Project delay analysis of HRSG

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Abstract. Completion of HRSG (Heat Recovery Steam Generator) fabrication project sometimes is not sufficient with the targeted time written on the contract. The delay on fabrication process can cause some disadvantages for fabricator, including forfeit payment, delay on HRSG construction process up until HRSG trials delay. In this paper, the author is using semi quantitative on HRSG pressure part fabrication delay with configuration plant 1 GT (Gas Turbine) + 1 HRSG + 1 STG (Steam Turbine Generator) using bow-tie analysis method. Bow-tie analysis method is a combination from FTA *(*Fault tree analysis) and ETA (Event tree analysis) to develop the risk matrix of HRSG. The result from FTA analysis is use as a threat for preventive measure. The result from ETA analysis is use as impact from fabrication delay.

1. Introduction

In Indonesia, most electrical procurements are still using diesel power plants – which are old and inefficient. But in recent development, both government and IPP (Independent Power Producer) are starting to use gas and steam power plants / HRSG (Heat Recovery Steam Generator). Gas and steam power plant is a combination of steam power plant and gas power plant, where the heats from gas power plant excess gases are used to produce steam that will generate the steam power plant.

In HRSG manufacturing process, there is always a contract between the owner and the fabricator. The contract contains of total manufacturing cost, time needed to complete the project, terms of payment and so on. According to Rosdianto[1] it is important to state the amount of fine that the fabricator has to pay to the owner if they cannot fulfil the contract.

But in reality, the existence of obstacles that happens usually caused a project to be late. In this paper, the author is using FTA (Fault Tree Analysis) and ETA (Event Tree Analysis) method to do an analysis on project delay.

The *FTA* (Fault Tree Analysis) method was used in analysing the failure or delay on a project, while the ETA (Event Tree Analysis) method was analysing the result from a project delay. From both analyses the bow-tie diagram will be produce and used as tool to analyse what are the impact that can be reduced by making a project mitigation so manufacture project scheduling can go as smooth as initial planning.

The Problems that will be accounted in this paper are:

1. What are the causes of HRSG pressure part fabrication project delay – using Fault Tree Analysis method?
2. What are the impacts that will be posed from HRSG pressure part fabrication project delay - using Event Tree Analysis method.

2. Fault Tree Analysis

According to Rosyid [2], Fault Tree Analysis is a method to identify all probable causes (component failure or other failure events that happened on its own or simultaneously) that caused a system failure and gave a footing for failure possibility calculation. Based on Ericson [3] there are eight steps on FTA, these are the steps that need to be followed:

1. Understanding the system design and operation. Gaining the current design data (drawing, scheme, procedures, diagram, etc.)
2. Descriptively defining the problems and determining components that are absolutely doesn't want to be analyse
3. Specified analysis' base rules and scope boundaries, also write down all of the base rules.
4. Follow the construction process, rules, and logics to build the system fault tree model.
5. Producing cut set and probability, then identify the weak-link and problems in design security.
6. Let the respondent check the fault tree model to determine its actuality, generality, and accuracy.
7. Modify the fault tree model following the facts acquired during validation or due to design system changes

3. Event Tree Analysis

According to Mahandeka [4], Event tree analysis is a method to analyse various impacts caused by an event. This method is used to estimate and judge the probability from each consequence that can emerge from a single event. Therefore, this method is used as a reference in anticipating various consequences.

First step in analysis process using event tree analysis method is by drawing parts of system that are correlating with main event as detail as possible. This is done to obtain estimation of events that probably happen after the main event. This process is very dependent to the part of system drawn; the more detailed the picture the more events that can be estimated. As a result, the consequences or scenario that's being predicted is more valid.

The second step is to draw a tree diagram event in accordance with all the events that have been estimated. Every event in each diagram, form a question that can be answered with "yes" or "no". Every answer initiates other related events and continues until the end of the known consequences of any branch of the estimated incidence. The third step is the time to find the value of the probability for every answer from each event that's written on the diagram. The total value of probability for each event then multiplied with the value of each answer's probability that correspondence with certain consequence sequence wanted, and by that the value of each consequence's probability are obtained.

Kurniawan [5] explains Bow-tie analysis is a method to form a diagram that showed and analyse the sequence of a risk from its cause to its impact. This method is often considered as a combination from FTA (fault tree analysis) method that analyse the cause of certain event using the ETA (event tree analysis) that analyse the impact. According to Gifford et.al [6], this method is called bow-tie because of the diagram produced resembling the shape of a bow-tie with cause and impact both forming the left and right wing – flanking the event's risk in the middle. Bow-tie is combining the components from Fault Tree Analysis, and Event Tree Analysis. Bow tie analysis has been used in many areas such as for identifying risk assessment of mobile mooring [7]. This paper will elaborate the useful of FTA and ETA to determining the delay of HRSG fabrication.

4. Elaboration of FTA and ETA

The elaboration of FTA and ETA can be explained as follows:

1. Problems identification and formulation
   Identification is a process to investigate a problem in HRSG and formulate the problems in order to find the solutions of project delay.
2. Data Collecting
   The required data used in this paper are:
   a. Initial schedule of HRSG pressure part fabrication data.
   b. Daily working hour data.

c. Data containing the number of workers involved.
d. Data containing production facilities (machinery and tools) owned.

3. Data Analysis and Discussion
From the data obtained, some analysis and discussion are done, amongst are:
a. Analyzing interview result to find items that experience some delay and what are the factors that affect those items.
b. Making FTA construction drawings from HRSG pressure part fabrication project.
c. Making ETA construction drawings from HRSG pressure part fabrication project.
d. Making bow-tie analysis from FTA and ETA output

5. The Result of FTA and ETA

FTA starts by formulating the root causes of Delay Fabrication of HRSG. In order to formulate the root causes of delay fabrication of HRSG, the experts in one of the fabrication company are involved. As can be seen in Figure 1, the fault diagram derived from the initial cause of HRSG pressure parts fabrication delay and broken down until the basic events are found.

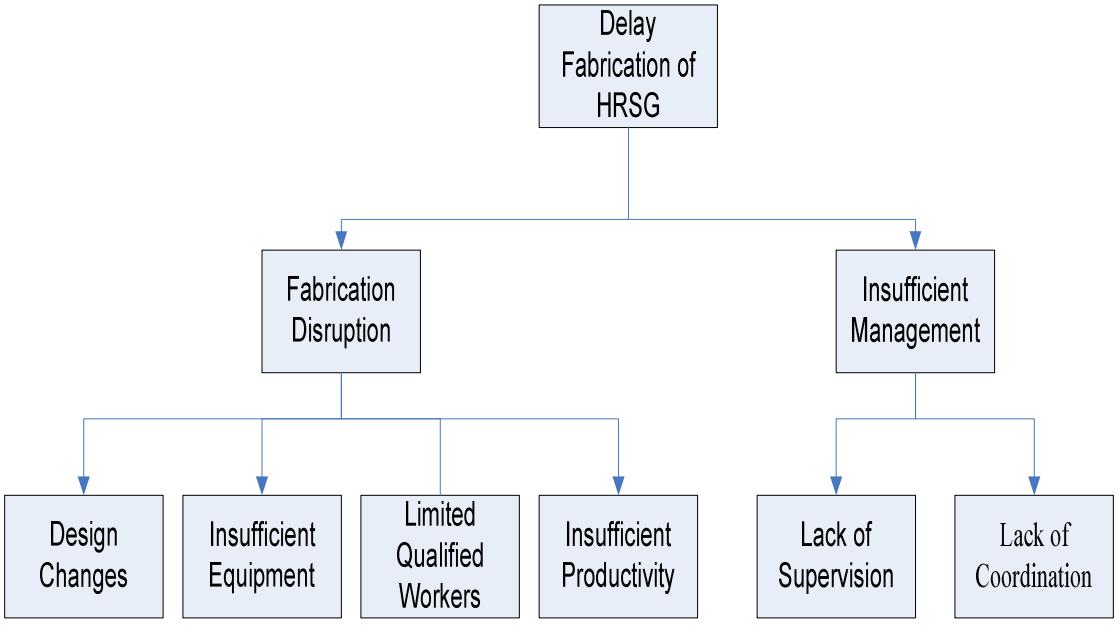

Figure 1. Fault Tree Main Branch

Once the fault tree diagram has been accomplished the next step is to determine the probability of each basic event. The probabilities of each of basic event on HRSG fabrication process are obtaining from questionnaires and interview with respondents. The frequency of the FTA basic events is referring to probability as follows:

Table 1. Probability

FI	Rating	Qualitative	Quantitave
5	Frequent	Likely to occur every new production HRSG	10^{-1}
4	Reasonably Probable	Likely to occur per 5 times new production HRSG	10^{-2}
3	Remote	Likely to occur per 25 times new production HRSG	10^{-3}
2	Extremely Remote	Likely to occur per 75 times new production HRSG	10^{-4}
1	Extremely Improbable	Likely to occur per 100 times new production HRSG	10^{-5}

After obtaining the probability for each basic event the next step is to find the minimum cut set from the two main branches which are "Fabrication Disruption" and "Insufficient Management". Based on the FTA calculation the probability of top event of "Delay Fabrication of HRSG" is 0.0635. The next step is to formulate the event tree of Delay Fabrication of HRSG as seen in Figure 2:

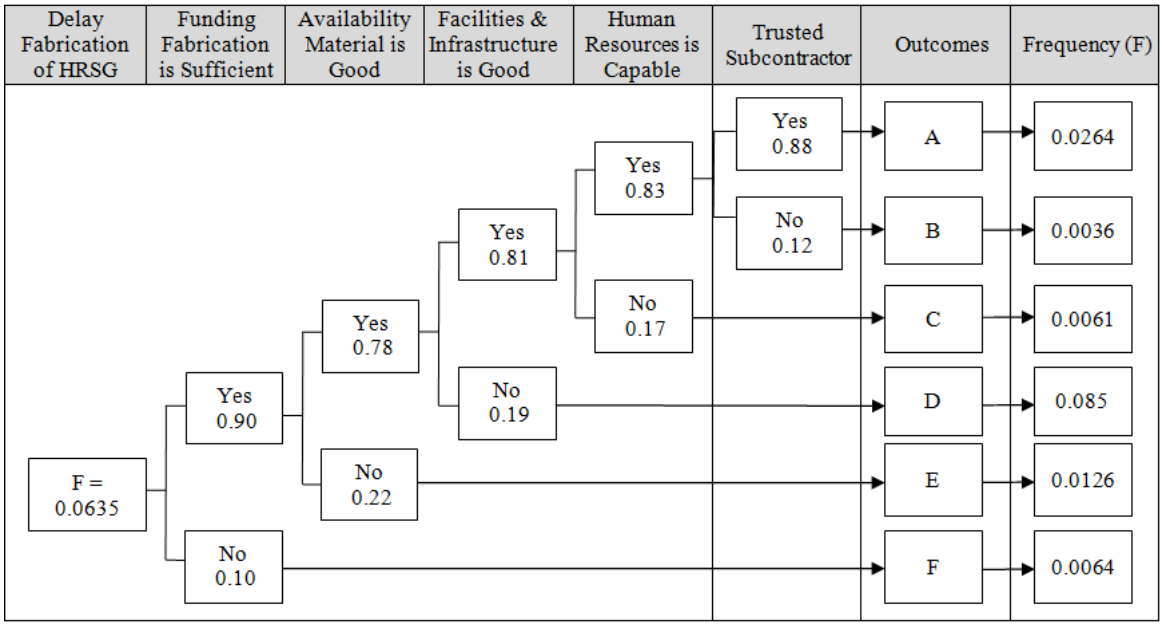

Figure 2. Event Tree Analysis Result

Each ETA result has consequences. The result for each part will be shown below:

1. Output A : the HRSG is completed but experienced some delay between 1 day to 2 week. Output A happens with probability of:
   0,0635 x 0,9 x 0,78 x 0,81 x 0,83 x 0,88 = 0,0264
2. Output B : the HRSG is completed but experience some delay between 2 week to 1 month because of an inexperience subcontractor. Output B happens with probability of:
   0,0635 x 0,9 x 0,78 x 0,81 x 0,83 x 0,12 = 0,0036
3. Output C : the HRSG is completed but experience some delay between 1 months to 3 month

because of lack of manpower. Output C happens with probability of:
0,0635 x 0,9 x 0,78 x 0,81 x 0,17 = 0,0061

4. Output D : the HRSG is completed but experience some delay between 3 month to 6 month year because of facilities and infrastructure that's not supportive. Output D happens with probability of:
0,0635 x 0,9 x 0,78 x 0,19 = 0,085
5. Output E : the HRSG is completed but experienced some delay between 6 month to 9 month because of material unpreparedness on the field.
Output E happens with probability of:
0,0635 x 0,9 x 0,22 = 0,0126
6. Output F : the HRSG is not completed in fabrication process because insufficient fund from the owner. Output F happens with probability of:
0,0635 x 0,1 = 0,0064

The probability from ETA's result will be used in determining the consequences category in risk matrix. The first step is to determine Probability (FI) and *Severity Index* (SI) from the output of *Event Tree Analysis* (ETA), followed by calculating the *Risk Index* (RI) to be categorized into the *risk matrix*. The table above shows the categorization of the quantitative and qualitative data from the ETA to FI where the rating of complications explains the time ranges of those complications during the production of new ships. The making of these data also requires the agreement of the ETA respondent by interview.

Table 2. Severity Index

SI	Rating	Qualitative	Quantitave
1	Minor	New project HRSG get max penalty 1M & delay between 1 day - 1 month	< 0,01
2	Moderate	New project HRSG get max penalty 15M & delay between 1 month - 6 month	0,01 - 0,1
3	Serious	New project HRSG get max penalty 30M & delay between 6 month - 1 year	0,1 - 1
4	Catastrophic	New project HRSG failed	1 - 10

Table 2 explains the categorization of the quantitative and qualitative data from the ETA to SI where the rating of complications explains the categorization for the impacts of those complications on the production of new ships. The results of frequency and severity index are derived from the respondents as seen in the table 3.

Table 3. Frequency of Index and Severity Index for Risk Matrix

No	Output	Frequency Index (FI)		Severity Index (SI)		Risk Index (RI)	
1	Output A	4	Reasonably Probable	1	Minor	5	Moderate
2	Output B	3	Remote	2	Moderate	5	Moderate
3	Output C	3	Remote	2	Moderate	5	Moderate
4	Output D	4	Reasonably Probable	2	Moderate	6	Moderate
5	Output E	4	Reasonably Probable	3	Serious	7	Moderate
6	Output F	3	Remote	4	Catastropic	7	Moderate

Once the frequency and severity index have been obtained, the next step is tabulated into the risk matrix as can be seen in Table 4. All the output of the consequences are in the Medium Level.

Table 4. Risk Matrix Results from ETA

FI	Rating	Severity Index (SI)			
		1	2	3	4
		Minor	Moderate	Serious	Catastrophic
5	Frequent	6	7	8	9
4	Rasonably Probable	(5)	(6)	(7)	8
3	Remote	4	(5)	6	(7)
2	Extremely Remote	3	4	5	6
1	Extremely Improbable	2	3	4	5
		A	BC	D	E	F

6. Conclusion

Based on the results of this paper, the following conclusions are made:

1. The main factors for the delay of the fabrication process of HRSG using the Fault Tree Analysis consist of fabrication disruption and insufficient management.
2. The delay of HRSG fabrication processes are obtained from each path of critical event associated with all their frequencies of pivotal events4).

References

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