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Investigation the Relationship between Performance Efficiency of Gas Steam Turbine Power Plant Components and the Inspection Time

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ABSTRAK

Dengan kerjaoperasional komponen yang tinggi, beberapa inspeksi harus dilakukan di industri pembangkit listrik. PT XYZ sebagai pembangkit listrik turbin gas melakukan inspeksi yang terdiri dari inspeksi pembakaran (CI), inspeksi turbin (TI), dan inspeksi utama (MI). Periode dari satu inspeksi ke inspeksi lainnya sekitar 8000 jam operasi. Tujuan dari penelitian ini adalah untuk mengetahui hubungan antara waktu inspeksi yang ditentukan oleh perusahaan manufaktur pembangkit listrik dan efisiensi itu sendiri. Berdasarkan hasil tersebut, inspeksi utama memiliki dampak terbesar pada reduksi laju panas suatu unit. Inspeksi utama tersebut juga menyebabkan nilai efisiensi kinerja tertinggi di unit A. Namun, jika inspeksi digabungkan dengan beberapa retrofit, efisiensi kinerja dapat meningkat menjadi nilai tertinggi, seperti pada inspeksi turbin di unit B.

Kata Kunci :inspeksi, efisiensi, performansi

ABSTRACT

Realizing the high operating work of the components, several inspections should be conducted in a power plant industry. In PT XYZ as a gas turbine power plant, the inspection consists of Combustion Inspection (CI), Turbine Inspection (TI), and Major Inspection (MI). The period from one inspection to another is about 8000 operating hours. The objective of the research is to identify the relationship between the inspection time which is defined by the manufactures of the power plant and the efficiency itself. Based on the result, major inspection has the biggest impact on the heat rate reduction of a unit. Those major inspection also causes the highest value of performance efficiency in unit B. However, if the inspection combining with some retrofit, the performance efficiency might increase to the highest value. Keywords: Inspection, efficiency, performance

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INTRODUCTION

A power plant industry has an important role to generate electricity in a country. Realizing the high operating work of the components in those company, several inspections should be conducted. For example, PT XYZ as a gas turbine power plant has three different inspection. In gas turbine part, the inspection consists of Combustion Inspection (CI), Turbine Inspection (TI), and Major Inspection (MI). The period from one inspection to another is about 8000 operating hours, which is started from Combustion Inspection (CI). The order of the inspection for gas turbine part and steam turbine part can be shown in Figure 1. Inspection Order (a) Gas Turbine (b) Steam Turbine, respectively.

In this research, the evaluation of maintenance is performed by using thermodynamic analysis-thermal efficiency. According to thermodynamic concept, thermal efficiency can be used to estimate the performance of the components and also detect the failure of the components. E. A. Ogbonnaya [1] found a preferable maintenance method to optimize the performance of gas turbine. He applied efficiency calculation to compare two different methods. The optimization could be achieved by combining compressor hand cleaning, offline and online washing method simultaneously. A. Franco and A. Russo [2] investigated the optimization of the heat recovery steam generator (HRSG). They found that an increases of the heat surface and a decrease of the pinch-points could increase of the thermal efficiency of the plant that approaches the 60%.

Moreover, M. Ameri [3] applied three simultaneous system analysis including Energy, Efficiency and Economic (3E analysis) for an integrated organic Rankine cycle and multi-effect desalination system. The results confirmed that by increasing compressor pressure ratio, the exergy efficiency increases and the cost rate decreases. S. Sengupta et. al [4] studied the effect of different condenser pressures i.e. 76 and 89 mmHg (abs.) by calculating the exergy efficiency using operating data. It is shown that the exergy efficiency decreased at the rise of the condenser back pressure. C. J. Koroneos et al. [5] performed exergy analysis of a 300 MW lignite thermoelectric power plant. The investigation revealed that the proposed Combined Heat and Power (CHP) systems had a significant increase of the energy efficiency, compared to the performance of the existing power plant.

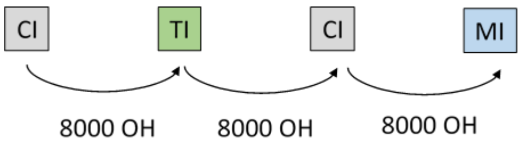

Figure 1. Inspection Order in Gas Turbine Power Plant

Accordingly, in the present study, the efficiency of gas turbine power plant in Gresik city is estimated to identify the relationship between the inspection time which is defined by the manufactures of the power plant and the efficiency itself. Further, a software is created to present the result in order to facilitate the operator to monitor the components frequently.

LITERATURE STUDY

Components Description

Compressor

The compressor work per unit of mass flow is:

$$\frac{\dot{W}_c}{\dot{m}} = h_2 - h_1 \qquad (1)$$

To calculate the compressor efficiency, isentropic efficiency equation is used. Isentropic efficiency compares between the work input to an isentropic process and the actual work output of the compressor. It is given by

$$\eta_{compressor} = \frac{(\dot{W}_c/\dot{m})_s}{\dot{W}_c/\dot{m}} = \frac{h_{2s} - h_1}{h_2 - h_1}$$

where

h_1: enthalpy of the fluid at the inlet of actual compressor

h_2 : enthalpy of the fluid at the exit of actual compressor

h_{2s}: enthalpy of the fluid at the exit of isentropic compressor

Combustor

The combustor efficiency is a dimensionless Performance measure that indicates how effectively fuel converted into useful energy. The efficiency of this component can be obtained as [1]

$$\eta_{combustor} = \frac{\Delta h_{actual}}{\Delta h_{theoretical}} = \frac{(\dot{m}_a + \dot{m}_f)h_3 - \dot{m}_a h_2}{\dot{m}_f (LHV)} \qquad (3)$$

where

$\dot{m}_a$: mass flow rate of gas

$\dot{m}_f$: mass flow rate of fuel

h_3 : enthalpy of gas leaving the combustor

h_2 : enthalpy of gas entering the combustor

LHV : heating value of fuel

Axial Flow Turbine

The efficiency of isentropic turbine can be written as follow

$$\eta_t = \frac{\dot{W}_t/\dot{m}}{(\dot{W}_t/\dot{m})_s} = \frac{h_3 - h_4}{h_3 - h_{4s}} \qquad (4)$$

Heat Recovery Steam Generators (HRSG)

HRSG receives flue gas from gas turbine to generate steam in the steam cycle. HRSG is made of four primary components: preheater, economizer, evaporator and super heater. The pressure level used in this HRSG are HP and LP (high pressure and low pressure). Thus, based on the stage of pressure, the heating surface in HRSG are LP-economiser, HP-economiser, LP-evaporator, HP-evaporator, HP-super heater 1 and HP-super heater 2. The basic equation of HRSG efficiency are

(5)

$$\eta_{HRSG} = \frac{\dot{Q}_{output}}{\dot{Q}_{input}}$$

The heat content of the steam output is determined from:

$$\dot{Q}_{output} = \dot{Q}_{Preheater} + \dot{Q}_{HP,out} + \dot{Q}_{LP,out} \quad (6)$$

$$\dot{Q}_{Preheater} = \dot{m}_{condensate\ flow} \cdot (h_{out} - h_{in})_{Preheater} \quad (7)$$

$$\dot{Q}_{HP,out} = \dot{m}.h|_{HP\ Steam} - \dot{m}.h|_{HP\ Feedwater} \quad (8)$$

$$\dot{Q}_{LP,out} = \dot{m}.h|_{LP\ Steam} - \dot{m}.h|_{LP\ Feedwater} \quad (9)$$

where

$$\dot{m}_{condensate\ flow} = \dot{m}_{HP\ FW} + \dot{m}_{LP\ FW} \quad (10)$$

Meanwhile, the heat content of the steam input is given by:

$$\dot{Q}_{input} = \dot{m}_{Flue\ gas,in} \cdot (T.Cp|_{Flue\ gas,in} - T.Cp|_{Ambient}) \quad (11)$$

Since the information about the mass flowrate of flue gas is not available, a reasonable approach to finding those data is applied by using the following equation:

$$\dot{m}_{Flue\ gas,in} = \frac{\dot{Q}_{output}}{\left(\frac{100-\dot{Q}_{radiation}}{100}\right).(T.Cp|_{Flue\ gas,in} - T.Cp|_{Flue\ gas,out})} \quad (12)$$

where Q˙_radiation is heat loss due to radiation. The value is assumed to be 0.3%.

Steam Turbine

Equation (13) performs the steam turbine calculation

$$\eta_t = \frac{Steam\ turbine\ production}{\dot{Q}_{Steam\ input}} \quad (13)$$

Where

$$Steam\ turbine\ production = ST_{Generator\ output} - ST_{Auxiliary\ output} \quad (14)$$

$$\dot{Q}_{Steam\ input} = \dot{m}_{HP\ steam}.1000.(h_{HP\ steam} - h_{Gland\ steam}) + \dot{m}_{LP\ steam}.1000.(h_{LP\ steam} - h_{Gland\ steam})$$

(15)

$$\dot{m}_{HP\ steam} = \dot{m}_{HP\ superheater\ 1} + \dot{m}_{HP\ superheater\ 2} + \dot{m}_{HP\ supe}$$

(16)

$$\dot{m}_{LP\ steam} = \dot{m}_{LP\ superheater\ 1} + \dot{m}_{LP\ superheater\ 2} + \dot{m}_{LP\ super}$$

Condenser

To evaluate the condenser performance, the effectiveness formula is used [7]

$$\varepsilon = \frac{q}{q_{max}} \quad (18)$$

$$\varepsilon = \frac{C_h(T_{h,i} - T_{h,o})}{C_{min}(T_{h,i} - T_{c,i})} \quad (19)$$

or

$$\varepsilon = \frac{C_c(T_{c,o} - T_{c,i})}{C_{min}(T_{h,i} - T_{c,i})} \quad (20)$$

Methodology

The data was collected by using performance test report released by power plant. The data consists of temperature, pressure, power generated by power plant. To evaluate how significant the performance efficiency with inspection time, plant efficiency and heat rate (HR) are calculated with equations as follows:

$$HR = \frac{\dot{m}_{fuel}.37{,}3248.HHV.252}{(W_{generator}.1000) - W_{auxiliary}} \quad (21)$$

$$Eff = \frac{860.100}{HR}$$

To reach another goal which is providing a simulation to monitor the efficiency of the component easily, visual basic application (VBA) was used to create the user form. In the simulation, the equation (1)-(22) were inserted.

RESULT AND DISCUSSION

In this experiment, two units were focused to define the relationship between performance efficiency of power plant and inspection time, (22) i.e. unit A and B.Table 1 & 2 show the record of inspection in unit A and B, respectively. Based on those table, major inspection has the longest inspection time. It is about 40 days. The second longest time is the period of turbine inspection. It is around 18 days. The rest, combustion inspection takes five days

Table 1. Inspections in Gas Turbine A and Their Impact on Several Parameters

No	Duration (days)	Year	Power Generated (MW)	Heat Rate (kcal/ kWh)	Efficiency (%)	Inspection
1	Normal Operation		106.13	3088.70	27.84	None
2	18	2010	113.70	3029.98	28.38	**Turbine Inspection**
3	Normal Operation		105.25	3163.47	27.19	None
4	5	2011	110.37	3067.26	28.04	**Combustion Inspection**
5	Normal Operation		105.57	3048.93	28.21	None
6	40	2012	114.50	2884.45	29.82	**Major Inspection**
7	Normal Operation		108.23	3042.70	28.26	None
8	5	2013	110.37	2940.17	29.25	**Combustion Inspection**
9	Normal Operation		104.30	3084.68	27.88	None
10	18	2014	114.30	2924.89	29.40	**Turbine Inspection**
11			106.97	3019.16	28.48	None
12	40	2015	109.67	2950.65	29.15	**Combustion Inspection**

Table 2**.** Inspections in Gas Turbine B and Their Impact on Several Parameters

No	Duration (days)	Year	Power Generated (MW)	Heat Rate (kcal/ kWh)	Efficiency (%)	Inspection
1	Normal Operation		104.75	3146.70	27.33	None
2	18	2010	107.30	3123.75	27.53	**Turbine Inspection**
3	Normal Operation		105.97	3121.78	27.55	None
4	5	2011	107.90	3120.91	27.56	**Combustion Inspection**
5	Normal Operation		102.10	3179.20	27.05	None
6	40	2013	107.67	3016.54	28.51	**Major Inspection**
7	Normal Operation		103.40	3133.99	27.44	None
8	5	2014	107.20	3079.07	27.93	**Combustion Inspection**
9	Normal Operation		106.23	3022.36	28.45	None
10	18	2015	110.20	2973.52	28.92	**Turbine Inspection**

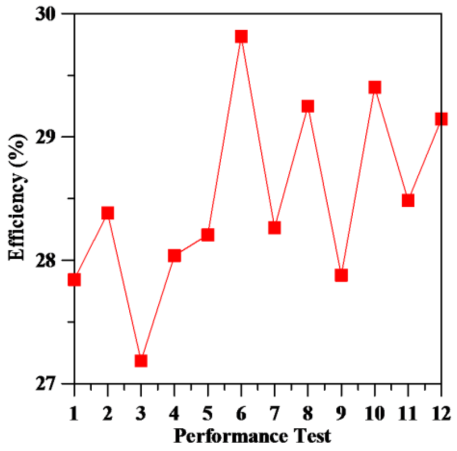

Figure 2. Impact of Inspections on Efficiency in Unit A

The duration of inspection time has an impact to performance efficiency of the gas turbine power plant. For example, in Figure 2, unit A has the highest efficiency in performance test 6. Performance test 6 was conducted after the major inspection was finished. Further, in Figure 3, the heat rate reduction at point 3 has the highest value. The data at point 3 is the performance test gap between performance test 5 (before Major Inspection) and 6 (after Major Inspection). It approaches to 164, 5 kcal/ kWh.

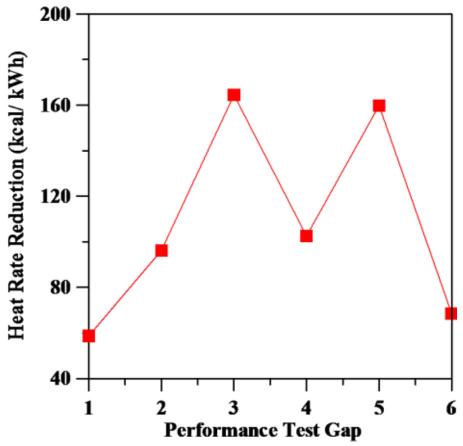

Figure 3. Impact of Inspections on Heat Rate Reduction in Unit A

Meanwhile, unit B shows a different phenomenon to unit A. The efficiency of unit B which is shown in Figure 3 has the highest value at point 10. The data at point 10 was obtained after the turbine inspection was conducted. Thosephenomenon can be explained by the fact that not only turbine inspection was conducted at that period, but also some retrofit was applied. However, the highest heat reduction is still the same as that of unit A

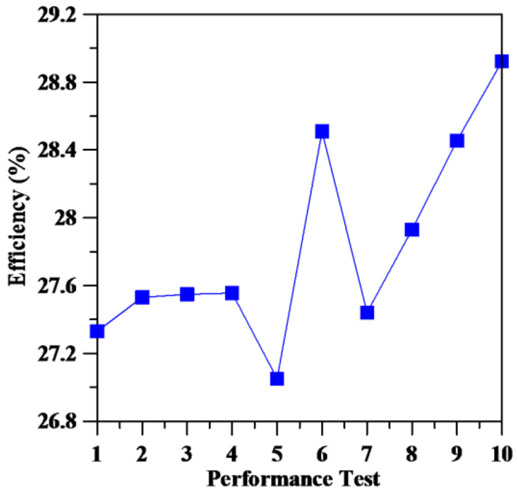

Figure 4. Impact of Inspections on Heat Rate Reduction in Unit B

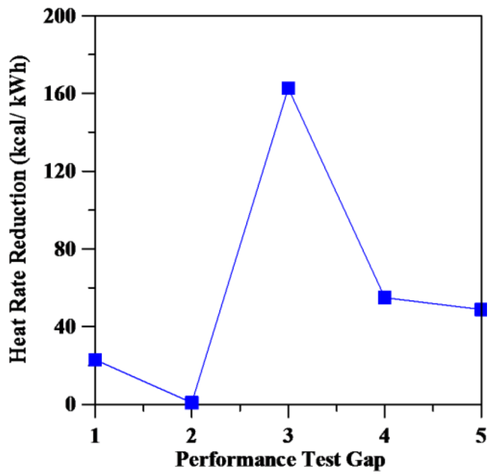

Figure 5. Impact of Inspections on Heat Rate Reduction in Unit B

To monitor the performance of the units and the component more efficiently, the user form which can be seen in Figure 6 was created. The gas turbine power plant company where this experiment took place always uses manually calculation using excel to observe the performance efficiency before and after the inspection. The efficiency is calculated The users should identify which units they want to monitor by filling the box. In addition, to get the data more comprehensively (the record for several years) menu duration can be filled. in Next, the graph containing the time and the efficiency can be released.

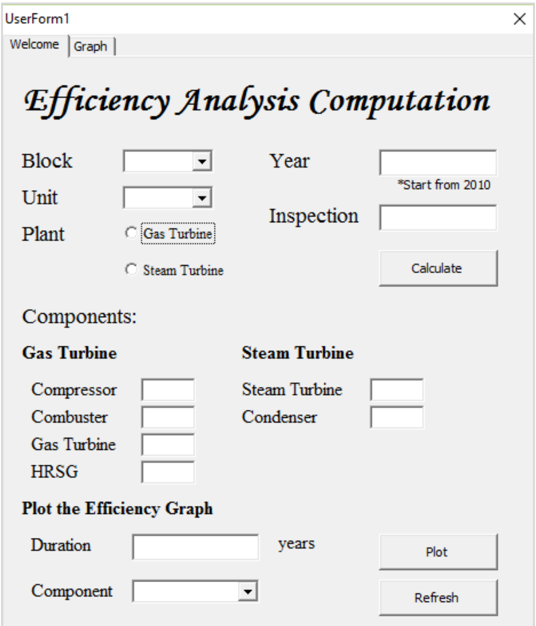

Figure 6. User Form to Monitor Performance Efficiency

CONCLUSION

In gas turbine power plant, there are three kinds of inspections. They are combustion inspection, turbine inspection, and major inspection. Based on the result, major inspection has the biggest impact on the heat rate reduction of a unit. Those major inspection also causes the highest value of performance efficiency in unit A. However, if the inspection combining with some retrofit, the performance efficiency might increase to the highest value. This phenomenon can be seen in unit B, where the highest efficiency can be obtained after turbine inspection was done. :

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