CHAPTER III

RESEARCH METHODOLOGY

This chapter will be steps conducting the research applied as references in order to keep focusing on the primary goals, which are going to be achieved. For the location of studies and selection already explain will repeat and a brief explanation about the location of studies and selection below.

3.1 Research Location and Object

The object of this research is to conduct an assessment of maintenance project management using CPM method to analyze the network diagram of wind turbine maintenance on the critical path of wind turbine maintenance process in order to minimize maintenance duration and cost of maintenance. As it has been elaborated in Chapter I, maintenance project management on renewable technology is one of updating issues that will be developed in the industrial field. This research will be focused on Hybrid Power Generation System, Bantul District, D.I.Y. Hybrid Power Generation System Pantai Baru is a power generator which produces the alternative electricity by using renewable energy. The electric power station in Hybrid Power Generation System Pantai Baru, Yogyakarta used energy wind to utilize the turbine so that can be used to excite electrical power through a generator and electricity is used to support electricity production process. Maintenance process which has conducted by PLTH Bayu Baru in outline contains preventive maintenance and corrective maintenance. Corrective maintenance conducted if there is the unpredicted fault of the generator machine. Corrective maintenance which conducted in PTLH Bayu Baru consists of unplanned maintenance which can occur by the weather condition. Unplanned maintenance is the kind of unexpected damage, which can lead to shutting down generating units. Below is the diagram of maintenance on wind turbine system in PLTH Bayu Baru:

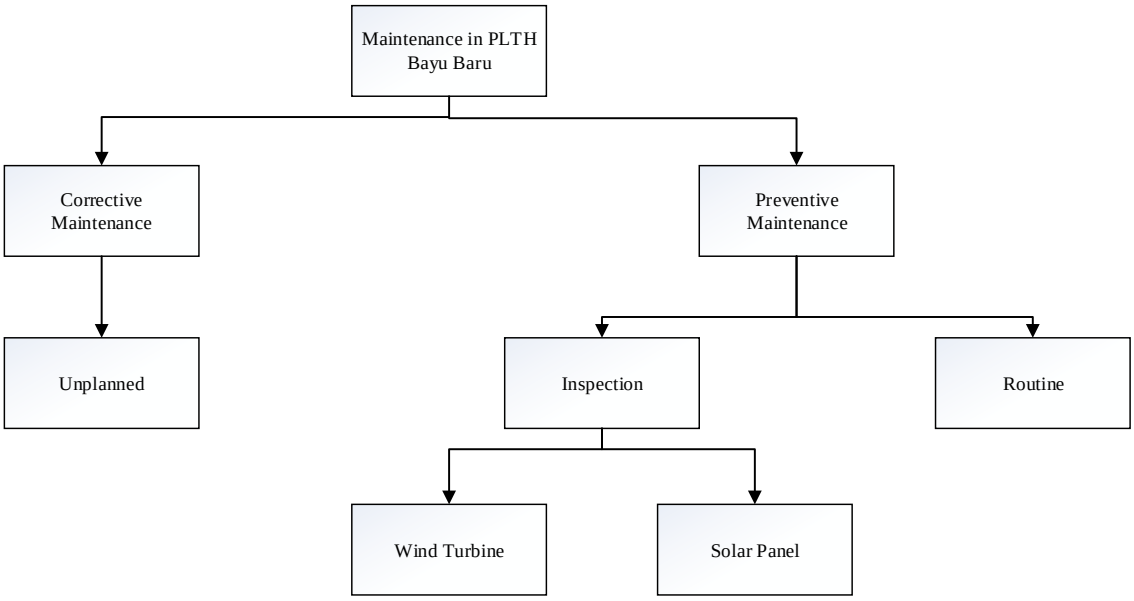

Figure 3.1 Maintenance Process on PLTH Bayu Baru

Source: PLTH Bayu Baru (2016)

From the diagram above, the maintenance process that conducts by PLTH Bayu Baru can be explained. Besides, the maintenance process that conducted by PLTH Bayu Baru is inspection and maintenance routine on the wind turbine system of the power plant which includes as preventive maintenance. From maintenance routine, the maintenance activity that has been done in order to conduct routine maintenance is checking periodically on the wind turbine power plant system to prevent the unpredict failure of the system. From the inspection, the activity that has been done in order to conduct the inspection are replacement failure part which is can be known by the age of the part on the wind turbine power plant system. Every part of the wind turbine power plant system has the average age limitation in order to know the condition of the part in the system based on the environmental factor, climate and the weather as its location is at the coastline. The maintenance problem on this research only focusing in the path for maintenance process wind turbine 1 KW by considering inspection of wind turbine unit 1 KW as already mentioned in Chapter I. This research only focuses on papers that research about maintenance in the wind turbine component which related to the maintenance scheduling and maintenance cost management. The whole process of the knowledge based on development has been elaborated in the K-Chart development at Figure 3.2.

3.2 Research Planning and Tools

The topic that will be discussed in this research is to conduct an assessment of maintenance project management using PERT method to analyze the network diagram of wind turbine maintenance on the critical path of wind turbine maintenance process in order to minimize maintenance duration and cost of maintenance. As it has been elaborated in Chapter I, maintenance project management on renewable technology is one of updating issues that will be developed in the industrial field. For the maintenance performance assessment, the type of manufacture to be identified is Hybrid Power Generator Plant (PLTH) Pantai Baru, Bantul, Daerah Istimewa Yogyakarta with the typology of performance of wind turbine maintenance process. The aspects which will be analyzed are the duration of maintenance, maintenance labor, maintenance schedule, and cost of maintenance. The performance of maintenance aspect will be assessed by using Microsoft Project with the parameters of maintenance scheduling and Microsoft Excel to calculate the total maintenance cost.

In 1958, Booz Allen Hamilton invented a scheduling method named PERT diagram, an abbreviation of the Program Evaluation and Review Technique. PERT diagrams can be used to simplify the planning and scheduling process for projects with large and complex capacity because they are able to overcome the uncertainties in the project without knowing the duration of each activity. Basically the principle of network and critical path on PERT and CPM methods almost the same that distinguish it is in PERT method, known three estimation numbers of each activity. The purpose of using three estimation figures is to provide the widest range of time in performing objectives in estimating the activity period. Third

The estimated duration is:

1. Optimistic time (optimistic duration time)

   An optimistic time period is the fastest duration to complete an activity if everything is going well. Duration used only once in a hundred times the activities performed repeatedly with almost the same conditions

2. Most likely time (most likely time)

   The most likely timeframe is the duration that most often occurs compared to the others when the activity is done repeatedly with almost the same conditions.

3. Pessimistic time duration (pessimistic duration time)

   The pessimistic time frame is the longest duration to complete the activity, if everything is not good. The duration here is exceeded only once in a hundred times, when the activity is repeated with similar conditions.

Then the third estimated time is formulated into a number called (te) or expected time duration (expected duration time). In determining the value (te) it is assumed that the probability of an optimistic event (a) and pessimistic (b) is the same. While the probability of occurrence of events is most likely four times greater than both optimistic and pessimistic events so that when summed it would be worth 6 (six) according to the range of standardized event distribution curves. The formula as follows:

$$te = \frac{a + 4m + b}{6}$$

While the estimated time period of activity on PERT method uses time range. This time span marks the degree of uncertainty associated with the process of estimating the activity period. The magnitude of this uncertainty depends on the magnitude of the estimated numbers for a and b. The parameters that describe this problem are known as standard deviations and variance. According to statistics, the standard deviation number is 1/6 of the distribution range (b-a) or when written by the formula is as follows:

Standard Deviation of Activity

$$S = \frac{1}{6}\,(b - a)$$

Variance of Activity

$$V(te) = S^2$$

Where :

S = standard deviation of activity

V (te) = activity variance

The possibility / uncertainty of reaching the schedule target on the PERT method is expressed by z as the relationship between the expected time (EET) with the target T (d) with the following formula:

$$Z\ Deviation = \frac{T(d) - EET}{S}$$

Where :

Z = Possible target to be achieved

T (d) = Project completion time target

EET = The earliest time of the event

S = Standard Deviation

Using the Comulative Normal Distribution table will be able to determine the percentage (%) of the project completed on target T (d).

In a desired project is completed within the time specified, the duration of the activity can be accelerated with the consequence would be an increase of cost. Acceleration of project duration at the lowest possible cost is called Crashing Project (Badri, 1997). To speed up the project completion time acceleration of activity duration on critical paths, provided that time reductions will not lead to new critical paths. One of the ways to speed up project execution time is by increasing the work time with available staff (overtime). The addition of working hours can be done with the addition of 1 hour, 2 hours, 3 hours and 4 hours of addition in accordance with the desired addition time. With the addition of working hours, it will reduce labor productivity, this is due to the fatigue factor by the workers. The indication of decreased worker productivity to the addition of working hours can be seen in Figure 3.2 below:

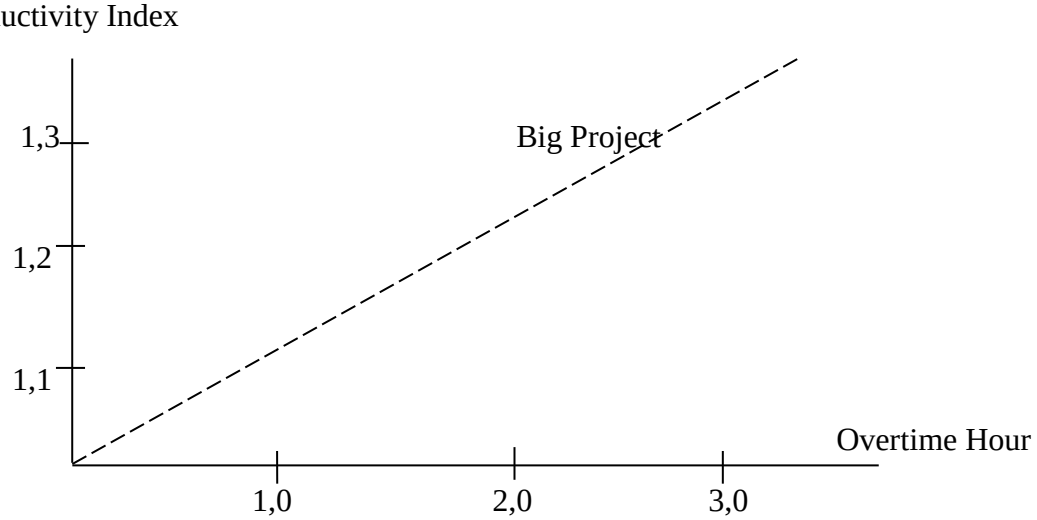

Figure 3.2. Indication of Decreased Productivity due to the Addition of Working Hour
(Source : Soeharto, 1999)

From the description above can be written as follows:

a. Daily Productivity

$$= \frac{Volume}{Normal\ Duration}$$

b. Hourly Productivity

$$= \frac{Daily\ Productivity}{8\ hours}$$

c. Daily Productivity After Crash

$$= (8\ Hours\ x\ Hourly\ Productivity) + (a\ x\ b\ x\ Hourly\ Productivity)$$

Where:

$a = duration\ of\ overtime$

$b = Productivity\ reduction\ coefficient\ by\ overtime$

d. Crash Duration

$$= \frac{Volume}{Daily\ Productivity\ After\ Crash}$$

The infromation about coefficient of decreased productivity will be deliver in Table 3.1.

Table 3.1 Coefficient of Decresed Productivity

Overtime (hour)	Depression of Index Productivity	Work Performance (%)
1	0.1	90

Overtime (hour)	Depression of Index Productivity	Work Performance (%)
2	0.2	80
3	0.3	70
4	0.4	60

With the addition of working time, the cost for labor will increase from the normal cost of labor. Based on the Decision of Minister of Manpower and Transmigration of the Republic of Indonesia Number KEP. 102 / MEN / VI / 2004 that the wage increase in employment varies, for the addition of the first hour work time, the worker gets an additional wage of 1.5 times the normal hour wage, and for the addition of the next working time the worker gets 2 times the normal hour wage. The calculation of additional costs of workers can be formulated as follows:

1. Daily Normal Labor Cost

$$= Daily\ Productivity\ x\ Unit\ Price\ Wage\ Workers$$

2. Hourly Normal Labor Cost

$$= Hourly\ Productivity\ x\ Unit\ Price\ Wage\ Workers$$

3. Overtime Labor Cost

$$= 1{,}5\ x\ an\ hour\ normal\ cost\ for\ first\ overtime +$$

$$2\ x\ n\ x\ an\ hour\ normal\ cost\ for\ the\ next\ overtime$$

Where:

n = duration of overtime

4. Daily Labor Crash Cost

$$= (8jam\ x\ normal\ cost\ labor) +\ (\ n\ x\ hourly\ overtime\ cost)$$

5. *Cost Slope* (Additional of direct costs to speed up activity per unit time)

$$= \frac{crash\ cost\ -\ normal\ cost}{normal\ duration\ -\ crash\ duration}$$

The total project cost is equal to the amount of direct costs plus indirect costs. The total cost of the project depends very much on the project's completion time, the longer the project finishes eating the expenses incurred will be even greater. The relationship between cost and time can be seen in Figure 3.2. Point A denotes the normal point, while point B is the shortened point. The line connecting between points A and point B is called the time-cost curve.

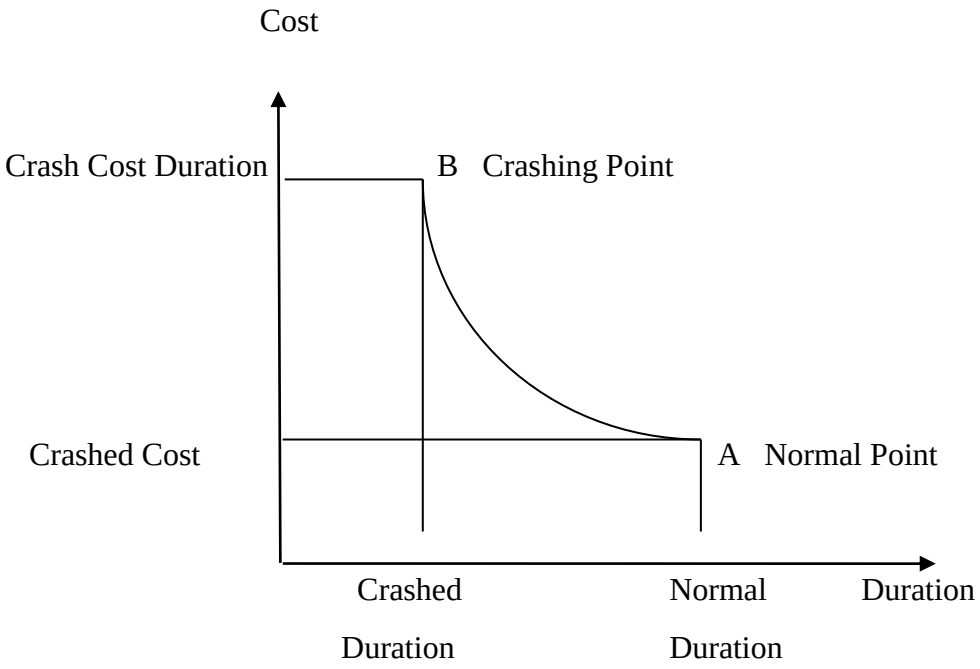

Figure 3.3. Time-Cost Relationship of Normal and Crashed for an Activity (Source : Soeharto ,1999)

The result will be used to assess the Condition Based Maintenance (CBM) strategy that monitors the actual condition of the asset to decide what maintenance needs to be done. (B. De Jonge et al., 2015) stated condition-based maintenance, on the other hand, leads to more effectively planned maintenance actions because it takes the condition of the maintainable unit into account. Also this result is to face the issued from the journal of Abderrazzaq & Hahn (2006) which stated that only few researchers have discussed the

performance and reliability of existing wind turbines. Whereas the majority of works in this field were either very general or just focused on the reliability of a specific part of wind turbine. Moreover, in order to monitor actual action, as it has been elaborated in Chapter II this research will assess techniques of CPM method which are obtained from the Project Management asessment. By using CPM the monitoring of maintenance wind turbine 1 KW are able to conducted in order to compare the current condition with the proposed condition of maintenance wind turbine 1 KW. The whole process of the knowledge based on development has been elaborated in the K-Chart development at Figure 3.3.

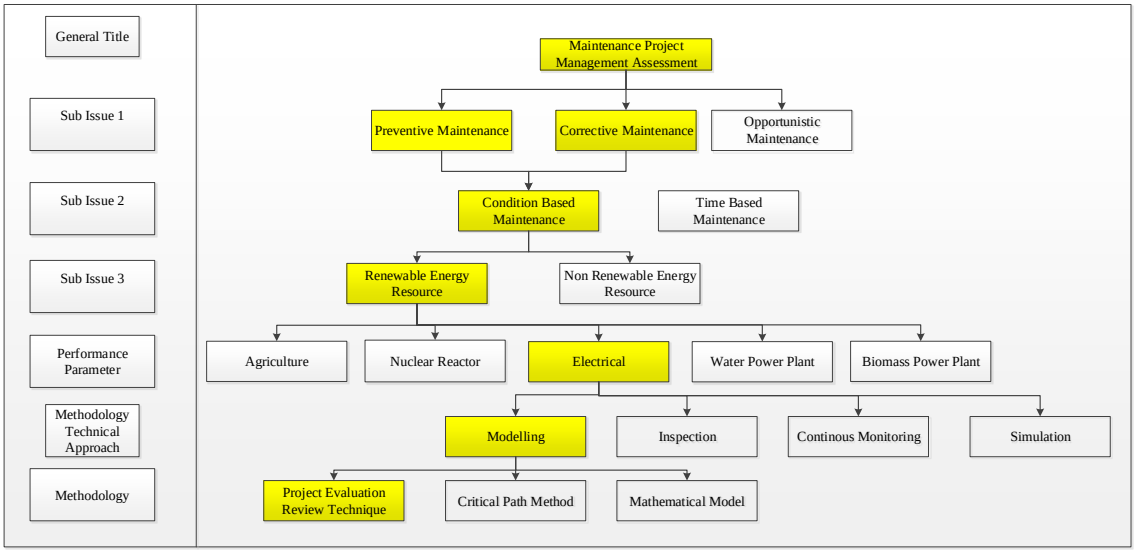

Figure 3.4. Research K-Chart

Sources Description:

1. (B. De Jonge et al., 2015)
2. (Abderrazzaq & Hahn, 2006)
3. (Soeharto , 1999)
4. (Badri, 1997)

3.3. Requirement of Data

In conducting the study, the data collected will be used to solve the existing problems so that those data must be completely reliable and accurate. Data collecting method that used in this study are:

1. Interview

From the interview method, the researcher gains a data from the technician and operational coordinator about the cost for maintenance, kind of maintenance activity and maintenance duration activity.

2. Observation

   Observation involved in the coordination meeting is one of the activity to gain the data about the legal document in order to find out the necessary step to conduct a maintenance. The observation is conducted directly in PLTH Bayu Baru to get the data of wind turbine 1 KW maintenance process which is needed for the PERT method calculation.

3. Literature review for data collecting is done by reading literature from books, journals, the internet, and previous research that related to the proposed research.

4.1.8 Conceptual Model

The research conceptual model conducted with the following steps:

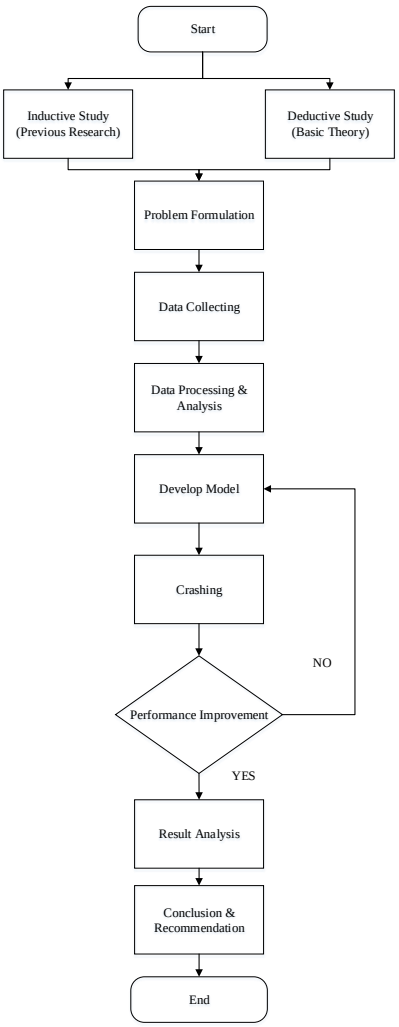

Figure 3.5 Flowchart of Conceptual Model

In Figure 3.3, the flowchart of critical path method step. Each step will be then elaborated as follows:

1. Data Collection

The data collection are obtained from the interview and observation in PLTH Bayu Baru. The data collection consisted of maintenance activity, maintenance duration, normal cost maintenance, and labor classification. The data about duration and activity are contained in the table of network data. The normal cost maintenance consists of cost labor and cost material of each maintenance activity. Normal means that the cost of maintenance is the current condition that conducted PLTH Bayu Baru. While the data about labor classification are consist of the labor requirement for each maintenance activity.

2. Develop Network Model

The network model of PERT method is consist of the code for each maintenance which already explained in the table of network data, the duration for each code, and the slack time of each code which can obtain from the calculation of earliest start time and earliest finish time. The PERT calculation is using forward and backward analysis in order to find the critical path of the PERT model of maintenance in the wind turbine 1 KW. From the network model of PERT method, slack time and the analysis of critical path and labor requirement can be obtained. The explanation of PERT Method are already discussed in Chapter II.

3. Crashing

Crashing analysis can be conducted after the network model for the normal maintenance of wind turbine 1 KW are already obtained. The crashing analysis are consist of the activity and labor that are available to allocate in order to get the performance improvement. In this condition, the difference in time of implementation of the project with the project planning that has been set. Time of project planning is usually shorter than the implementation project itself. Optimization of the time and expense that will do is speed up the duration of the project with the addition of minimum cost. One of the steps to speed up duration of the project is by using crashing in PERT method. Terminology crashing process is to reduce the duration of a workload that will affect the project completion time. Crashing process is centered on activities that in line with the critical path. The acceleration duration can be done on activates that passed by the

critical path. There are several ways to speed up an activity, in order to get the best alternative in accordance with the conditions of the contractor. Those activities are changes the logic dependency relationship between activities, adding human resources implement over time, adding or replacing equipment, and increase the availability of material. It certainly will add to cost activity. The addition of these fees will provide a massive difference in cost is due to the acceleration of the time according to the acceleration time, in this case, the optimization time is limited by the increased cost.

4. Performance Improvement

The performance improvement is the result of the crashed PERT analysis from the crashed PERT model. The performance improvement are an improvement of duration and cost of maintenance between crashed PERT and normal PERT model seen from the critical path of each model. If the duration and the cost of maintenance which obtained from crashed PERT model are not fulfilled the requirement or have an improvement, then it should be back to the step of crashing analysis. If the performance is improved, then the next step of analysis performance can be conducted.

5. Duration After Crashing

The analysis of duration after crashing can be conducted after the performance improvement is already obtained. The analysis is explained in the form of a table which consists of slack time, earliest start time, earliest finish time, latest start, latest finish and the critical path of crashed CPM. From the table of duration after crashing, the information about duration improvement can be obtained.

6. Labor Allocation

Labor Allocation are conducted after the improvement duration is already obtained. The labor allocation analysis is used to analyze the labor classification after crashing and the cost of labor after crashing. After the information about cost labor already obtained, then the cost of maintenance can be analyzed by adding the cost of material.

7. Cost and Duration Improvement

The information on the cost and duration improvement are already explained in form of table duration after crashing and the labor allocation. Moreover, the information of the cost and duration for normal maintenance process also used in this point in order to find

the provit for PLTH Bayu Baru by comparing the cost and duration current condition with the proposed condition. By comparing the current and proposed condition, the different and the improvement of the cost and duration of maintenance process can be obtained.

8. Discussion

The discussion is the explanation of the improvement between the current condition and the proposed condition after PERT model are applied in the maintenance of wind turbine 1 KW. This explanation are consist of critical path of current and proposed condition of maintenance wind turbine 1 KW, labor allocation, cost labor and material after Crashing from PERT normal condition in order to develop the proposed PERT model. Then the information of cost and duration improvement are able to obtained by analyze the PERT model for normal maintenance and Crashed PERT model of maintenance of wind turbine 1 KW.