmed the feasibility of the proposal analyzed and showed the additional yearly incomes [2].

Another study conducted in Vijayawada Thermal Power Station. It studied the parameters which directly or indirectly influence the performance of the heater. The parameters include inlet temperature, saturation temperature, terminal tap difference, drain cool approach and temperature raise.

The study concluded that the efficiency of the power plant increases with an increasing number of heaters. It is not economical to have a large number of heaters to increase efficiency on the basis of the techno-economic. The study of numbers of heaters generally used in 210 MW units are 6 to 7. The efficiency increases by 5 to 6% approximately, see Figure. 1. The operation and maintenance of the heaters in the current power plant must be increased. There is no much deviation in the design and calculations values. It is also observed that with this operation and maintenance the heaters are giving an efficiency of about 75% - 80% [3].

In this study which is written by Vedran Mrzljak [4], it analyzed the high-pressure feedwater heater, as one of the essential components in the LNG carrier steam propulsion system.

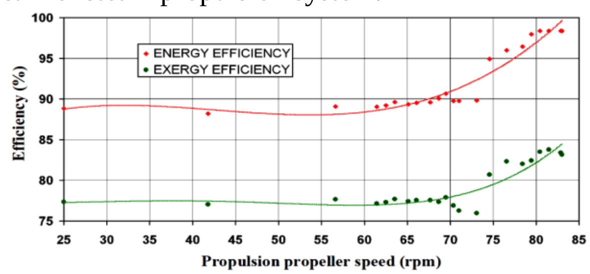

Figure 1: High-pressure feedwater heater energy and energy efficiency change

Measurements of all operating parameters (fluid streams) at the analyzed heat exchanger inlets and outlets were performed. Changes of the operating parameters were measured at different steam system loads, not at full load as usual. Through these measurements were enabled insight into the behavior of the heat exchanger operating parameters during the whole exploitation. The numerical analysis was performed, based on the measured data.

The changes in energy and energy efficiency of the heat exchanger were analyzed. Energetic and energetic power inputs and outputs were also calculated, which enabled an insight into the change of energetic and energetic power losses of the heat exchanger at different steam system loads. Changes in energetic and energetic power losses and operating parameters have the strongest influence on the high-pressure feedwater heater losses were described.

The analyzed heat exchanger was compared with similar heat exchangers in the base loaded conventional steam power plants. From the conducted analysis, it was concluded that the adjustment and control modes of these high-pressure heat exchangers are equal, regardless of whether they were mounted in the base loaded conventional steam power plants or marine steam systems. Whereas, their operating parameters and behavior patterns differ greatly [5].

The study considered the HP heater as shell and tube heat exchanger used for waste heat recovery from the steam power plant. It represented a mathematical model of high-pressure feedwater heater. The heater was divided into three zones de-superheating, condensing and, sub-cooling for the modeling purpose. The same input parameters were given to the Aspen FRAN software and results are obtained, Figure 2.

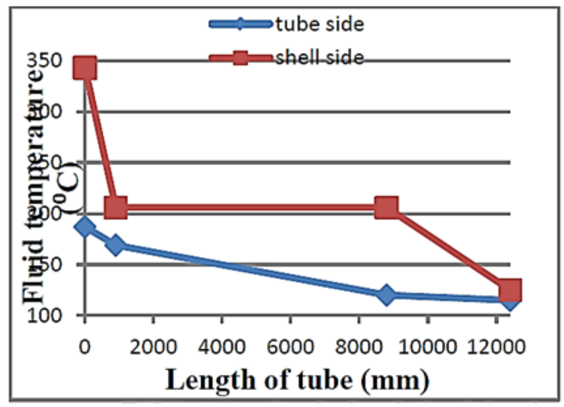

Figure 2: The effect of the tube length to the HP heaters to rise in temperature

The study concluded that the maximum amount of heat duty is handled in the condensing zone of the feedwater heater. The Shell side heat transfer coefficient has a large influence on the overall heat transfer coefficient and hence area of the feedwater heater.

The Fouling factor effects in the calculation of surface area to a large extent. Condensing zone accounts for the maximum amount of area of feedwater heater than the other two zones. The pressure drop on the shell side was maximum in the sub-cooling zone as compared to the other two zones while the pressure drop on the tube side of the feedwater heater is negligible [6].

A.A.A.Abuelnuor, et al.,2017 give an exergy analysis of Garri “2” 180 MW combined cycle power plant. the results proved that combustion chambers are the main sources of exergy destruction due to their high irreversibility [7].

Abuelnuor A. A. Abuelnuor, et al.,2019 emphasizes that exergy analysis is useful in determining irreversibilities and losses in

Elroseires hydropower plant to improve its thermodynamic performance [8].

3. Heat Exchanger Model

Heat exchangers are devices used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact [9].

3.1 Garri4 Power Plant Steam

It is a first power plant in the Middle East that used solid fuel (sponge coke). This coke can be used to generate electric power. Garri-4 is a steam power plant. It works with the regeneration cycle. It consists of two steam turbines each one generates 55 MW. Each turbine has a boiler to supply superheated steam to the turbine. This boiler is known as a Circulating Fluidized Bed Boilers (CFB Boilers).

TABLE 1: MAIN TECHNICAL PARAMETER OF TURBINE UNIT [10]

No	Technical Parameter	Value
1	Rated power	55MW
2	Maximum power:	62MW
3	Rated pressure of main steam	8.83± 0.49MPa
4	The rated temperature of main steam	535 ºC 510+–
5	Exhaust steam pressure:	11.80 a
6	Rated main stream flow	219.5t/h
7	Maximum main stream flow	252T/H
8	Rotating speed	3000r/min
9	Cooling water temperature	33ºC(max.38 ºC)
10	Feedwater temperature	234 ºC
11	Heat consumption	9823.8kJ/kWh
12	Steam consumption	3.987 Kg/KW.h
13	Rated steam flow	219.5 t/h
14	Flow path stages	19 stages in total
15	One governing stage adds 18 pressure stages	-
16	2 HP heaters and 3 LP heaters	-

3.2 The layout of Garri4 Power Station

The layout of the station as follows; it has two CFB boilers, the main power building which contains two steam turbines with generators and auxiliary equipment's, substation, clarified water tank, composite pump house, demineralization plant, wastewater treatment plant, cooling towers, circulating water pumps house.

LDO storage tank and pump house, sponge coke shed, convey system. There are an auxiliary boiler and emergency generator house, administration building, and Workshop. Table 1 explains the main technical parameters of the turbine unit [8].

3.4 High pressure (H.P) heater model in Garri4 power plant

The utility of H.P heater is to use the extract-steam from the turbine to heat the feed water of the boiler to reach the required temperature. The process can increase thermal efficiency.The H.P heater of the 55MW turbine is installed vertically. The U tube bundle is assembled. It has two zones de-superheating zone and condensing zone. The H.P heater has the small feedwater bypass system with (1) set of inlet/ outlet feed-water valve for each H.P heater.

4. Mathematical Modeling

The mathematical modeling follows the thermodynamics equations, mass and heat transfer equations. The heat balance principle used to calculate the power produced by the turbine as well as the power consumed by pumps.

The actual operating characteristic is collected during the operation of the power plants at various loads. They are used in the calculation to find out the overall power plant performance characteristics for both when they operate with HP heaters and without HP heaters. Figure .4; explains the P&ID sketch for the garri-4 power plant.

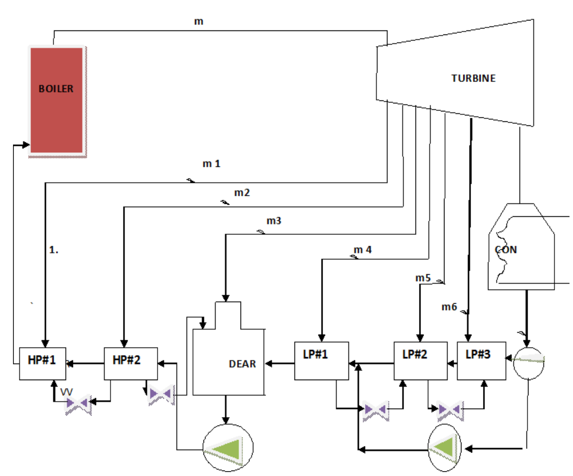

Figure 4: P&ID sketch for garri-4 power plant

4.1 Equation used in Calculations

Calculations use mathematical equations and thermodynamic laws in studying the effect of high-pressure heat exchangers in efficiency and cost [9][11].

- The Turbine Power:

$$W_T = \dot{m}_1(h_1-h_2)+(\dot{m}_1-\dot{m}_2)(h_2-h_3)+(\dot{m}_1-\dot{m}_2-\dot{m}_3)(h_3-h_4)+(\dot{m}_1-\dot{m}_2-\dot{m}_3-\dot{m}_4)(h_4-h_5)+(\dot{m}_1-\dot{m}_2-\dot{m}_3-\dot{m}_4-\dot{m}_5)(h_5-h_6)+(\dot{m}_1-\dot{m}_2-\dot{m}_3-\dot{m}_4-\dot{m}_5-\dot{m}_6)(h_6-h_7)+(\dot{m}_1-\dot{m}_2-\dot{m}_3-\dot{m}_4-\dot{m}_5-\dot{m}_6+\dot{m}_7)(h_7-h_8) \quad (1)$$

- The Pump power:

$$W_p = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4)(h_9 - h_{10}) + \dot{m}_1(h_{18} - h_{17}) \quad (2)$$

- The net of mechanical power:

$$W_{net} = W_T - W_p \quad (3)$$

- The heat supplied:

$$Q_{in} = m_{sk} * CV_{sk} \quad (4)$$

- The overall efficiency of the power plant:

$$\eta = \frac{w_{net}}{Q_{in}} \quad (5)$$

where:

w_T : The Mechanical Power of Turbine (kW).

h_n : The specific enthalpy at the point n (KJ/Kg).

$\dot{m}_1$: The main steam mass flow rate (kg/s).

$\dot{m}_2$: The 1st bleeding mass flow rate (kg/s).

$\dot{m}_3$: The 2nd bleeding mass flow rate (kg/s).

$\dot{m}_4$: The 3rd bleeding mass flow rate (kg/s).

$\dot{m}_5$: The 4th bleeding mass flow rate (kg/s).

$\dot{m}_6$: The 5th bleeding mass flow rate (kg/s).

$\dot{m}_7$: The 6th bleeding mass flow rate (kg/s).

w_p : The power consumed by the pumps (kW).

Q_{in} : The heat rate supplied by the boiler (kW).

m_{sk} :Mass flow rate supplied by sponge coke (kg/s).

W_{net} : The net of mechanical power (KW).

CV_{sk} : Sponge coke calorific value (36000KJ/Kg).

η : The overall efficiency of the power plant.

4.2 Sample Calculation model for 55Mw

When high-pressure heaters in service the following values are calculated in Table. 2.

5. Results and Discussions

The influence of high-pressure heater into the Garri-4 power plant is discussed in terms of efficiency and operation cost. There are four models used to evaluate the influence of HP heaters when they are both in service, and when HP heater no 1 or no 2 out of service.

The overall power plant performance calculated for different operation conditions, at different loads 55, 44, 33, and 22 MW. The HP heaters operation status is also considered in calculations. There are four models of study used to calculate the power plant performance as follow:

TABLE 2: CALCULATION MODEL FOR 55MW [9][11]

No:	Technical Parameter	value
A. When high-pressure heaters in service		
1	The turbine power w_T	56125.9 kW
2	The Pump power W_P	1324.0 kW
3	The net of mechanical power	54801.9 kW
4	The heat supplied	174000.000 kW.
5	The overall efficiency of the power plant	31.5%
6	Price per hour	5585.4 SDG
B. When high-pressure heaters out of service		
7	Main stream flow m1	190.6 ton/hr (m_2 and m_3=0)
8	Sponge coke consumption	19.8ton/hr
9	The turbine power w_T	56125.2 kW.
10	The Pump power W_P	1201.527 kW
11	The net of mechanical power	54923.67 kW
12	The heat supplied	198000.000 kW
13	The overall efficiency of the power plant	27.74%
14	Price per hour	6355.8 SDG

- study of power plant performance when both HP heaters in the service.
- study of power plant performance when the HP heater no 1 is out of service.
- study of power plant performance when the HP heaters no 2 is out of service.

- study of power plant performance when both HP heaters are out of service.

5.1 The overall power plant efficiency and operation cost at 55 MW

As shown in Figure. 5, when HP heaters are out of service is 27.74%. It's increased by 3.76% when the HP heater in service. It is also increased by 1.03% if HP heater no (1) in-service, and also increased by 2.55% if HP heater no (2) in service. Also, the effect of HP heaters obviously can be shown in figure. 6, when HP heater is out of service the cost 6356 SDG/hr, that it's decreased when HP heater1# in service up to 5812SDG/hr. It decreased cost when HP heater2# in service to 6123 SDG, and also decreased to 5585 SDG/hr if both of heaters in service.

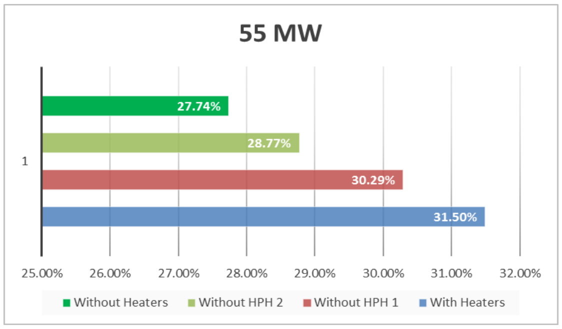

Figure 5: The overall power plant efficiency for 55 MW.

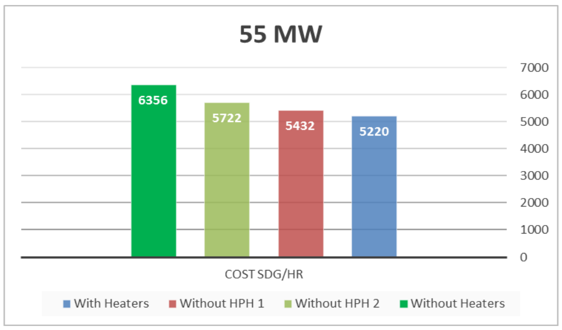

Figure 6: The cost SDG per hour, for 55 MW.

5.2 The overall power plant efficiency and operation cost at 44 MW

As shown in figure.7, when HP heater is out of service it represents 27.67%, that it is increased by 3.8% when the HP heater in service. It is increased by 1.02% if HP heater no 1 in service, and also increased by 2.58% if HP heater no 2 in service.

The effect of HP heaters obviously shown in the figure.8, when HP heater is out of service the cost is 5085 SDG/hr. it is decreased when HP heater (1) in-service up to 4650 SDG/hr, and decreased cost when HP heater (2) in-service to 4898 SDG. It also decreases to 4463 SDG/hr if both heaters in service.

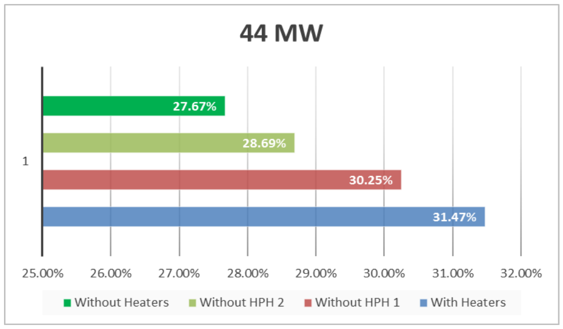

Figure 7: The overall power plant efficiency for 44 MW.

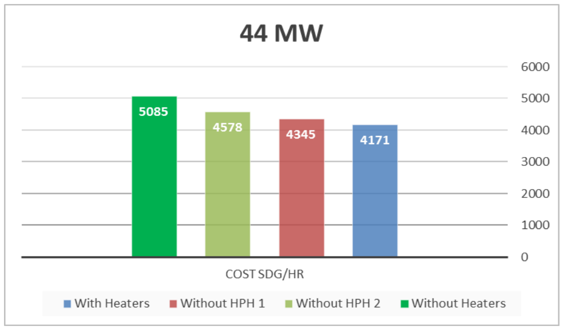

Figure 8: The cost SDG per hour, for 44 MW.

5.3 The overall power plant efficiency and operation cost at 33 MW

As shown in figure.9, when HP heater is out of service it represents 27.68%. It is increased by 3.76% when the HP heater in service. It is increased by 1% if HP heater no 1 in service, and also increased by 2.55% if HP heater no (2) in service.

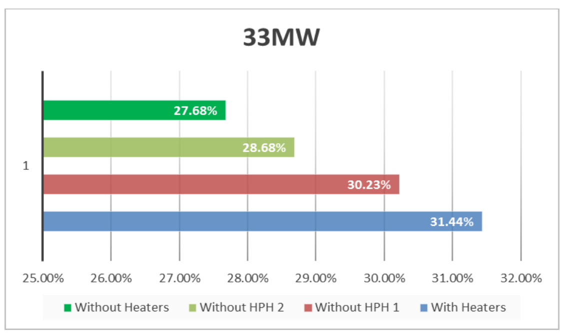

Figure .9: The overall power plant efficiency for 33 MW.

The effect of HP heaters obviously can be shown in figure.10. When HP heater is out of service the cost is 3810 SDG/hr. It is decreased when HP heater (1) in-service up to 3487 SDG/hr. It is decreased cost when HP heater (2) in-service to 3674 SDG, and also decreased to 3351 SDG/hr if both of heaters in service.

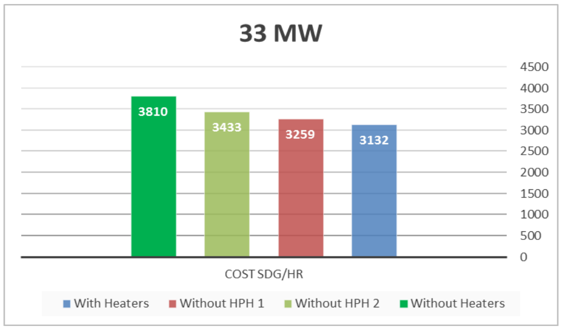

Figure.10: The cost SDG per hour, for 33 MW.

5.4 The overall power plant efficiency and operation cost at 22 MW

As shown in figure 11, when HP heater is out of service it represents 27.60%. It is increased by 3.79% when the HP heater in service. It is increased by 1.05% if HP heater no (1) in-service, and also increased by 2.58% if HP heater no (2) in service.

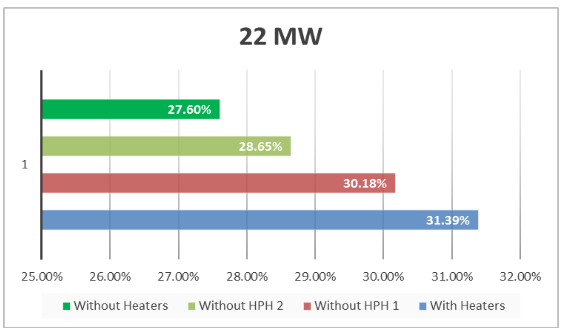

Figure. 11: The overall power plant efficiency for 22 MW.

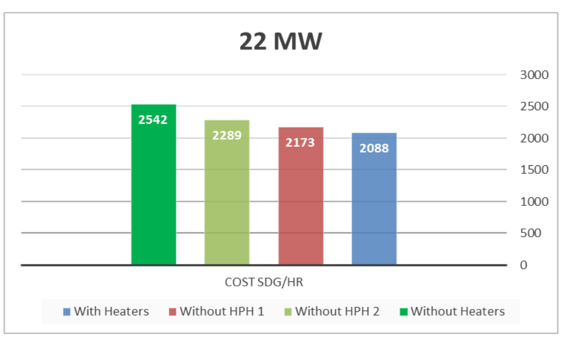

Figure 12: The cost SDG per hour, for 22 MW

The effect of HP heaters obviously can be shown in the figure 12, when HP heater is out of service the cost 2542 SDG/hr. It is decreased when HP heater (1) in-service ups SDG/hr. And decreased cost when HP heater2# in service to 2449 SDG, and also decreased to 2234 SDG/hr if both of heaters in service.

6. Discussion

The results show the effect of high-pressure heat exchangers in the Garri-4 power plant has been calculated. The study found that the efficiency of the second HP heater is greater inefficiency because it is closer to the place of attrition. The HP heaters no1 and no 2 together have a good performance increasing efficiency and decrease the cost.

The presence of HP heater exchangers in the service also reduces the risk of vibrations in the shaft of the turbine.

The metal temperature of the boiler tube reduces by taking feed heaters in service and hence increases the boiler tube life and reduces the outage due to tube leakages.

When the HP heater is out of service there is some steam drained to maintain some operational conditions. It is considered a loss of opportunity cost of power generation. It is also considered the loss of fuel that added in early steam generation.

The HP heater does not put in service at a lower load due to the high difference in temperature between the bleeding steam and the feed water. This causes the thermal stresses in heaters so that the bleeding no2 can be used for both deaerator and HP heater no2. It allows small different between feed water and bleeding steam. The plant in high load with both HP heaters no1 and no2 to increase the efficiency and decrease the quantity of the fuel. It reduces the operation cost, where the increase the lifetime of the power plant through optimizing the use of the boiler and turbine utilities.

7. Conclusions and Recommendation

The study concluded that, to put the HP heaters in service, increase the overall power plant efficiency by 3.78% from 27.67%, and when HP heater no1 in service it is increased by 1.03%. When HP heater no 2 in service it is increased by 2.56%, where the efficiency of the power plant without

HP heaters is 27.67%. Also, a little bit increased inefficiency with the increase in the load. The cost is also directly proportional to the efficiency.

The decrease in efficiency means the chance of more fuel consumption. This increases the number of exhaust gasses, which increases air pollution. When the HP heaters are out of service, the economizer inlet water temperature is low. This leads to more heat transfer in the economizer, and decrease the temperature of flow gasses, where the drop in the flow gasses temperature increases the chance of NO_X intensity formation, which increases the corrosion of the chimney.

For recommendation it's very important to use HP heaters for increase the overall power plant performance and reduce the pollution due to the decreasing of fuel consumption, as well as increasing the life time of the power plant.

As shown in the results the efficiency of HP heater no1, having less than half of HP heater no2 efficiency, so that further study can be conducted to study the HP heater no1 efficiency, and the factor that affecting its efficiency, also the number of HP heaters can be studied to optimize the HP heaters usage in Garri-4 power plant.

REFERENCES

[1] Ravinder Kumar, Avdhesh Kr. Sharma, and P. C. Tewari, “Thermal Performance and Economic Analysis of 210 MWe Coal-Fired Power Plant,” Journal of Thermodynamics, vol. 2014, Article ID 520183, 10 pages.

[2] Devandiran. E, Shaisundaram. V.nS, P. S. Ganesh, Vivek. S, (2016), "Influence of Feed Water Heaters on the Performance of Coal-Fired Power Plants" Journal of Applied Mechanical Engineering (IJRME), Research ArticleOpen AccessAlmedilla et al., J Appl Mech Eng 2018, 7:3DOI: 10.4172/2168-9873.1000308Research ArticleOpen AccessJournal of Applied Mechanical Engineering, Vol. 7, No. 3.

[3] Konarskiego. G. P. , (2005), "Influence of Regenerative Feed Water Heaters on the Operational Costs of Steam Power Plants" Int. J. of Thermodynamics, Vol. 8, No. 3.

[4] Vedran. M, Igor. P, & Vedran. M. V, (2017) "Thermodynamical Analysis of High - Pressure Feed Water Heater in Steam Propulsion System During Exploitation", Brodogradnja, Vol. 68 No. 2, pp., 45-61.

[5] Ch. K, Dhananjaya. k, (2014) "Performance Analysis of Regenerative Feed Heating in a Steam Power Plant", IOSR Journal of Mechanical and Civil Engineering, Vol. 11, No. 2, pp., 01-08.

[6] Yunus A. Ç, AFSHIN J. G, (2015) "Heat And Mass Transfer, Fundamentals & Applications", Fifth Edition, McGraw-Hill Education.

[7] Abuelnuor, A.A.A., Saqr, K.M., Mohieldein, S.A.A., Abdullah, M.M., Nogoud, Y.A.M., (2017) "Exergy analysis of Garri “2” 180 MW combined cycle power plant", Renewable and Sustainable Energy Reviews 79, 960-969.

[8] Abuelnuor, A.A.A., Ahmed, K., Saqr, K.M., Nogoud, Y.A.M., Babiker, M.E.A.M, (2019) "Exergy analysis of large and impounded hydropower plants: Case study El Roseires Dam (280 MW) " , Environmental Progress and Sustainable Energy.

[9] Suhas. D, Gawali. B. S, Sane. N. K, Vinaykumar. K, Ajit. G, (2016) "Design and Analysis of High-Pressure Feed Water Heater", International Journal of Research in Mechanical Engineering (IJRME), vol.3, No. 3.

[10] China National Machinery, Equipment, Import & Export Corporation (2008), "Garri- 4 Operation and Maintenance Documentation, Steam Turbine Instruction".

[11] Rajput. R. K., (2007) "Engineering Thermodynamics", Fourth Edition, Publisher: Laxmi Publications; 4 edition SBN-13: 978-8131800584.