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The Risk Assessment of Genset Installation Project Using Fault Tree Analysis In Indonesia

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***Abstract*—The XYZ company had a project to install the generator set (genset) in several island in Indonesia. The project was estimated to finish in 10 months, but it delayed up to 20 months. This delayment made the company experience cost overruns. In the other hand, according to Indonesian Ministry of Energy and Mineral Resource (MSDM) in 2016, the electrification in this project area has not reached 100%. The area are including Kalimantan, West Nusa Tenggara (WTB), Papua, Sulawesi and Maluku. The tardiness was caused by the company can't mitigate the project risk optimally. Therefore this research aims to evaluate this genset installation project to assess the risk, thus in the next project the company can avoid project delay and the overruns cost. The research uses Fault Tree Analysis (FTA) in risk assessment to identify the basic event of the project's problem. First, this research collect the report of the project. Second, this project collect the problems that caused project delay. There are 154 problems found in this research. The FTA method divides the problems found into 13 basic event. The highest risk that triggers problem for this project are from two basic events, which are user error with the probability rate 0,2013 and installation error with the probability rate 0,1494.**

***Keywords*—genset installation, fault tree analysis, risk assessment.**

I. INTRODUCTION

XYZ COMPANY is one of generator set (genset) provider in Indonesia. In this research, we use data from this company to determine the problems and the risk of genset installation project. Because of the delayment that caused by several factors, the company refused to expose the company name. However, the data is still can be used as data research for study purposes.

The segment is all of area in Indonesia and several country in southeast Asia. Different problem and from different risk found in every area. In 2017 – 2018, the XYZ company received a project to install genset in several islands in Indonesia, there are Kalimantan, West Nusa Tenggara (WNT), Papua, Sulawesi and Maluku. In theese areas, the electricity is not fully charged. Based on Indonesian Ministry of Energy and Mineral Resource the electricity in selected area still in 96,96% [1].

Electricity in Indonesia is obtained from steam power plants. In the other hand, to optimize the electricity in Kalimantan, WTB, Papua, Sulawesi and Maluku, it need more steam power plant units, but it also need a huge investment both in cost and time. Therefore, in some area in Indonesia that mentioned before, it needs complementary electricity.The compliment should can be back the electricity power up when the main electric power is down.

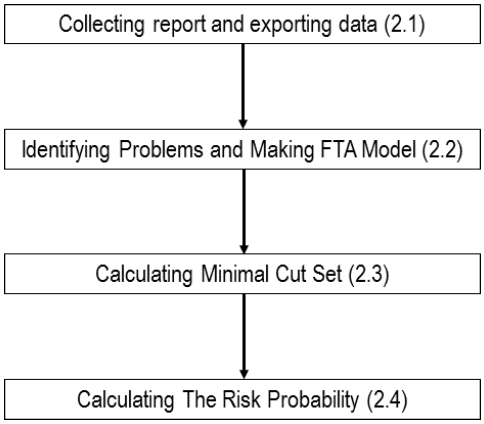

Figure 1. The steps of the research.

Table 1.
Formatting Rules

Number	Genset Problem	Frequency
1.	Broken battery	7
2.	Broken AVR	10
3.	Broken CT	4
4.	Broken varistor diode	5
5.	Broken dop byonet	4
6.	Broken earth fault protection neutral	2
7.	Broken ECU	4
8.	Broken Flexible pipe	1
9.	Broken hand pump	2
10.	Broken thermocouple sensor cable	2
11.	Genset canopy leaked	4
12.	BBroken MCCB	17
13.	Oil cooler leaked	1
14.	Broken pilot lamp RST	7
15.	Flith solar pre filters	9
16.	Flith CAC dan radiator	10
17.	Broken rotor exsiter	1
18.	Broken water separator	1
19.	Crank shaft seal leaked	2
20.	Broken Thermocouple	12
21.	Broken UVT	27
22.	Disconnected V-Belt	1
23.	Water pump leaked	2
24.	Broken DSE Module	19
	TOTAL	**154**

The power plant that can be asily built is diesel power plant or as known as generator set (genset). Genset can be installed in desolated area such as several area in Kalimantan, WTB, Papua, Sulawesi and Maluku. It can be easly moved and carried without need large space.

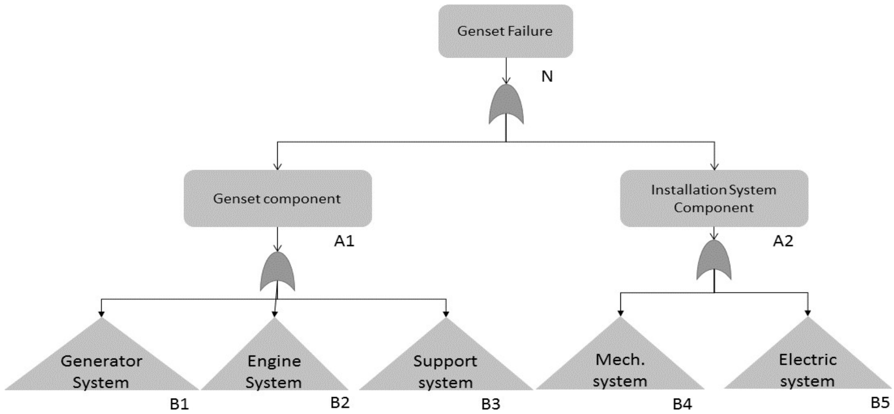

Figure 2. General FTA model.

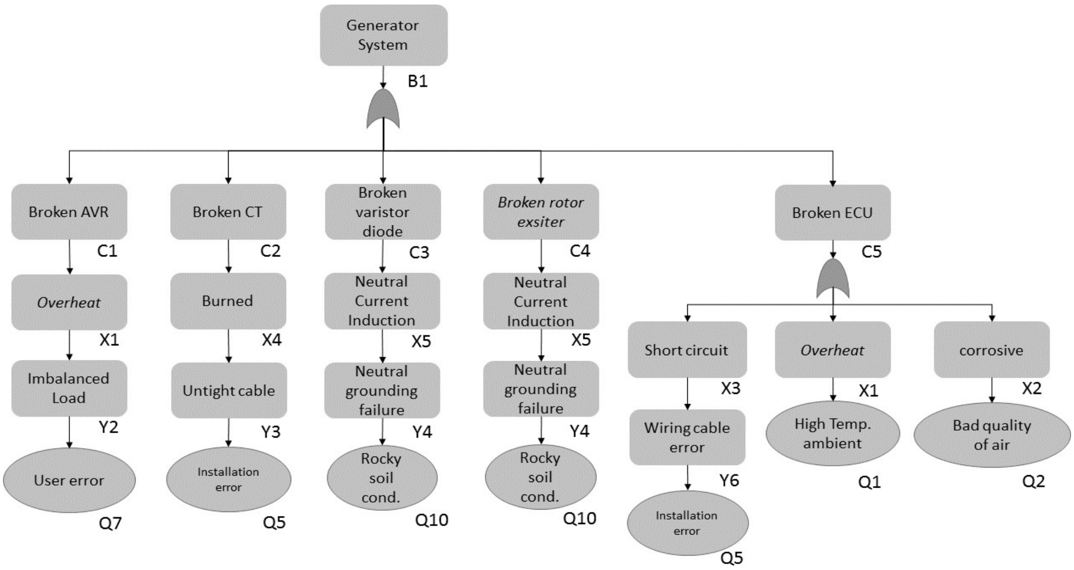

Figure 3. FTA model for the error of generator system.

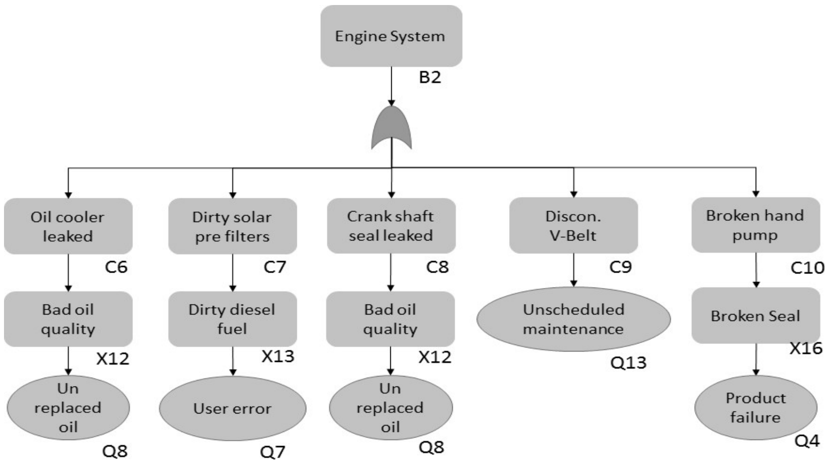

Figure 4. FTA model for the error of engine system.

The XYZ company can fulfill the rquirement to install genset in those areas. The company need to install the genset with capacity 100 Kw and 200 Kw. It needed genset with open type and silent type. While the open type genset need to be placed in the private room, the silent genset is more flexible and can be placed anywhere outside the room or the building. There are 156 genset unit need to be installed. The genset installation project started in April 2017 and estimated to end in February 2018 or in 10 months. But in implementation, the project delayed until 20 months and ended in December 2018. It caused cost overhead and made some disadvantages for company.

The company realise that the project team were unprepared and didn’t identify the risk of the project, so they have not set the mitigation step. Therefore, this research aims to assess the risk of genset installation project, because the company need to accept this kind of project in the future. The company doesn’t want to make the some mistake, so they use the data from the last project to make a mitigation plan if there were such risk as in the last project.

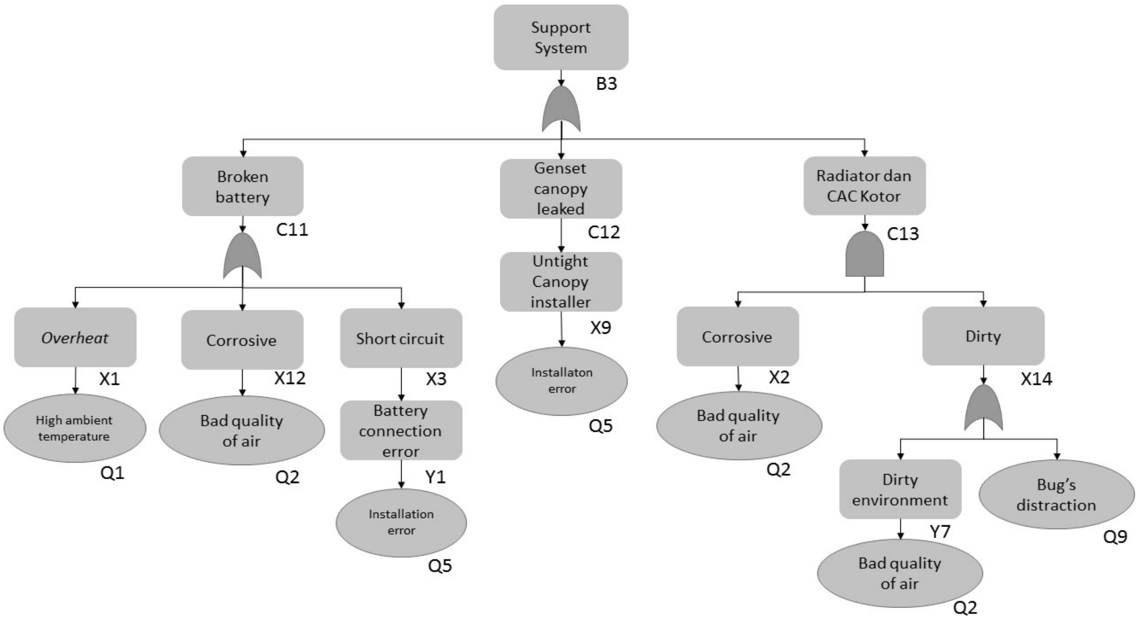

Figure 5. FTA model for the error of support system.

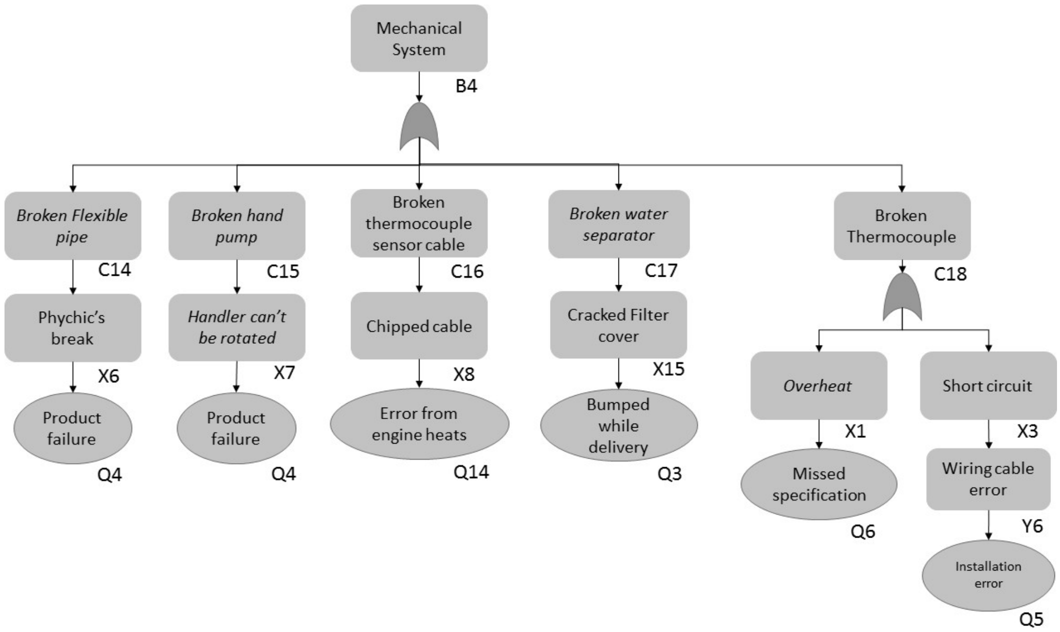

Figure 6. FTA model for the error of mechanical system.

The risk assessment method that have been used is Fault Tree Analysis (FTA). Before assessing the risk of the installation project, this research have been search for other literature about the causes of the delayment of another genset installation project. Marzouk and Razaz [2] generally stated that the delayment of the project can be caused by several factors, there are human resources, material, tools, external aspects, communication, project's area, financial and design. Another prior research that focused on genset installation project stated that the biggest risk that caused the delayment of project are engine tool failure and the generator problems[3]. Based on this prior research, lead this research to focused to the risk that caused engine tool failure and generator problems.

In the field of risk management, there are also several method to assess the risk. Such as Fault Tree Analysis (FTA), Failure Mode Effect and Analysis (FMEA), Value at Risk (VAR), Management Oversight Risk Tree (MORT) and others. Each method has its own advantages and disadvantages. This research uses FTA because it's more efficient to identify and analyse risk by making a tree of basic event to other events. FTA provides the information about the iteraction among events. This method is also easily to calculate the probability of the risk[4]. Since this research have purpose to do the risk assessment to identify the probability of risk that caused problem in genset instalation project. Then in the next research, the XYZ company can explore the mitigation of every risk that found from this research. Therefore, in the next project, the XYZ company

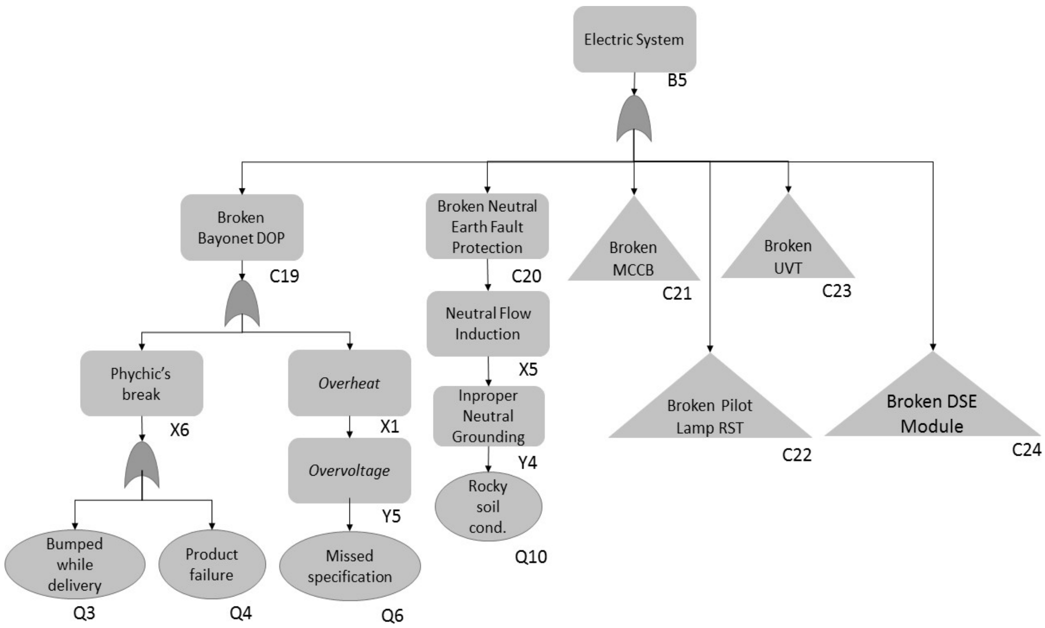

Figure 7. FTA model for the error of electric system.

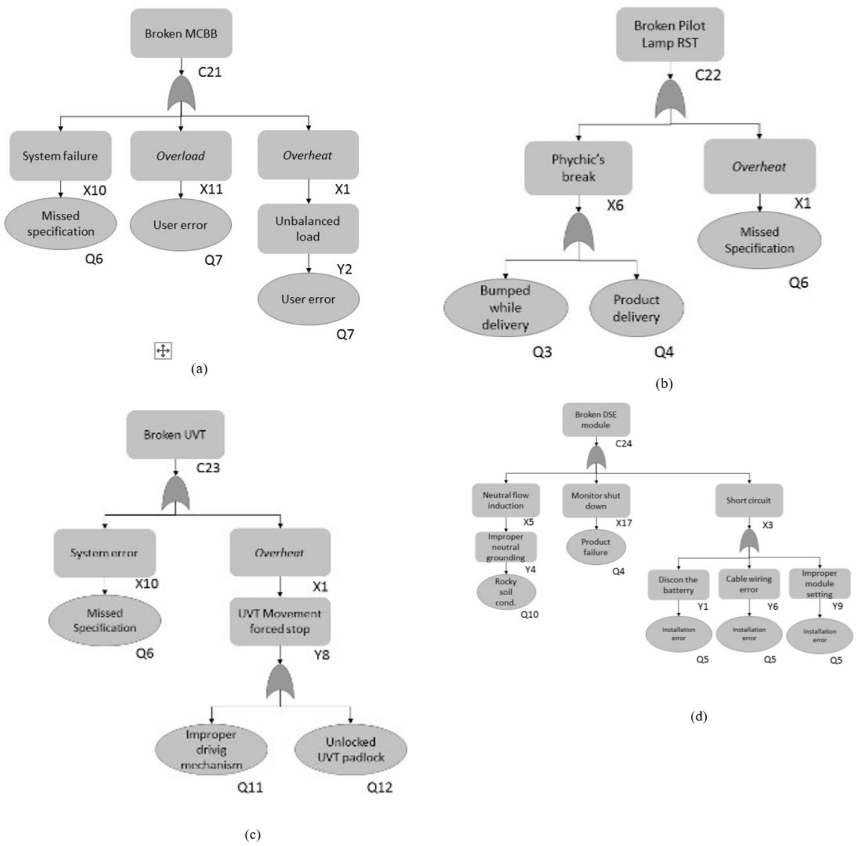

Figure 8. The continued FTA model for the error of electrical system.

can avoid this such problems and minimize the cost because of the risk.

II. METHOD

Fault Tree Analysis or FTA is a tool to identify the failure from a system. FTA uses top-down approach, therefore this method started from top level to the down level [5].

The system in FTA is represented by the combination of logic gate of an event that caused the failure of top event. From this explanation, there are four step that's been used to complete this research. The step and its method can be described as Figure 1.

Every step that shown in Figure 1 will be explained more in each sub point. Starting from collcting report and exporting data, identifying problems and making FTA Model, calculating minimal cut set and calculating the risk probability. The purpose

A. Collecting report and extracting data

After a genset successfully installed in an area, then a member of the team project need to make a report. A report contains the location of genset installation, genset serial number, the genset capacity, the problem of installation, the solution of the problem, problem check to identify wether the problem are solved or not, and the date when the installation completed.

This research needs to collect all of the report from all of 156 unit gensets that installed. After that, it needs to extract the problem that happened while the installation. However, not all of data can be used in this research. The boundary of this research only collect the problem that caused of several categories, which are mechine failure, generator failure, equipment error, human error and error that caused by the environment. The genset failure would be the top event of the tree in FTA. The next step is identify other problems from the project report that caused the top event.

From this step 154 data have been collected that grouped into 24 problem. The further deyail can be seen as in Table 1.

B. Identifying Problems and Making FTA Model

The FTA modelling was created to identify the basic event that caused problem of genset failure. The genset failure is a top event of the FTA. After that, the research breaks down the data of the problems in genset installation project that have been collected before. Then the research looks for the interaction between all of the problem, thus every risk that caused the problem can be linked as it found the basic events and the intermediete level events.

The FTA model devided into several models. First model is for the general model of the FTA. The next step is break every basic event down and make a new FTA model that more specific.The basic event in every FTA model created the new basic events. These basic events in the every specific FTA model will be calculated the probability and calculate the minimal cut set to identify the risk that don't have huge impact to the project.

C. Calculating Minimal Cut Set

The minimal cut set calculation is used to simplify the model. So it can dismiss the basic event that don't have the huge impact to the top events. It can be dismiss because the interaction between top event to every basic event in the FTA model have different logic gates. The minimal cut set uses boolean calculation, so there is a probability that the basic event would be eliminated. The rest basic events that would not be eliminated becomes the basic events from FTA model that needs to be calculated the probability in the next step.

D. Calculating The Risk Probability

The selected basic events from previous step will be calculated its probability. The probability is obtained from divided the frequency of the basic events with all of total cases, which is 154. It can be described as in formula 1 below.

After a genset successfully installed in an area, then a member of the team project need to make a report. A report contains the location of genset installation, genset serial number, the genset capacity, the problem of installation, the solution of the problem, problem check to identify wether the problem are solved or not, and the date when the installation completed.

III. RESULT AND DISCUSSION

In the method section, it have been mentioned that the top event of this research FTA model is "Problem of Genset Failure". In the section 2.2 it's been explained that there will be several FTA model. The first FTA model is a general model that explained the risk that caused the problem in top event. Since FTA can be used to identify problem deductively, the top event can be break down to the basic events. The general FTA model can be seen in the Figure 2.

Theere are two main problems that lead to the genset failure, which are the error in genset component (A1) and installation system component (A2). The logical gate is or. The error in genset component can be caused by either generator system (B1), engine system (B2), or support system (B3), while the logical error is OR. In the other hand, the error in installation system component can be caused either mechanical system (B4) or electric system (B5).

The B1 until B5 elements symbolize by triangle modul. It describes that those events are transferred event, meaning that there is another tree that caused those events happened. In the next step, every event from B1 to B5 will be explained more to identify the basic event. In this case, the research needs to make specific FTA model. Data that listed in Table 1 started to be used in the specific FTA model. Every event from Table 1 in the specific FTA model symbolize by C code as it started to appear in Figure 3 until Figure 8.

The first specific FTA model explains the causes of error in generator system. This FTA model can be seen in Figure 3.

From the first specific FTA model that break down the causes of error in generator system, this research gets five basic events. There are user error (Q7), installation error (Q5), rocky soil condition (Q10), high ambient temperature (Q1), and bad quality of air (Q2). From this FTAM model that shown in Figure 3 also explains that a basic event can caused one or more problems in the upper level. All of the logical gate that's been used are OR.

The next FTA model is a model that described the causes of error in engine system. There are more specific basic events found. Further detail about it can be shown in Figure 4 below.

FTA model in Figure 4 uses OR logical gate. There are three new basic events found. There are unreplaced oil (Q8), unscheduled maintenance (Q13), and product failure (Q4). The next FTA model that's been created is FTA model for the error of support system. This FTA model can be seen in Figure 5.

In the Figure 5, there is new basic events found which is bug's distraction (Q9). The FTA model in figure 5 is not like the other FTA models before. There is an AND logical gate that caused radiator and CAC leaked (C13). It means, event C13 can be occur when there are some corrosives (X2) and dust (X14). The other logical gates that's seen in Figure 5 use OR logical gate. The next specific FTA model is a model that

Table 2.
The probability of basic event

Code	Basic Event	Frequency	Probability
Q1	High temperature ambient	2	0,0130
Q2	Bad quality of air	17	0,1104
Q3	Bumped while delivery	7	0,0455
Q4	Product failure	11	0,0714
Q5	Installation error	23	0,1494
Q6	Missed specifications	14	0,0909
Q7	User error	31	0,2013
Q8	Unreplaced oil	3	0,0195
Q10	Rocky soil condition	18	0,1169
Q11	Improper driving mechanism	8	0,0519
Q12	Unlocked UVT padlock	17	0,1104
Q13	Unscheduled maintenance	1	0,0065
Q14	Error from the engine heat	2	0,0130

represent the causes of error in mechanical system that's been seen Figure 6.

Three are three new basic events found in the Figure 6. There are error from the engine heat (Q14), bumped while delivery (Q3) and missed specification (Q6). All the logical gate that's used in FTA model in Figure 6 are OR logical gate. The next specific FTA model is a model to identify the causes of error in electric system. The model can be seen in Figure 7.

All of the basic events that found in Figure 7 have been found before in the previoud specific FTA model. All of the logical gates that used are OR logical gates. In the Figure 7, there are four model that symbolized by triangle shape. That means there are other model that will continue this specific FTA model, there are broken MCCB (C21), broken pilot lamp RST(C22), broken UVT (C23) and broken DSE module (C24). All of the specific FTA model that continue event C21, C22, C23 and C24 can be seen in Figure 8.

In all of figure 8, the logical gate that's been used are OR logical gate. Figure 8a explains the specific FTA model for the causes of broken MCBB. Figure 8b explains the specific FTA model dor the causes of Pilot Lamp RST. Figure 8c explains the specific FTA model for the causes of broken UVT. The last, Figure 8d explais the specific FTA model for the causes of broken DSE module.

In Figure 8a, Figure 8b and Figure 8d, there are no new basic event found. However, in Figure 8c, there are two new basic events found that caused UVT movement force stopped. They are improper driving mechanism (Q11) and unlocked UVT padlock (Q12).

A. Calculating The Minimal Cut Set

Every event in FTA model symbolize by a code. For example, the top event from Figure 2 was coded by N symbol. The lowest level in the Figure 2 is symbolized with B1, B2, B3 and B4 nad B5. Because the logical gate is OR, it can be formulated that the sum of B1, B2, B3 and B4, B5 represents the N. The formula 2 can explain it more.

$$N = (B1 + B2 + B3) + (B4 + B5) \quad (2)$$

After that in the specific FTA model shows that event B1, B2, B3, B4 and B5 have the lowest level as its basic event. As it mentioned before that total 14 basic events found from the FTA model. Every basic event coded with Q symbol from Q1 to Q14. The formula of B1 can be seen in the formula 3, the formula of B2 can be seen in the formula 4, the formula of B3 can be seen in formula 5, the formula of B4 can be seen in formula 6 and the formula of B5 can be seen in formula 7.

$$B1 = Q7 + Q1 + Q2 + Q5 + Q10 \quad (3)$$

$$B2 = Q8 + Q7 + Q13 + Q4 \quad (4)$$

$$B3 = Q1 + Q2 + Q5 \quad (5)$$

$$B4 = Q3 + Q4 + Q14 + Q6 + Q5 \quad (6)$$

$$B5 = Q3 + Q4 + Q5 + Q6 + Q7 + Q10 + Q11 + Q12 \quad (7)$$

In the calculation of minimal cut set, it uses idempotent operation where x + x can simplyfied as x only. Therefore, the final formula of tope evnet can be seen as in formula 8.

$$N = Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8 + Q10 + Q11 + Q12 + Q13 + Q14 \quad (8)$$

From the final formula of top event or N, it can be concluded that Q9 which is bug's distraction was elimiated from the minimal cut set calculation. Therefore, only 13 from 14 basic events that will be calculated the probability.

B. Calculating The Probability of Basic Event

After getting the basic events from FTA model and minimal cut set simulation, the research then calculates the probability of the basic event using formula 1 and resulting the data as shown in Table 2.

From Table 2, can be concluded that the three highest risk that caused error in genset installation are user error (Q7) with probability error 0,2013, installation error (Q5) with probability rate 0,1494 and rocky soil condition (Q10) with the probability rate 0,1169. Besides, the lowest risk from this risk assessment using FTA is unscheduled maintenance (Q13) since it only happened once with probability rate 0,0065.

FTA can breakdown the top event to the specific basic event and minimal cut set calculation can eliminate some basic event, so it can identify the proper basic event that caused error in genset installation project. Therefore, in the next research, it need to implement some methods to identify critical risk. But, this result can give information for XYZ company some risks that need to be considered its mitigation, specially the top three risks which are user error, installation error and the rocky soil environment in the area in Indonesia. Thus in the next project, they can avoid this kind of risk to get an optimal cost for such a genset installation project.

IV. CONCLUSION

From the risk assessment of generaor set (genset) installation project using Fault Tree Analysis (FTA), there are 14 basic events found from the top event error in genset installation. Only 13 basic events that can be calculated its probability, because one basic event was eliminated during calculating the minimal cut set. The highest risk is user error with the probability rate 0,2013 and the lowest risk is unscheduled maintenance with the probability rate 0,0065.

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