

## CHAPTER IV

### DATA COLLECTING AND PROCESSING

#### 4.1 Data Collection

This chapter will elaborate the collection of the data as well the processing of the data. The data collection is divided into the primary as well as the secondary. Data accumulation are derived from direct observation and historical data provided by the company. The data processing will be developed based on the methodology which has been built in the previous chapter.

##### 4.1.1 Data of Wind Turbine Maintenance 1 KW Duration

Maintenance on wind turbine unit type 1 KW are divided by 2 division, there are Mechanical Division and Electrical Division. In order to analyze the data of network wind turbine maintenance 1 kw, the optimistic time, realistic time, and pessimist time should be analyzed first to get the estimated duration to complete the maintenance. Where the estimated duration is obtained from the interview of senior technician. After period time of project completion is already calculated, researcher can continue the research to find shorten period by first using PERT in activity time of project. The PERT system measures and uses time as a common denominator to reflect resource applications and technical performance for research and development projects.

Inside PERT method there were calculation about the optimist time and pessimist time in activity of project. First researcher need to find the way to solve optimist time in project management. Working Hours, working rest time, overtime were controlled in Law article 77 to article 85 of UU no. 13 year 2003 about Manpower. They were some of companies that include the rules by following Collective Labor Agreement (CLA). For employees who work for six days a week means that working

hours should be about 7 hours in 1 day and 40 hours in one week. According to Article 1 paragraph 1 of Regulation No. 102 / MEN / VI / 2004 explained that the maximum overtime for workers is 3 hours / day. Moreover, for example when workers go to work in company for 7 hours / day according to law company have right to persuade their worker to do overtime if they need to achieve their target.

After researcher find the optimist time by using overtime calculation, the next step is to calculate the pessimist time. The prediction of pessimist time happens when the estimated duration of the project not running well and the delay occurred. There were several factors that estimated duration in working time become pessimist time or delay are defective product or material, material transportation (got traffic jam in delivery process), and late ordering the material. According to technician as an expert stated that pessimist time usually occur in the unconditional situation and can happen anytime during the working progress in current project. Therefore, the researcher assumed that each day there is probability for the delay occurs in the middle of progress. According to historical data in the previous project the maximum delay in work time is 3 hour/day.

Calculation:

Normal day work:

1 day = 8 hours working time

By using overtime for optimist calculation:

Give additional 3 hour / day

1 day = 8 hours + 3 hours = 11 hours working time

By using delay for pessimist calculation:

1 day = 8 hours – 3 hours = 5 hours working time

From the calculation above, the information about overtime duration and delay duration are obtained. Therefore, the calculation of optimist time and pessimist time are shown as follows:

- Optimist time calculation :

$$\text{Overtime Duration (od)} = \text{realistic time (tm)} + 3 \text{ Hours}$$

$$\text{Optimist time (to)} = \frac{\text{realistic time (tm)}}{\text{overtime duration (od)}}$$

Where :

tm = realistic / most likely duration which obtained from field data.

od = overtime duration to accelerate the duration.

to = optimist time

- Pessimist time calculation :

$$\text{Delay Duration (dd)} = \text{realistic time (tm)} - 3 \text{ Hours}$$

$$\text{Pessimist time (tp)} = \frac{\text{realistic time (tm)}}{\text{delay duration (dd)}}$$

Where :

tm = realistic / most likely duration which obtained from field data.

dd = delay duration to estimate the duration while delay occurred.

to = pessimist time

The results of the whole project analysis for optimistic duration (to), realistic/most possible duration (tm) and pessimistic duration (tp) are elaborated in Table 4.1.

Table 4.1 Data of Wind Turbine Maintenance 1 KW Duration with PERT

Activity Code	Activity	Optimist time (to = tm/od)	Realistic time (tm)	Pessimist time (tp = tm/dd)
<b>I</b>	<b>Preparation</b>			
<b>1</b>	Shut Down system control, battery fuse and tools instalation	1,82	2	2,4
<b>II</b>	<b>Mechanical Work Inspection and Repairment</b>			
<b>2</b>	Binding blade of wind turbine which connected with orientation	3,64	4	4,8
<b>3</b>	Taking down blades, nosle, generator, and wind turbine vane of 1 KW wind turbine west group	3,64	4	4,8
<b>4</b>	Identification wind turbine failure	1,82	2	2,4
<b>5</b>	Releasing blades from hub	5,45	6	7,2
<b>6</b>	Balance checking on wind turbine blades	3,64	4	4,8
<b>7</b>	Identification on wind turbine generator	1,82	2	2,4
<b>8</b>	Dismantling and replacement bearings on generator	7,27	8	9,6
<b>9</b>	Furling and Replacing 3 phase of generator wires email	21,82	24	28,8
<b>10</b>	Dismantling and replacing Bross on slipring	9,09	10	12
<b>11</b>	Cleaning the ring of generator	1,82	2	2,4
<b>12</b>	Bolt and bosh replacement on wind vane	5,45	6	7,2
<b>13</b>	Replacement bolt on the tower	3,64	4	4,8
<b>III</b>	<b>Electrical Work Inspection and Repairment</b>			
<b>14</b>	Dismantling and checking part of system control	1,82	2	2,4
<b>15</b>	Checking and replacing MCB C63, avometer analog, and dioda bridge	0,91	1	1,2

<b>Activity Code</b>	<b>Activity</b>	<b>Optimist time (to = tm/od)</b>	<b>Realistic time (tm)</b>	<b>Pessimist time (tp = tm/dd)</b>
<b>16</b>	Checking indicator of current and voltage on system control	0,91	1	1,2
<b>17</b>	Checking wires indicator from system control into battery	0,91	1	1,2
<b>18</b>	Releasing the battery from connector and checking upper and lower level on accumulator	2,73	3	3,6
<b>19</b>	Checking battery voltage	1,82	2	2,4
<b>20</b>	Checking terminal cable ( + ) and ( - )	1,82	2	2,4
<b>21</b>	Checking connector from battery to inverter	1,82	2	2,4
<b>22</b>	Checking cable from system control to battery	3,64	4	4,8
<b>23</b>	Cooling down battery	5,45	6	7,2
<b>24</b>	Testing battery voltage after cooling down	2,73	3	3,6
<b>25</b>	Releasing the battery from connector	1,82	2	2,4
<b>26</b>	Turning on generator dan Charging the battery using generator	1,82	2	2,4
<b>27</b>	Checking MCB control from battery to inverter	3,64	4	4,8
<b>28</b>	Checking voltage from battery to inverter	2,73	3	3,6
<b>29</b>	Checking cable from battery to inverter	2,73	3	3,6
<b>30</b>	Checking and replacing inverter fuse AC and DC	3,64	4	4,8
<b>31</b>	Turning on and testing the inverter	3,64	4	4,8

Description of the inspection work will be described below:

- 1 Shut Down system control, battery fuse and tools installation

Shut down unit are an activity which consists of shut down system control and battery fuse. From the system control, the operator shut down the fuse from the

system control manually in order to stop the generator working. For the battery fuse, the operator also shut it down manually in order to cut the current voltage which is produced by the generator in order to fill the battery current. After shutting down unit, then the technicians which consist of 3 technicians and 1 helper start the tools installation in order to do the next maintenance activity and helping the technicians to do maintenance on wind turbine unit.

2 Binding blade of wind turbine which connected with orientation

This activity is done by the technician after the tools installation in order to prevent the mobility of wind turbine which is affected by the wind current. The technicians bind part of a wind turbine which is consist of blades, vane, and generator with the orientation to stop the movement, because of the orientation that supports the wind turbine to move 360°.

3 Taking down blades, nozzle, generator, and wind vane of 1 KW wind turbine

This activity only can be done with the tools installed and the blade of a wind turbine is already bound with the orientation. In this activity, the technicians are divided by 3. One of the technicians stays on top of the tower to deliver the part from the top into the ground. The other 2 technicians are on the bottom to accept the part that comes from the top of the turbine.

4 Identification wind turbine failure

This activity can be done after part of a wind turbine which is blades, nozzle, generator, and wind vane already in the ground so that the technicians can identify the failure of the wind turbine. In this activity needs 3 technicians.

5 Releasing blades from hub

This activity can be done after failure identification on a wind turbine. It needs 2 technicians with 1 helper in order to release the blades of the wind turbine from its hub.

6 Balance checking on wind turbine blades

This activity is done by 1 technicians that consist of blades that connect to a wire and then the technicians starting to balance the blades. If the blades still unbalanced, then the technicians add some vaseline on the side of the blades that

is unbalanced. This activity no needs some technicians because 1 technician can do the activity alone.

7 Identification on wind turbine generator

This activity can be done by 2 technicians by checking the generator part of the wind turbine. This activity also can be done only by 2 technicians and cannot be accelerated by adding the technician.

8 Dismantling and replacement bearings on generator

After the identification on wind turbine generator is done, the activity of maintenance on the generator is dismantling and replacement bearing on the generator. This activity can be done by 2 technicians and the time of maintenance cannot be accelerated by adding more technicians.

9 Furling and Replacing 3 phase of generator wires email

This activity is the activity that require most of time of the maintenance because it is only can be done by one technician because the expert of this activity only 1 person of the technicians, so this time of maintenance cannot be accelerated by adding more technicians because there is lack of the technician which expert on this furling and replacing the 3 phase of generator wires email.

10 Dismantling and replacing brush on slip ring

This activity is done by 2 technicians which can be done after the generator is ready to apply. This activity is needed because the brush on the slip ring allows the transmission of power and the electrical signal from a stationary to a rotating structure which is the wind turbine. The brush is reduced gradually as long as the wind turbine is working. So, this activity is important to do in order to prevent the electricity power outage.

11 Cleaning the ring of generator and slip ring

This activity can be done after the brush on the slip ring is already replaced. This activity needs 1 technician and 1 helper. This activity can be done simultaneously with bolt and Bosh replacement on wind vane a tower.

12 Bolt and Bosh replacement on wind vane

This activity needs 1 technician and 1 helper. The bolt and Bosh replacement not only on the wind vane but also on the generator and the hub. For the generator,

also this activity can be done if the parts of the generator are ready to use. This rule also works on the hub and the wind vane Bosh and bolt replacement.

13 Replacement bolt on the tower

This activity needs more technician rather than Bosh and bolts replacement on the wind vane, hub, and generator. This activity needs 2 technicians and 1 helper. This activity cannot be accelerated by adding more technician on it, also same as the bosh and bolt replacement on the wind vane, hub, and generator.

14 Dismantling and checking part of system control

This is the first activity which is included in the electrical work inspection and repairment. This activity needs 2 technicians and 1 helper. This activity consists of checking and replacement on the diode bridge on the system control.

15 Checking MCB C63 and replacing Avometer analog

This activity needs 1 technician because it can be done in one activity. MCB C63 and Avometer are the part of system control. MCB C63 or Miniature Circuit Breaker used for safety short circuit (surge) and also serves as a safety overload. MCB automatically immediately decide if the flow exceeds the flow through of the nominal current specified in the MCB which is 63 ampere. Avometer is a tool to measure current (amps), voltage (volts) and the resistance (Ohm) in system control. This activity cannot be accelerated by adding technician because it is already optimal if done by one technician.

16 Checking indicator of current and voltage on system control

An indicator of current and voltage on system control used to show the current flow from the wind turbine and the voltage that produced by wind turbine generator. This activity can be done by 1 technician and it is already optimum if done by 1 technician because this activity only can be done after the previous activity which is checking MCB C63 and replacing Avometer analog.

17 Checking wires indicator from system control into battery

Checking wires indicator from system control into battery is used to maintain the condition of the wires which is from system control to battery because it has an important role on the delivering electricity current which is already processed in

the system control into the electricity storage. This activity also can be done by 1 technician because it is the further activity from the activity before.

- 18 Releasing the battery from connector and checking upper and lower level on accumulator

This activity consists of 9 technicians which are releasing the battery from the connector that used to prevent the current entering the electricity storage. After the connector is already release, then the accumulator liquid must be checked the upper and the lower on the accumulator in order to control the storage from lack of accumulator liquid. This activity can be done by the helper as long as there are 2 technicians for this activity.

- 19 Checking battery voltage

Checking battery voltage can be done by multimeter which is rotate the selector on position activity Volt DC. After that connect the multimeter positive (red) to the battery positive and negative cable (black) negative into terminal factory standard batteries. The standard battery charge full or optimum are between 13.0 to 13.2 volts and for the lower voltage are 12 volts.

- 20 Checking terminal cable ( + ) and ( - )

Checking terminal cable positive and negative are used to ensure that the current can flow through into the battery. This activity can be done by 9 technicians. Also, this activity can be replaced by the helper as long as there are 2 technicians stand by on this activity.

- 21 Checking connector from battery to inverter

This activity is done by 2 technicians which are cannot be replaced by a helper. In this activity, the connector has been checked to prevent shorting electricity from battery to inverter.

- 22 Checking cable from system control to battery

This activity is done by 2 technicians which are cannot be replaced by a helper. This activity is done in order to check the cable usage which is still good to deliver the current from system control to battery or not.

- 23 Cooling down battery

After activity which is included in the battery system, then the battery need cooling down in order to check whether after maintenance the battery is still good for charging the electricity current or not. This activity is done by 2 technicians.

24 Testing battery voltage after cooling down

After cooling down the battery, testing battery voltage is important in order to ensure the condition of the current battery. If the battery cannot charge full or optimum are between 13.0 to 13.2 volts, then the battery needs replacement. In this case, the battery after maintenance is still good which mean that the battery still can charge optimum. This activity needs 2 technicians.

25 Releasing the battery from connector

After the battery has been checked, then the battery needs to release from the connector in order to go to the next step of the maintenance in electricity work. This activity needs 9 technicians and also the technicians could be replaced by the helper as long as there are 2 technicians stand by in this activity.

26 Turning on generator dan Charging the battery using generator

This activity is done by 3 technicians after the battery already released from the connector. After the battery is ready to use, then the technician turning on the generator in order to charge the battery. The battery voltage is produced from the generator which is already turned on by the technicians.

27 Checking MCB control from battery to inverter

After the battery are already charged by the generator, then the technicians should be checking the MCB control from the battery to the inverter in order to ensure that MCB shows the current flow from the battery to inverter normally or not. In this case, the MCB control is rarely broken so there is no need replacement for MCB from the battery to inverter. This activity can be done after the battery charged and done by 2 technicians.

28 Checking voltage from battery to inverter

Checking voltage from battery to inverter can be done by 2 technicians after the battery has released from the connector. This activity is done in order to check whether the voltage from the battery can deliver properly into the inverter or not.

## 29 Checking cable from battery to inverter

This activity can be done by 2 technicians after the battery has released from its connector. This activity is done in order to check the condition of the cable which is used to deliver the electricity current from the inverter whether it is still in good condition or not. This activity also is the activity which prevents the shorting of the system from battery to inverter.

## 30 Checking and replacing inverter fuse AC and DC

This activity is done by 2 technicians after the battery has released from its connector. The inverter fuse AC and DC must be check and replace periodically in order to keep the performance of the inverter optimum.

## 31 Turning on and testing the inverter

After the electrical work is already done, then the last maintenance from the wind turbine generator are turning on and testing the inverter by connecting all of the wind turbine systems. This activity is done by 2 technicians.

After the data about network maintenance already explained, then below are the table data of the labor data:

#### 4.1.2 Estimated Duration Maintenance Wind Turbine 1 KW

After the information of duration from each activity already explained by PERT, then the information about estimated duration, standard deviation, and variance of wind turbine maintenance 1 kw are available to be calculated. Therefore, the explanation of the estimated duration, standard deviation, and variance of each activity will be deliver in Table 4.2.

Table 4.2 Estimated Duration Wind Turbine Maintenance 1 KW

Activity Code	Activity	Estimated duration (te)	Std. deviaton $[(t_o-t_p)/6]$	Variance (S <sup>2</sup> )
<b>I</b>	<b>Preparation</b>			
<b>1</b>	Shut Down system control, battery fuse and tools instalation	2,0	0,10	0,01

<b>Activity Code</b>	<b>Activity</b>	<b>Estimated duration (te)</b>	<b>Std. deviaton [(to-tp)/6]</b>	<b>Variance (S<sup>2</sup>)</b>
<b>II</b>	<b>Mechanical Work Inspection and Repairment</b>			
<b>2</b>	Binding blade of wind turbine which connected with orientation	4,1	0,19	0,04
<b>3</b>	Taking down blades, nosle, generator, and wind turbine vane of 1 KW wind turbine west group	4,1	0,19	0,04
<b>4</b>	Identification wind turbine failure	2,0	0,10	0,01
<b>5</b>	Releasing blades from hub	6,1	0,29	0,08
<b>6</b>	Balance checking on wind turbine blades	4,1	0,19	0,04
<b>7</b>	Identification on wind turbine generator	2,0	0,10	0,01
<b>8</b>	Dismantling and replacement bearings on generator	8,1	0,39	0,15
<b>9</b>	Furling and Replacing 3 phase of generator wires email	24,4	1,16	1,35
<b>10</b>	Dismantling and replacing Bross on slipring	10,2	0,48	0,24
<b>11</b>	Cleaning the ring of generator	2,0	0,10	0,01
<b>12</b>	Bolt and bosh replacement on wind vane	6,1	0,29	0,08
<b>13</b>	Replacement bolt on the tower	4,1	0,19	0,04
<b>III</b>	<b>Electrical Work Inspection and Repairment</b>			
<b>14</b>	Dismantling and checking part of system control	2,0	0,10	0,01
<b>15</b>	Checking and replacing MCB C63, avometer analog, and dioda bridge	1,0	0,05	0,00
<b>16</b>	Checking indicator of current and voltage on system control	1,0	0,05	0,00
<b>17</b>	Checking wires indicator from system control into battery	1,0	0,05	0,00

<b>Activity Code</b>	<b>Activity</b>	<b>Estimated duration (te)</b>	<b>Std. deviaton [(to-tp)/6]</b>	<b>Variance (S<sup>2</sup>)</b>
<b>18</b>	Releasing the battery from connector and checking upper and lower level on accumulator	3,1	0,15	0,02
<b>19</b>	Checking battery voltage	2,0	0,10	0,01
<b>20</b>	Checking terminal cable (+) and (-)	2,0	0,10	0,01
<b>21</b>	Checking connector from battery to inverter	2,0	0,10	0,01
<b>22</b>	Checking cable from system control to battery	4,1	0,19	0,04
<b>23</b>	Cooling down battery	6,1	0,29	0,08
<b>24</b>	Testing battery voltage after cooling down	3,1	0,15	0,02
<b>25</b>	Releasing the battery from connector	2,0	0,10	0,01
<b>26</b>	Turning on generator dan Charging the battery using generator	2,0	0,10	0,01
<b>27</b>	Checking MCB control from battery to inverter	4,1	0,19	0,04
<b>28</b>	Checking voltage from battery to inverter	3,1	0,15	0,02
<b>29</b>	Checking cable from battery to inverter	3,1	0,15	0,02
<b>30</b>	Checking and replacing inverter fuse AC and DC	4,1	0,19	0,04
<b>31</b>	Turning on and testing the inverter	4,1	0,19	0,04

#### **4.1.3 Data of Maintenance Wind Turbine 1 KW Network**

In order to find the network analysis of maintenance wind turbine 1 kw, the data of estimated duration and predecessor of the activity should be expected. Therefore, the information about network data will be deliver in Table 4.3

Table 4.3 Data of Network Wind Turbine Maintenance 1 KW

No	Activity	Estimated Duration (hours)	Activity Code	Predecessor
<b>I</b>	<b>Preparation</b>			
1	Shut Down system control, battery fuse and tools installation	2,0	1	-
<b>II</b>	<b>Mechanical Work Inspection and Repairment</b>			
2	Binding blade of wind turbine which connected with orientation	4,1	2	1
3	Taking down blades, nosle, generator, and wind vane of 1 KW wind turbine	4,1	3	2
4	Identification wind turbine failure	2,0	4	3
5	Releasing blades from hub	6,1	5	4
6	Balance checking on wind turbine blades	4,1	6	5
7	Identification on wind turbine generator	2,0	7	3
8	Dismantling and replacement bearings on generator	8,1	8	7
9	Furling and Replacing 3 phase of generator wires email	24,4	9	7
10	Dismantling and replacing Bross on slip ring	10,2	10	6, 8, 9
11	Cleaning the ring of generator	2,0	11	10
12	Bolt and Bosh replacement on wind vane, hub, and generator	6,1	12	10
13	Replacement bolt on the tower	4,1	13	10
<b>III</b>	<b>Electrical Work Inspection and Repairment</b>			
14	Dismantling and checking part of system control	2,0	14	3
15	Checking MCB C63 and replacing Avometer analog	1,0	15	14
16	Checking indicator of current and voltage on system control	1,0	16	15
17	Checking wires from system control into battery	1,0	17	16
18	Releasing the battery from connector and checking upper and lower level on accumulator	3,1	18	11, 12, 17
19	Checking battery voltage	2,0	19	18

No	Activity	Estimated Duration (hours)	Activity Code	Predecessor
20	Checking terminal cable ( + ) and ( - )	2,0	20	19
21	Checking connector from battery to inverter	2,0	21	20
22	Checking cable from system control to battery	4,1	22	20
23	Cooling down battery	6,1	23	20
24	Testing battery voltage after cooling down	3,1	24	23
25	Releasing the battery from connector	2,0	25	21, 22, 24
26	Turning on generator dan Charging the battery using generator	2,0	26	25
27	Checking MCB control from battery to inverter	4,1	27	25
28	Checking voltage from battery to inverter	3,1	28	25
29	Checking cable from battery to inverter	3,1	29	25
30	Checking and replacing inverter fuse AC and DC	4,1	30	25
31	Turning on and testing the inverter	4,1	31	26, 27, 28, 29 30

#### 4.1.4 Normal Cost Maintenance Wind Turbine 1 KW

Normal cost maintenance is consist of cost which PLTH Bayu Baru spent when the maintenance is running. The normal maintenance cost consists of the cost for a replacement part that broken and needs replacement and cost of tools which are used for maintenance part of wind turbine generator. The cost of part replacement and tools are included in the cost of material. For the cost of labor is the cost for labor to conduct maintenance. Work hours for the labor in PLTH Bayu Baru are follows the government regulation Law article 77 to article 85 of UU no. 13 year 2003 about Manpower. For employees who work for six days a week means that working hours should be about 7 hours in 1 day and 40 hours in one week. According to Article 1 paragraph 1 of Regulation No. 102 / MEN / VI / 2004 explained that the maximum overtime for workers is 3 hours / day. Moreover, for example when workers go to work in company for 7 hours / day according to law company have right to persuade their worker to do

overtime if they need to achieve their target. PLTH Bayu Baru applied 8 hours/ day for labor work hours which means that PLTH Bayu Baru are fulfilled the requirement of government regulation. The calculation of normal maintenance for technician and helper will be explained as follows:

Technician : Rp 1.400.000,00 : 28 days : 8 hours = Rp 6.250,00/hours

Helper : Rp 150.000,00 : 28 days : 8 hours = Rp 670,00/hours

The data above are already provided by PLTH Bayu Baru and follow the government regulation on a regional minimum wage (UMR) of Bantul district year 2017. Below are the table of normal cost maintenance wind turbine 1 KW east group data:

Table 4.4 Normal Cost Maintenance Wind Turbine 1 KW

Activity Code	Activity	Cost Labor	Material Cost
<b>I</b>	<b>Preparation</b>		
<b>1</b>	Shut Down system control, battery fuse and tools instalation	Rp20.313	
<b>II</b>	<b>Mechanical Work Inspection and Repairment</b>		
<b>2</b>	Binding blade of wind turbine which connected with orientation	Rp54.167	
<b>3</b>	Taking down blades, nosle, generator, and wind turbine vane of 1 KW wind turbine west group	Rp54.167	Rp100.000
<b>4</b>	Identification wind turbine failure	Rp40.625	
<b>5</b>	Releasing blades from hub	Rp16.741	
<b>6</b>	Balance checking on wind turbine blades	Rp25.000	
<b>7</b>	Identification on wind turbine generator	Rp27.083	
<b>8</b>	Dismantling and replacement bearings on generator	Rp104.167	Rp165.000
<b>9</b>	Furling and Replacing 3 phase of generator wires email	Rp287.500	Rp607.000

<b>Activity Code</b>	<b>Activity</b>	<b>Cost Labor</b>	<b>Material Cost</b>
<b>10</b>	Dismantling and replacing Bross on slipring	Rp129.167	Rp196.000
<b>11</b>	Cleaning the ring of generator	Rp7.813	Rp50.000
<b>12</b>	Bolt and bosh replacement on wind vane	Rp10.268	Rp165.200
<b>13</b>	Replacement bolt on the tower	Rp15.402	Rp60.000
<b>III</b>	<b>Electrical Work Inspection and Repairment</b>		
<b>14</b>	Dismantling and checking part of system control	Rp27.083	
<b>15</b>	Checking and replacing MCB C63, avometer analog, and dioda bridge	Rp14.583	Rp240.000
<b>16</b>	Checking indicator of current and voltage on system control	Rp14.583	Rp50.000
<b>17</b>	Checking wires indicator from system control into battery	Rp8.333	Rp50.000
<b>18</b>	Releasing the battery from connector and checking upper and lower level on accumulator	Rp283.125	Rp72.000
<b>19</b>	Checking battery voltage	Rp25.000	
<b>20</b>	Checking terminal cable (+) and (-)	Rp172.500	
<b>21</b>	Checking connector from battery to inverter	Rp25.000	
<b>22</b>	Checking cable from system control to battery	Rp50.000	
<b>23</b>	Cooling down battery	Rp79.167	
<b>24</b>	Testing battery voltage after cooling down	Rp39.583	
<b>25</b>	Releasing the battery from connector	Rp65.625	
<b>26</b>	Turning on generator dan Charging the battery using generator	Rp43.750	
<b>27</b>	Checking MCB control from battery to inverter	Rp54.167	

Activity Code	Activity	Cost Labor	Material Cost
28	Checking voltage from battery to inverter	Rp37.500	
29	Checking cable from battery to inverter	Rp37.500	
30	Checking and replacing inverter fuse AC and DC	Rp52.083	
31	Turning on and testing the inverter	Rp52.083	
		Rp1.874.077	Rp1.755.200
Total Cost Maintenance		Rp3.629.277	

#### 4.1.5 Data Labor Classification

In order to conduct inspections on the maintenance of wind turbines to performed the inspections all existing technicians field or workstation in PLTH Bayu Baru are qualified to perform maintenance on wind turbines so that almost all the technicians can be performed as a senior technician and can each fill a void of any maintenance activity. On each category of work has several senior technicians to give instructions to the helper work. Helper is a labor that can be taken from the student interns who have learned the basic about the renewable energy hybrid power plant especially wind turbine generator. The data about labor classification are shown in Table 4.5 below:

Table 4.5 Labor Classification

No	Activity	Labor Classification
<b>I Preparation</b>		
1	Shut Down system control, battery fuse and tools installation	3 technicians + 1 helper
<b>II Mechanical Work Inspection and Repairment</b>		
2	Binding blade of wind turbine which connected with orientation	2 technicians

No	Activity	Labor Classification
3	Taking down blades, nozzle, generator, and wind vane of 1 KW wind turbine West group	2 technicians
4	Identification wind turbine failure	3 technicians
5	Releasing blades from hub	2 technicians + 1 helper
6	Balance checking on wind turbine blades	1 technicians
7	Identification on wind turbine generator	2 technicians
8	Dismantling and replacement bearings on generator	2 technicians
9	Furling and Replacing 3 phase of generator wires email	2 technicians
10	Dismantling and replacing Bross on slip ring	2 technicians
11	Cleaning the ring of generator	1 technicians + 1 helper
12	Bolt and Bosh replacement on wind vane, hub, and generator	1 technicians + 1 helper
13	Replacement bolt on the tower	2 technicians + 1 helper
III	<b>Electrical Work Inspection and Repairment</b>	
14	Dismantling and checking part of system control	2 technicians
15	Checking MCB C63 and replacing Avometer analog	2 technicians
16	Checking indicator of current and voltage on system control	2 technicians
17	Checking wires indicator from system control into battery	1 technicians
18	Releasing the battery from connector and checking upper and lower level on accumulator	9 technicians
19	Checking battery voltage	2 technicians
20	Checking terminal cable ( + ) and ( - )	9 technicians
21	Checking connector from battery to inverter	2 technicians

<b>No</b>	<b>Activity</b>	<b>Labor Classification</b>
<b>22</b>	Checking cable from system control to battery	2 technicians
<b>23</b>	Cooling down battery	2 technicians
<b>24</b>	Testing battery voltage after cooling down	2 technicians
<b>25</b>	Releasing the battery from connector	9 technicians
<b>26</b>	Turning on generator dan Charging the battery using generator	3 technicians
<b>27</b>	Checking MCB control from battery to inverter	2 technicians
<b>28</b>	Checking voltage from battery to inverter	2 technicians
<b>29</b>	Checking cable from battery to inverter	2 technicians
<b>30</b>	Checking and replacing inverter fuse AC and DC	2 technicians

The specification of the technician is the labor that has learned and already mastered in the hybrid power plant. The specification for helper is the student from senior high school which is doing an internship on the hybrid power plant also the student from college which is doing the research on the hybrid power plant. Not only by the student, but also the fish seller and the fisherman are able to be the helper. On each category of work has several senior technician to give instructions to the helper work. all existing technicians field or workstation in PLTH Bayu Baru qualified to perform maintenance on wind turbines, so that almost all the technicians can be performed as a senior technician and can each fill a void of any maintenance activity. Helper is a labor that can be taken from the student interns who have learned the basic about the renewable energy hybrid power plant especially wind turbine generator.

Because, initially PLTH Bayu Baru are developed in order to fulfill the demand of electricity of the traders around the area of power plant because (PLN) unavailable to reach the demand of electricity for the traders because of the area is to far from the Main Station of PLN. After the duration, activity, and the technician allocation are

known, below will show the network diagram model from PERT method by using the value of  $t_e$  (expected duration) for the normal maintenance on wind turbine 1 KW east group which is already conducted by PLTH Bayu Baru:

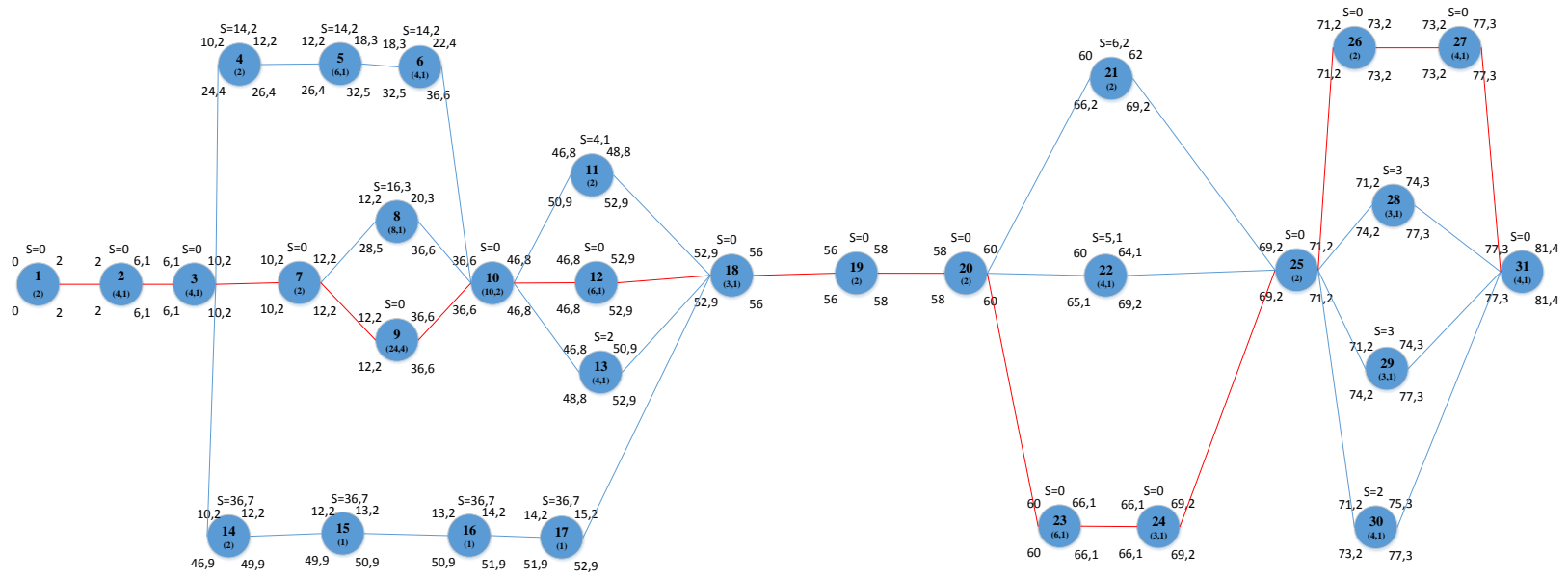
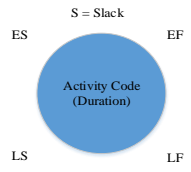


Figure 4.1 Network Diagram Initial Maintenance



From the results of network diagram analysis with PERT method with the value of  $t_e$  as the duration used in the calculation, the known completion of the project ( $t_e$ ) for 81,4 hours. Critical path of wind turbine maintenance process 1 kw east group indicated by a red line above. The results of the above network analysis generate critical path are:

1 – 2 – 3 – 7 – 9 – 10 – 12 – 18 – 19 – 20 – 23 – 24 – 25 – 26 – 27 – 31

From the result of the critical path above, the duration for maintenance wind turbine 1 KW east group is 81,4 hours or 10,17 days. After the slack time and the critical path are already obtained, then the next step is to analyze the critical path and labor requirement in order to conduct the improvement from the initial maintenance condition. From the information above, the labor allocation are available to conducted because there are lack of labor requirement which affect to the number of slack. By analyzing the critical path, the labor allocation are available to conduct in activity (18) and (20). In activity 18, all of the technicians are involved in the maintenance activity. Based on the recommendation from the technician, in this activity are available to allocate the labor with the helper as long as 2 technicians are standing by in this activity in order to control the helper. Also in the activity 20, by recommendation of the technician in PLTH Bayu Baru this activity can be done the labor allocation as long as 2 technicians are standing by in this activity. It means that the others 7 technicians will be replaced with the helpers in order to allocate the labor of maintenance wind turbine 1 kw.

Moreover, the labor in activity 18 and 20 are available to be allocated because 18 and 20 are included in the critical path of normal maintenance. This labor allocation can cause the changes of the duration and cost labor of maintenance wind turbine 1 KW because the activity before activity 18 and 20 are able to changes as long as the mechanical works are already conducted. In order to analyze the network analysis after the labor are allocated, the network diagram model will be delivered in Figure 4.2:

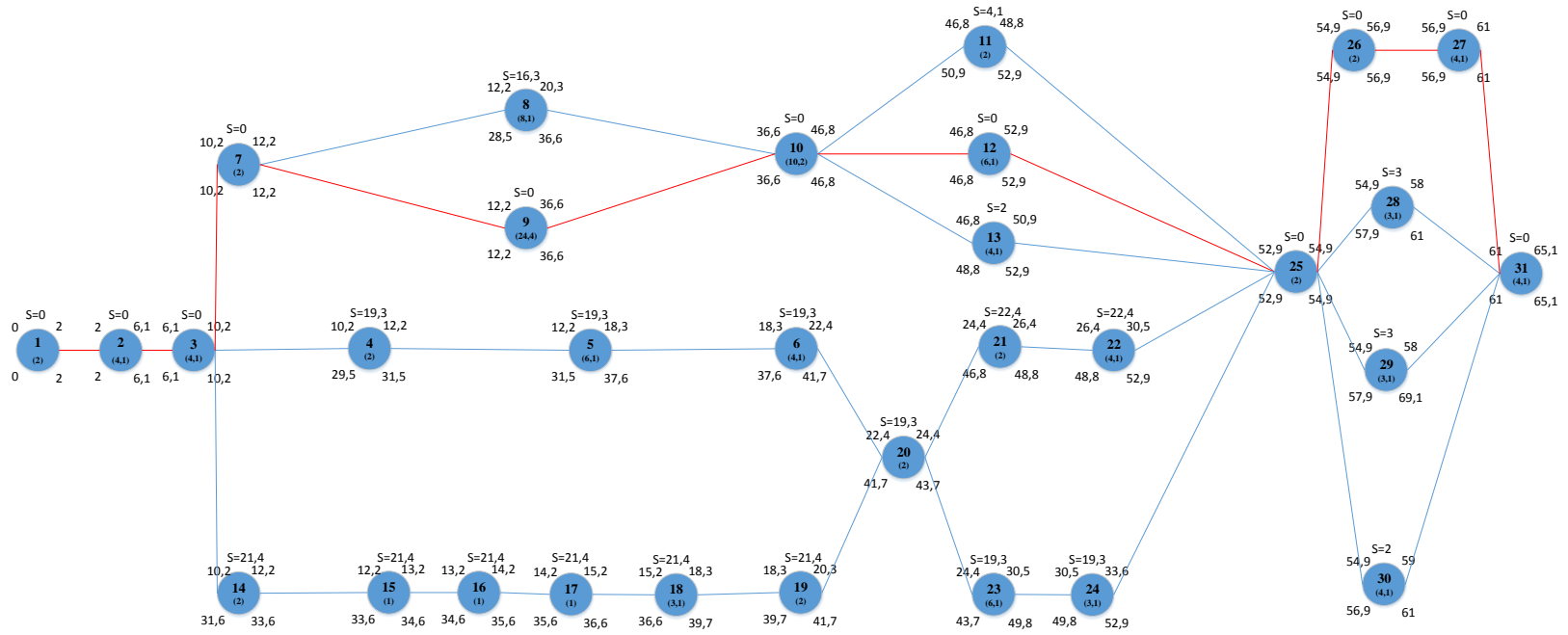


Figure 4.2 Network Diagram After Resource Allocation

From result of network diagram analysis with PERT method with value of  $t_e$  as duration used in calculation, hence known completion of project ( $t_e$ ) during 65,1 hours and obtained critical path in network diagram at activity:

1 – 2 – 3 – 7 – 9 – 10 – 12 – 25 – 26 – 27 – 31

From the result of the critical path above, the duration for maintenance wind turbine 1 KW east group is 65,1 hours or 8,13 days. Based on the critical path that has been obtained on the calculation, then determine the standard deviation value and the variance of the whole activity. The standard deviation and the variance of whole activity will explain at Table 4.6.

Table 4.6 Standard Deviation Values and Activity Variance on PERT Method

Activity Code	Activity	Optimist time ( $t_o$ )	Pessimist time ( $t_p$ )	S	V( $t_e$ )
1	Shut Down system control, battery fuse and tools instalation	1,82	2,4	0,10	0,01
2	Binding blade of wind turbine which connected with orientation	3,64	4,8	0,19	0,04
3	Taking down blades, nosle, generator, and wind turbine vane of 1 KW wind turbine west group	3,64	4,8	0,19	0,04
7	Identification on wind turbine generator	1,82	2,4	0,10	0,01
9	Furling and Replacing 3 phase of generator wires email	21,82	28,8	1,16	1,35
10	Dismantling and replacing Bross on slipring	9,09	12	0,48	0,24
12	Bolt and bosh replacement on wind vane	5,45	7,2	0,29	0,08
25	Releasing the battery from connector	1,82	2,4	0,10	0,01
26	Turning on generator dan Charging the battery using generator	1,82	2,4	0,10	0,01
27	Checking MCB control from battery to inverter	3,64	4,8	0,19	0,04
31	Turning on and testing the inverter	3,64	4,8	0,19	0,04
$\Sigma V(t_e)$	1,96				
S	3,2				

From the table above can be seen the total value of variance 1,87 and total value of standard deviation 3,09. Then after calculated the total variance and standard deviation, the next step is find the z value in order to know the percentage of the completion of maintenance wind turbine 1 KW. Because the company needs to accelerate the completion of maintenance wind turbine 1 kw, crashing analysis will conducted in order to accelerate the duration of maintenance wind turbine 1kw completion.

#### 4.1.6 Crashing Network Analysis

After the establishment of network analysis with PERT method, here will be made a way to accelerate the completion of project time with alternative hours of working hours is for 1 hour based on the recommendation from the technician. In the acceleration of the project for alternative hours added this applies only to activities that are on the critical path because activities on the critical path are activities that should not be delayed. In order to achieve the target, crashing duration will be conducted by giving additional 1 hours of each activity which includes in critical path. The information about duration after crashing on the critical path of maintenance process wind turbine unit 1 KW are shown in Table 4.7.

Table 4.7 Crashing Network Analysis Data

Activity Code	Activity	Normal Duration	Crash Duration
<b>1</b>	Shut Down system control, battery fuse and tools instalation	<b>2</b>	<b>1</b>
<b>2</b>	Binding blade of wind turbine which connected with orientation	<b>4,1</b>	<b>3,1</b>
<b>3</b>	Taking down blades, nosle, generator, and wind turbine vane of 1 KW wind turbine west group	<b>4,1</b>	<b>3,1</b>
<b>7</b>	Identification on wind turbine generator	<b>2</b>	<b>1</b>
<b>9</b>	Furling and Replacing 3 phase of generator wires email	<b>24,4</b>	<b>23,4</b>
<b>10</b>	Dismantling and replacing Bross on sliping	<b>10,2</b>	<b>9,2</b>
<b>12</b>	Bolt and bosh replacement on wind vane	<b>6,1</b>	<b>5,1</b>
<b>25</b>	Releasing the battery from connector	<b>2</b>	<b>1</b>

Activity Code	Activity	Normal Duration	Crash Duration
26	Turning on generator dan Charging the battery using generator	2	1
27	Checking MCB control from battery to inverter	4,1	3,1
31	Turning on and testing the inverter	4,1	3,1
		65,1	54,1

From the information above, the duration of maintenance wind turbine 1 kw completion time decreased from 65,1 to 54,1. Because the duration to complete the maintenance process are already accelerated, then the value of T(d) will be 54,1. In order to find the probability of the project will be finish in 54,1 hours, then the z value should be calculated. The calculation of Z value are shown below:

$$Z \text{ value} = \frac{T(d) - TE}{S}$$

$$Z \text{ value} = \frac{54,1 - 65,1}{3,2}$$

$$Z \text{ value} = -3,43$$

From the data above, the Z value is -3,43. By using the cumulative normal distribution in appendix, the table with z = -3,43 then the result is 0.0003. It is possible that the whole activity to be completed within 54,1 hours is about 0.03 %. From the table above, the result of the crashing network analysis found that the duration of maintenance from normal inspection is decreasing from 65,1 hours into 54,1 hours or in daily calculation became:

Duration Before Crashing : 65,1 hours : 8 hours = 8,13 days.

Duration After Crashing : 54,1 hours : 8 hours = 6,76 days.

Because of this result, PLTH Bayu Baru are able to get benefits of 1,36 days or 10,8 hours to utilize the wind turbine 1 KW in order to produce the electricity. After the information of duration already obtained, then the next step analyzes the cost of maintenance after crashing. Because each of activity in critical path are added by 1 hour.

#### 4.1.7 Total Maintenance Cost Analysis

The information of cost analysis after crashing area able to deliver after the information of labor cost after allocation are already calculated. Therefore, the information about the labor cost after maintenance are shown in Table 4.8 The information about the cost maintenance analysis of labor allocation and cost maintenance analysis are shown explained in Table 4.8 below:

Table 4.8 Labor Cost Before and After Allocation

No	Initial Labor	Cost Labor	Labor Allocation	Cost Labor After Allocation
I	Preparation		Preparation	
1	3 technicians + 1 helper	Rp20.312,50	3 technicians + 1 helper	Rp20.312,50
II	Mechanical Work		Mechanical Work	
2	2 technicians	Rp54.166,67	2 technicians	Rp54.166,67
3	2 technicians	Rp54.166,67	2 technicians	Rp54.166,67
4	3 technicians	Rp40.625,00	3 technicians	Rp40.625,00
5	2 technicians + 1 helper	Rp16.741,07	2 technicians + 1 helper	Rp16.741,07
6	1 technicians	Rp25.000,00	1 technicians	Rp25.000,00
7	2 technicians	Rp27.083,33	2 technicians	Rp27.083,33
8	2 technicians	Rp104.166,67	2 technicians	Rp104.166,67
9	2 technicians	Rp287.500,00	2 technicians	Rp287.500,00
10	2 technicians	Rp129.166,67	2 technicians	Rp129.166,67
11	1 technicians + 1 helper	Rp7.812,50	1 technicians + 1 helper	Rp7.812,50
12	1 technicians + 1 helper	Rp10.267,86	1 technicians + 1 helper	Rp10.267,86
13	2 technicians + 1 helper	Rp15.401,79	2 technicians + 1 helper	Rp15.401,79
III	Electrical Work		Electrical Work	
14	2 technicians	Rp27.083,33	2 technicians	Rp27.083,33
15	2 technicians	Rp14.583,33	2 technicians	Rp14.583,33
16	2 technicians	Rp14.583,33	2 technicians	Rp14.583,33
17	1 technicians	Rp8.333,33	1 technicians	Rp8.333,33
18	9 technicians	Rp178.125,00	2 technicians + 7 helpers	Rp283.125,00
19	2 technicians	Rp25.000,00	2 technicians	Rp25.000,00
20	9 technicians	Rp112.500,00	5 technicians + 4 helpers	Rp172.500,00
21	2 technicians	Rp25.000,00	2 technicians	Rp25.000,00
22	2 technicians	Rp50.000,00	2 technicians	Rp50.000,00
23	2 technicians	Rp79.166,67	2 technicians	Rp79.166,67

No	Initial Labor	Cost Labor	Labor Allocation	Cost Labor After Allocation
24	2 technicians	Rp39.583,33	2 technicians	Rp39.583,33
25	9 technicians	Rp65.625,00	9 technicians	Rp65.625,00
26	3 technicians	Rp43.750,00	3 technicians	Rp43.750,00
27	2 technicians	Rp54.166,67	2 technicians	Rp54.166,67
28	2 technicians	Rp37.500,00	2 technicians	Rp37.500,00
29	2 technicians	Rp37.500,00	2 technicians	Rp37.500,00
30	2 technicians	Rp52.083,33	2 technicians	Rp52.083,33
31	2 technicians	Rp52.083,33	2 technicians	Rp52.083,33
Total Cost		Rp1.709.077,38	Total Cost	Rp1.874.077,38

From the table above, the information of total maintenance cost before and after allocation are already obtained. From the data above, the labor allocation are conducted in activity 18 and 20. There are gap from the cost of labor at activity 18 and 20 between labor cost before and after allocation. The cost gap are occurs because the additional helper in activity 18 and 20. Because the company need to hire the helper, then the company requires to add the cost for the helper. Based on the recommendation from the technician, the additional cost for hire the helper are Rp 15.000,00 for the operational cost while perform the maintenance process. Because of this action, then the cost of labor are increased after the allocation. The calculation of maintenance cost as follows:

1. Initial Cost : Rp1.709.077,38 (Labor Cost) + Rp 1.755.200 (Material Cost) = Rp 3.464.277,38.
2. Cost After Resource Allocation : Rp1.874.077,38 (Labor Cost) + Rp 1.755.200 (Material Cost) = Rp 3.629.277,38.

From the information above, PLTH Bayu Baru need to add cost to hire the helper in order to allocate the labor. From the information above, the cost gap between initial maintenance cost and maintenance cost after labor allocation are Rp 165.000,00. Therefore, the information of additional cost to hire the helper area already conducted. 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 hourly

wage, and for the addition of the next working time the worker gets 2 times the normal hour wage. Therefore, after the labor cost are already calculated, then the information about the maintenance cost after crash by additional 1 hour are shown in Table 4.9.

Table 4.8 Maintenance Cost After Crashing

No	Activity	Normal Cost	Crash Cost	Cost Slope
<b>I</b>	<b>Preparation</b>			
1	Shut Down system control, battery fuse and tools instalation	Rp20.312,50	Rp31.964,29	Rp11.275,92
<b>II</b>	<b>Mechanical Work Inspection and Repairment</b>			
2	Binding blade of wind turbine which connected with orientation	Rp54.166,67	Rp61.666,67	Rp7.258,06
3	Taking down blades, nosle, generator, and wind turbine vane of 1 KW wind turbine west group	Rp154.166,67	Rp61.666,67	Rp7.258,06
4	Identification wind turbine failure	Rp40.625,00		
5	Releasing blades from hub	Rp16.741,07		
6	Balance checking on wind turbine blades	Rp25.000,00		
7	Identification on wind turbine generator	Rp27.083,33	Rp34.583,33	Rp7.500,00
8	Dismantling and replacement bearings on generator	Rp269.166,67		
9	Furling and Replacing 3 phase of generator wires email	Rp894.500,00	Rp295.000,00	Rp3.750,00
10	Dismantling and replacing Bross on slipring	Rp325.166,67	Rp136.666,67	Rp7.258,06
11	Cleaning the ring of generator	Rp57.812,50		
12	Bolt and bosh replacement on wind vane	Rp175.467,86	Rp14.419,64	Rp4.151,79
13	Replacement bolt on the tower	Rp75.401,79		
<b>III</b>	<b>Electrical Work Inspection and Repairment</b>			
14	Dismantling and checking part of system control	Rp27.083,33		
15	Checking and replacing MCB C63, avometer analog, and dioda bridge	Rp254.583,33		
16	Checking indicator of current and voltage on system control	Rp64.583,33		
17	Checking wires indicator from system control into battery	Rp58.333,33		

No	Activity	Normal Cost	Crash Cost	Cost Slope
18	Releasing the battery from connector and checking upper and lower level on accumulator	Rp355.125,00		
19	Checking battery voltage	Rp25.000,00		
20	Checking terminal cable ( + ) and ( - )	Rp172.500,00		
21	Checking connector from battery to inverter	Rp25.000,00		
22	Checking cable from system control to battery	Rp50.000,00		
23	Cooling down battery	Rp79.166,67		
24	Testing battery voltage after cooling down	Rp39.583,33		
25	Releasing the battery from connector	Rp65.625,00	Rp99.375,00	Rp33.750,00
26	Turning on generator dan Charging the battery using generator	Rp43.750,00	Rp55.000,00	Rp10.887,10
27	Checking MCB control from battery to inverter	Rp54.166,67	Rp61.666,67	Rp7.258,06
28	Checking voltage from battery to inverter	Rp37.500,00		
29	Checking cable from battery to inverter	Rp37.500,00		
30	Checking and replacing inverter fuse AC and DC	Rp52.083,33		
31	Turning on and testing the inverter	Rp52.083,33	Rp59.583,33	Rp7.758,62
Total Cost		Rp3.629.277,38	Rp911.592,26	Rp108.105,68
Normal Cost		Rp3.629.277,38		
Crash Cost		Rp911.592,26		
Cost Slope		Rp108.105,68		
Total Cost After Crashing		Rp4.648.975,33		

From the information above, the normal maintenance cost are increase from Rp3.629.277,38 became Rp4.648.975,33 because of the crashing on the critical path by additional 1 hour. These results cause the cost additional for PLTH Bayu Biru which are Rp 1.019.697,95 as the result from the crash cost and the cost slope after additional 1 hour on the critical path in order to decrease the duration of maintenance wind turbine 1 kw. This result already fulfilled the recommendation to perform the improvement in the maintenance of wind turbine 1 kw by decrease the duration to complete the maintenance project. Because, the completion time are

decreased, the additional cost are occurs in order to achieve the target to improve the duration of the project completion time.

Based on the result above, also it is fulfilled the requirement from 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 hourly wage, and for the addition of the next working time the worker gets 2 times the normal hour wage. The calculation for the additional wage are obtained from the calculation of overtime cost. Therefore, the calculation of cost slope or cost which directly arised after crashing method are conducted also already obtained. The value of overtime cost for the technician and helper on each activity which includes in critical path of project activity maintenance wind turbine 1 kw is Rp 911.592,26. Therefore, the value of cost slope for the consequences of crashing method in critical path of project maintenance wind turbine 1 kw by decreasing 1 hours in order to accelerate the project completion duration is Rp 108.105,68.

Based on the calculation above, the estimation of total maintenance cost for wind turbine maintenance 1 kw project with the duration to complete the project 54,1 hours is Rp4.648.975,33. The total estimation cost for maintenance project are increasing from the initial maintenance cost which is Rp3.629.277,38. The cost gap arised because of the crashing method in order to accelerate the project of maintenance wind turbine 1 kw to find the optimum duration to complete to project. Therefore, the crashing method are available to conduct in the maintenance wind turbine 1 kw project by reducing 1 hour of work on critical path activity and add the extra cost for crashing about Rp 1.019.697,95.