CHAPTER 9 Technology Transfer

Chapter 9 Technology Transfer

9-1 Maintenance of Transmission and Distribution Equipment

9-1-1 State of Power Transmission/Distribution Facilities

Trees are in close proximity to transmission lines and distribution lines in many places in Palau, especially the Nekken transmission line, which runs through long sections of jungle. The main case of power outages on the feeder lines along the Nekken line is contact with trees.

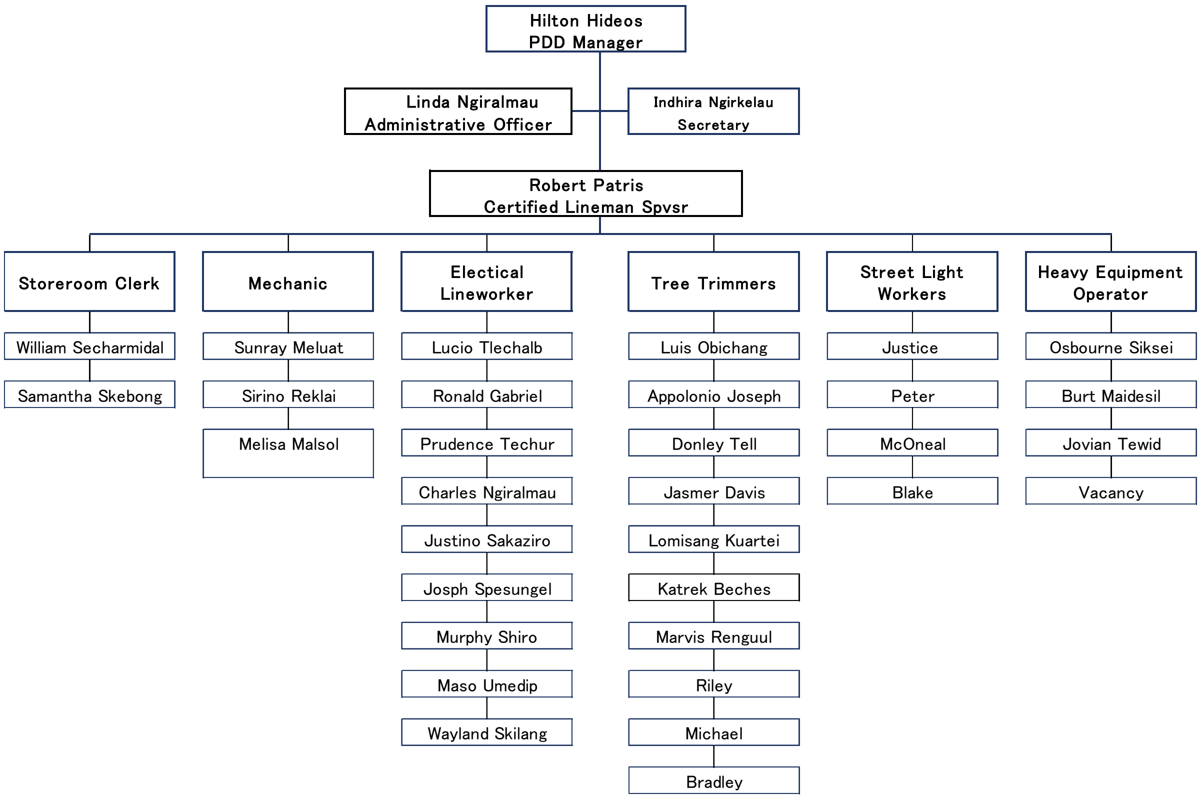
While the major power line facilities are new as a whole and free from any fatal superannuation, many of the sectionalizing switches and reclosing circuit breakers installed in the major 34.5 kV and 13.8 kV power transmission/distribution feeders have been left in faulty states (with some loss of functionality) in spite of their importance for system operation and restoration from faults. Detailed inspection, measurement, and maintenance works and accompanying repair works to address the inspection results do not seem to have been duly implemented.

Additionally, the arms, bolts and other steel materials in the equipment installed near the coastline are recognizably deteriorated by rust.

9-1-2 Organizational Structure Relating to Facility Maintenance and Management Work

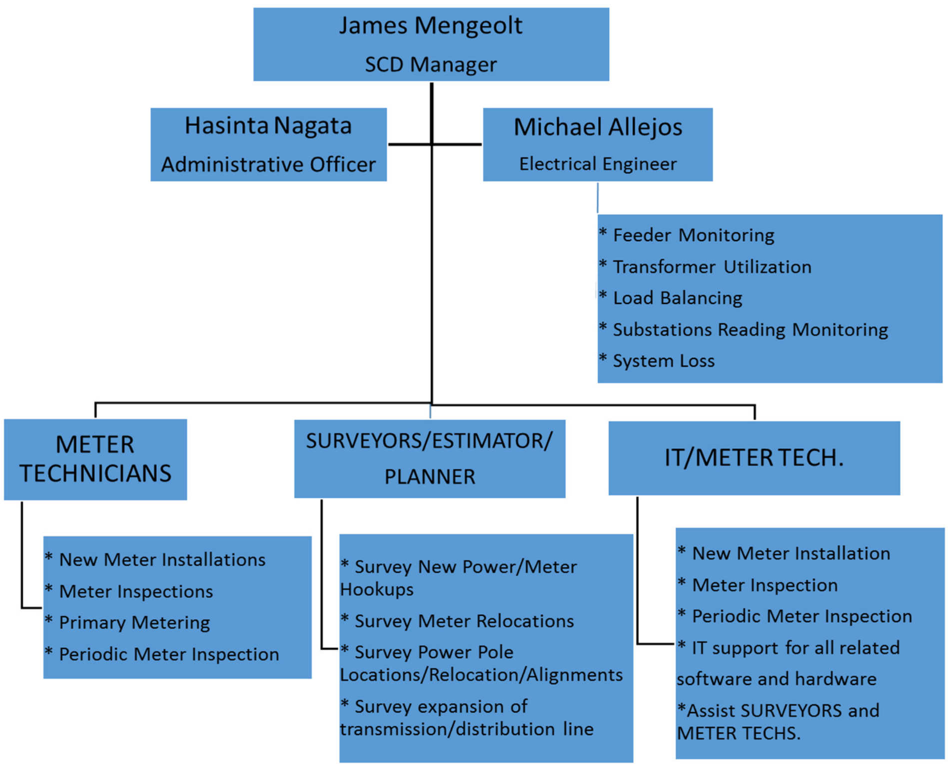
The power transmission/distribution facilities in PPUC are maintained and managed by the Power Distribution Division (PDD) and System Control Division (SCD).

The organizational structures of PDD and SCD are shown in Figure 9-1-2.1 and Figure 9-1-2.2, respectively.



Source: PPUC

Figure 9-1-2.1 Organization chart of the Power Distribution Division (PDD)



Source: PPUC

Figure 9-1-2.2 Organization chart of the System Control Division (SCD)

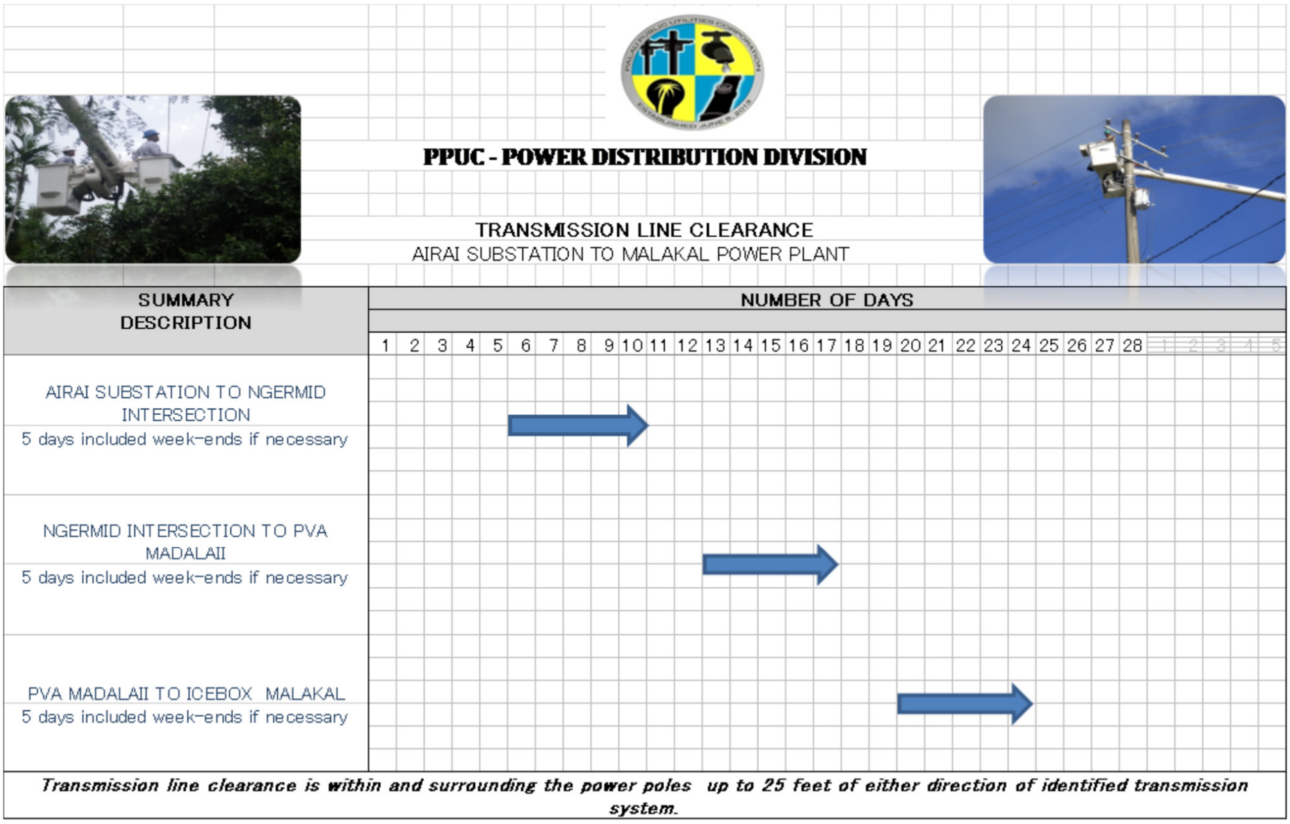
(1) Operations overseen by the Power Distribution Division (PDD) and the present status

PDD installs, replaces, and repairs facilities, restores power during transmission/distribution line faults, patrols and trim trees along the lines, and performs other tasks. Electrical Line Workers, who account for the majority of personnel shown in Figure 9-1-2.1, are in charge of restoration work during transmission/distribution line faults and related facilities. The Tree Trimmers, another large part of the organization, are exclusively engaged in the patrol and trimming of trees close the power lines.

1) Tree trimming work

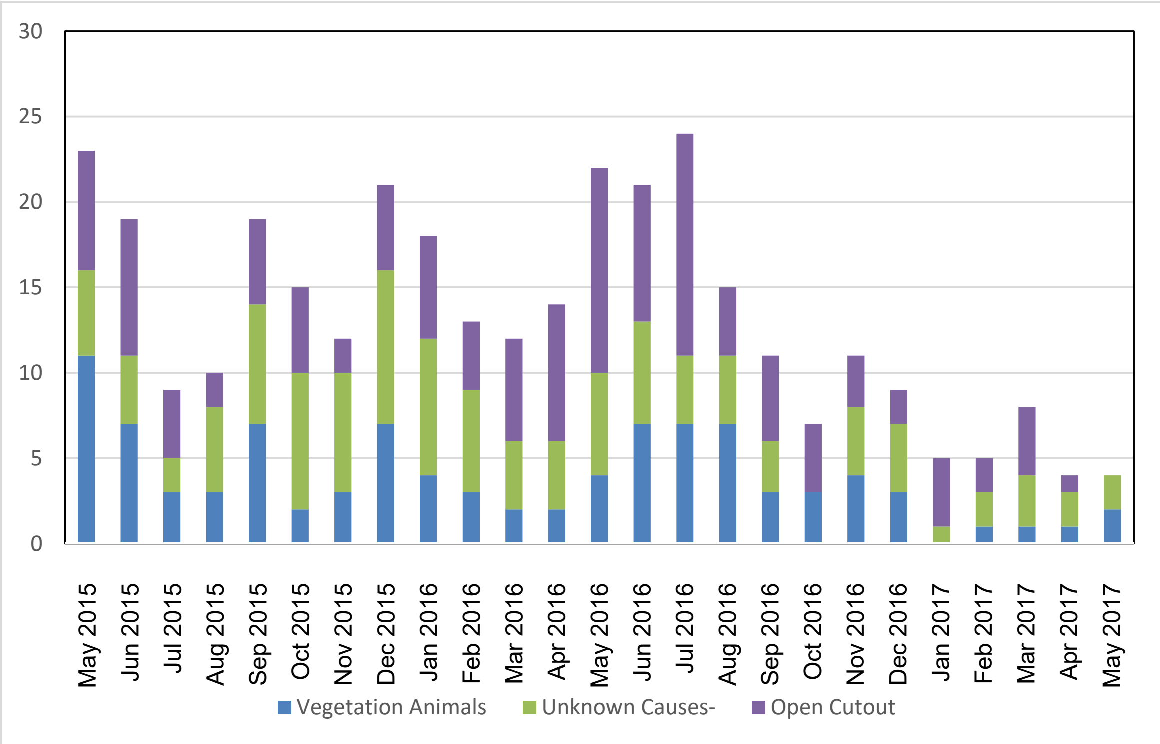
Tree trimming work is carried out systematically (Figure 9-1-2.3) by two teams, each composed of five Tree Trimmers and 5 external subcontractors. These Tree Trimmers and Line Workers are counterparts in the tree management technology transfer (Pilot Project 1).

Under this structure, PPUC is intensively working based on the newly formulated "Tree Management Plan." Figure 9-1-2.4 shows extracted data on a number of factors considered to be deeply associated with tree contact (vegetation & animals, unknown causes, and fuses blown), based on power outage data on Babeldaob Island. Though the number of power outage fluctuates from month to month, it has been reduced substantially during tree trimming period , showing that the ongoing tree trimming efforts have been effective in reducing power transmission/distribution line faults.



Source: PPUC

Figure 9-1-2.3 Monthly tree trimming plan



Source: Factors associated with tree contact (vegetation & animals, unknown causes, and fuses blown) extracted from data provided by PPUC

Figure 9-1-2.4 Trend of the number of power outages on Babeldaob Island (KEIUKL and DESBEDALL areas)

2) Restoration from fault

In the case of restoration from power transmission/distribution line fault, a team of electrical Line Workers (9 persons) takes the lead in emergency survey and repair. In the off-duty hours (including nighttime) two stand-by crews remain constantly on hand. In the event of a major power outage, power is restored by replacing the protective fuses in the power line (Figure 9-1-2.5, 9-1-2.6) or damaged equipment. Details on individual outage cases are shared across the company in Power Transmission/Distribution Line Fault Reports (Figure 9-1-2.7). However, work cycles for sufficient the use of this report aiming at systematic facility replacement (preventive maintenance) have not yet been developed.

Figure 9-1-2.5 PC (primary cutout) enclosed fuse (installed on a power line with a fuse attached inside)

Figure 9-1-2.6 Example of an enclosed fuse installed on a PPUC power line (left, new product; right, after fusing)

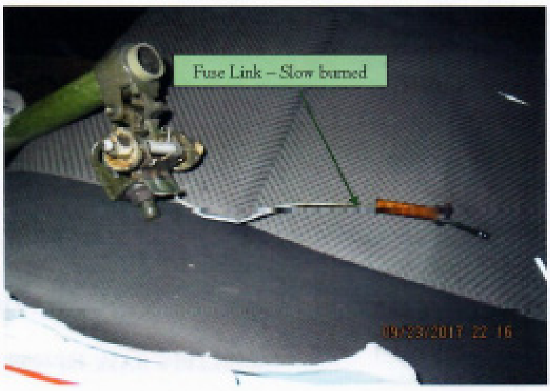
Power Distribution Division

Unscheduled Power Outage

Caller	Customer Service Representative
Date	9/23/2017
Time	9:45pm – 11:30pm
Feeder Affected	None
Cutout	Open (Line B)
Affected Areas	Part of Melekeok State (all customers connected to Line B)
Stand By Crew	Prudence Techur & Charles Ngiralmau
Work	No Power (affected area mentioned above)

PDD Crew

- Crew found an open Cut-Out (Line B) at Melekeok Sewer Pump Station.
- Fuse Link slow burned
- Replaced Fuse Link and closed Cut-Out.
- Power was restored back to normal.



Source: PPUC

Figure 9-1-2.7 Example of a Power Distribution Line Fault Report

(2) Operations overseen by the System Control Division (SCD) and the present situation

SCD shall undertake the inspection and design of power transmission/distribution line facilities (electrical equipment). Organizationally, SCD is composed of managers and three sections with staffs of a few persons each (see Figure 9-1-2-1.2). Its principal operations are the design of new power transmission/distribution facilities, installation and maintenance of energy meters, and the monitoring of power transmission/distribution lines, including the load management of transformers and evaluations power system loss (see Figure 9-1-2-1.2). No section has yet been established, however, to undertake the maintenance and management of major facilities (lines, transformer, switches, etc.).

The above tasks at SCD are supposed to be concurrently carried out by members from the relevant sections described above. In practice, however, SCD lacks the manpower to respond to the tasks. The tasks have in fact been neglected for a long time, largely because the standards, various management documents, and vehicles necessary for the maintenance and management tasks have not been developed or equipped. In other words, the entity that is to become the counterpart in implementing the technology transfer for facility maintenance and management (Pilot Project 3) has yet to be established and accordingly cannot be determined at present.

9-1-3 Planning of the Pilot Project

In light of the field survey on power transmission/distribution facility maintenance and management, as well as survey on work the implementation status, the JICA Survey Team liaised with PPUC to discuss and review how to proceed with the Pilot Project for the technology transfer.

9-1-3-1 Tree management technology (Pilot Project 1)

The JICA Survey Team reviewed the need for adopting materials and equipment that are to be used in the planned Pilot Project and discussed related matters with PPUC. The results are as follows.

(1) Polyethylene insulation tubing

The polyethylene insulation tubing for mitigating tree contacts is generally to be applied in places where the tree-trimming work will be either impossible or too infrequent to keep up with the speed of growth. The field survey, however, clearly showed that the need for applying the tubing on the PPUC transmission and distribution lines has already declined, as shown in a. to c. below. The JICA Survey Team has therefore concluded that tubing is not to be applied as routine work.

a) It was confirmed, as a result of PPUC’s systematic tree trimming started from 2015, that the number of faults caused by tree contacts has decreased. Tree trimming is considered effective as a preventive measure against power outages and is an important effort to continue.

b) There are currently no sites where the application of polyethylene insulation tubing seems to be effective. Part of the Nekken transmission line running through the jungle is the line route targeted for the measures against trees. The line on this route runs a long distance and always under conditions where the chance of tree contact is high. Furthermore, the trees grow so fast that it will be necessary to repeat trimming in these sections. Although the application of polyethylene insulation tubing is intended only as a provisional measure until the trees are trimmed, the tubing could become permanent equipment if applied at the place described above.

c) Power outages to allow the work to install and remove polyethylene insulation tubing would not be desirable at present, from the standpoint of PPUC. Further, tree trimming as a permanent measure would be more operationally efficient than spending much labor on a tentative measure.

(2) Measures to prevent vines

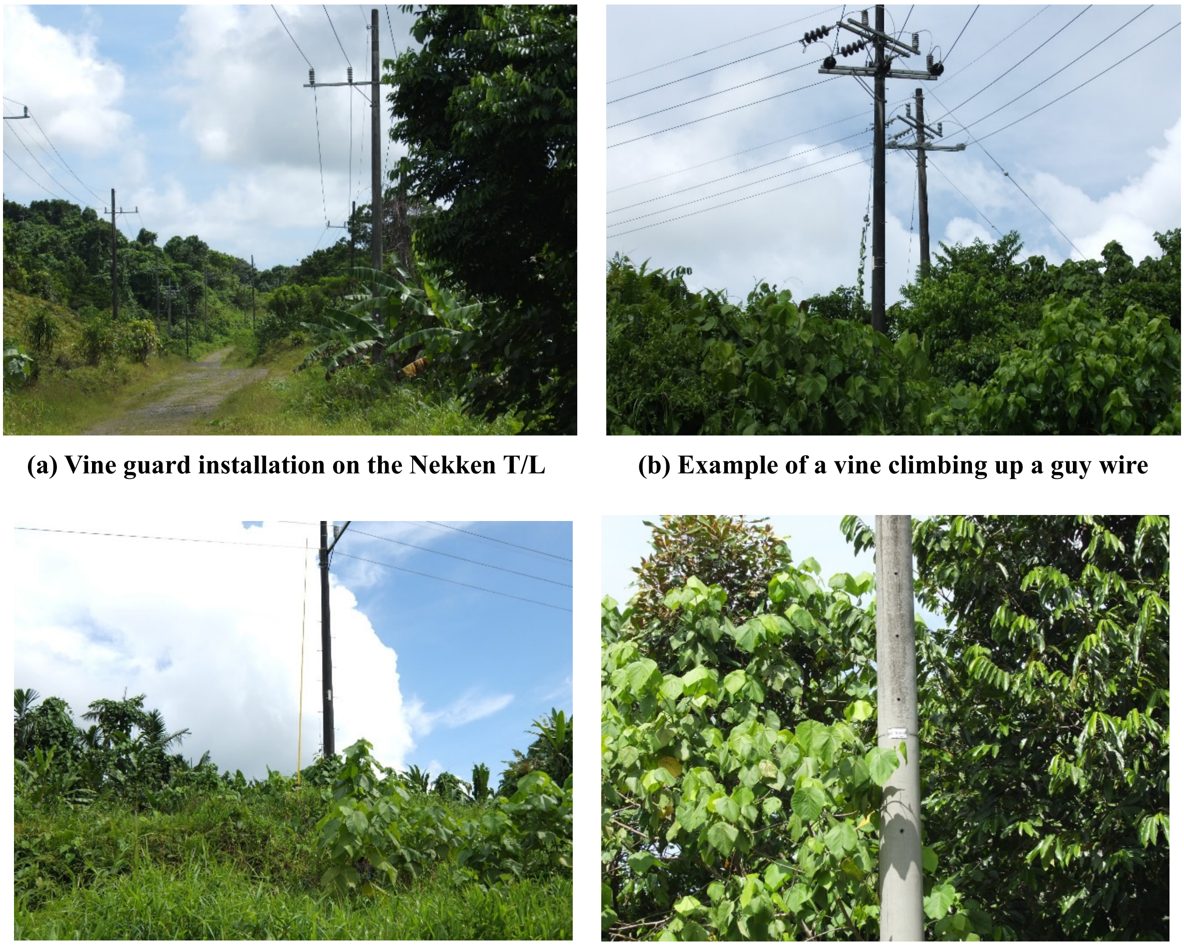
1) Selecting locations to install vine guards and understanding the status of vine growth

Since vines grow more rapidly than other forms of vegetation in general, frequent trimming and other measures distinct from those applied for trees are required. The JICA Survey Team will be installing vine guards for the purpose of either omitting trimming work or reducing the frequency with which it has to be performed. The target facility for installation is the Nekken transmission line, which has frequent short-time power outages, transient faults that are not attributable to known causes but are assumed to be caused by tree contact.

Poles and guy wires near the outgoing line from Aimeliik Substation have been mainly selected as specific candidate points for installation, based on discussions with PPUC. This section is important to the reliability of the system, as the Nekken transmission line and Aimeliik-Malakal transmission line are laid on the same pole.

This effort was started by conducting a survey to select the installation locations, and the poles and guy wires subject to the installation have been determined. Under the current plans, poles combined with guy wires are to be installed at 66 locations (as of November 30, 2017). Examples of vine growth at the time of the survey (before the installation of the vine guard) are shown in Figure 9-1-3-1.1.

Because the vine guards procured outnumber the above-stated numbers, the remaining materials are to be adopted to lines nearer to the end than Kokusai Substation in the Nekken transmission line.



(a) Vine guard installation on the Nekken T/L **(b) Example of a vine climbing up a guy wire**

(c) Measurement of the distance from the wire **(d) A pole that a vine may climb up**

Figure 9-1-3-1.1 Results of the survey on vine guard installation locations

2) Documents for managing vine guard installation locations and the status of vine growth

We will conduct a fixed-point observation to check the effects of vine guard installation and assess the speed of vine growth. A management sheet has been created for this purpose. (Figure 9-1-3-1.2)

Vine guards to be installed at the above-mentioned survey locations (90 vine guards for poles and 80 for guy wires) were procured and provided to PDD. These materials should be installed at the necessary locations as soon as the above-mentioned survey of the Nekken transmission line is completed.

PALAU PUBLIC UTILITIES CORPORATION										
POWER DISTRIBUTION DIVISION										
Management table of vine prevention material										
Line/Location:		AIMELIIK POWER PLANT TO NEKKEN SUBSTATI(			Date:	2017/11/27	Supervisor:	ROBERT PATRIS		
Pole No.	Location/ID	Equipment (Pole or Guywire)	Clearance from Conductors						Growing	Effect of Material
			Date 1st survey	Length from hardware	Date 2nd survey	Length from hardware	Date 3rd survey	Length from hardware	Length/week	
1	Aimeliik	BOTH	2017/11/27	36FT						
2	Aimeliik	BOTH	2017/11/27	36FT						
4	Aimeliik	GUY	2017/11/27	38FT						
6	Aimeliik	GUY	2017/11/27	36FT						
16	Aimeliik	POLE	2017/11/27	35FT						
17	Aimeliik	POLE	2017/11/27	32FT						
18	Aimeliik	POLE	2017/11/27	36FT						
27	Aimeliik	BOTH	2017/11/27	35FT						
39	Aimeliik	GUY	2017/11/27	35FT						
42	Aimeliik	POLE	2017/11/27	32FT						
50	Aimeliik	POLE	2017/11/27	37FT						
51	Aimeliik	BOTH	2017/11/27	38FT						
56	Aimeliik	GUY	2017/11/27	35FT						
57	Aimeliik	POLE	2017/11/27	35FT						
63	NEKKEN SUB	POLE	2017/11/27	38FT						

Figure 9-1-3-1.2 Vine guard management sheet (Source: created by the Survey Team)

(3) Detection of sections with frequent tree contacts using overcurrent indicators

1) Background leading up to the overcurrent indicator installation

PDD trims trees systematically in all 34.5 kV power transmission line sections, including the Nekken transmission line. If this work is carried out without fail, power transmission faults due to tree contact will not often occur. Hence, the installation of polyethylene insulation tubing may be unnecessary.

If, however, trees grow faster than expected or the tree trimming is delayed, the frequency of short-term outages (transient faults) caused by tree contact will increase again. We will address this circumstance by identifying sections where outages are caused and finding the causes, and use our results to set the review priority in the tree trimming plan. By following this process, more overcurrent indicators will be installed in sections subject to high tree risks along the Nekken transmission line. Through the above approach, we will accumulate data on transient fault in order to detect the sections where they frequently occur.

The subdivision of sections where overcurrent indicators are to be installed will also further facilitate fault investigation. We therefore also plan to install about 10 sets on distribution lines on Koror Island with a view to improving the quality of operations in urban areas (with high load density).

2) Specifications of the overcurrent indicators

The specifications of two types of overcurrent indicators to be installed at the sites are shown in Table 9-1-3-1.1. The external appearances of these indicators are shown in Figure 9-1-3-1.3

The Nekken transmission line bears a low load over a long distance, so fault current at the end of the line will be low. Considering this, the overcurrent indicator's fault detection sensitivity has been set to 50A and more. The range of the corresponding load current is 10-25 (A).

Table 9-1-3-1.1 Specifications of the overcurrent indicators

Type [Model]	AR360 [AR360-4-8]	AR-OH [BTRI0050IR4N]
Trip Threshold Range（A）	50	50
Load Current (A)	10～25	10～25
Maximum Fault Current	25 kA for 10 Cycles	25 kA for 10 Cycles
Trip Response Time	24 ms, Nominal	24 ms
Permanent Flash Clearing Time 50 and 100 A Trip Levels	4 Hours	4 Hours
Temporary Flash Clearing Times	8 Hours	4 Hours

Source: SEL Overhead Auto RANGER Instruction Manual, Modified by the JICA Study Team

(1) AR-OH　　　　(2) AR360

Source: SEL Overhead Auto RANGER Instruction Manual

Figure 9-1-3-1.3 Appearance of the overcurrent indicators

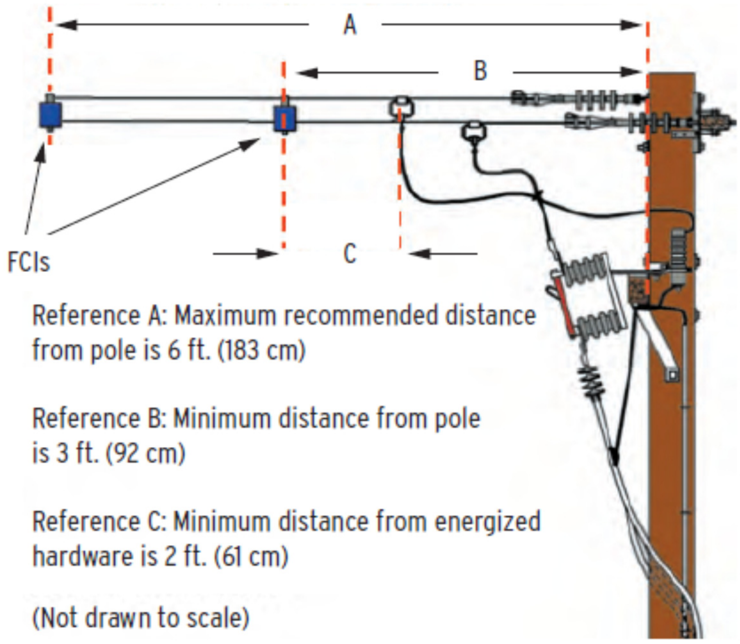
Table 9-1-3-1.1 shows the states and functions of the overcurrent indicators in operation.

Figure 9-1-3-1.4 illustrates how an overcurrent indicator is installed on a pole.

Table 9-1-3-1.2 States and behaviors of an overcurrent indicator in operation

State	Description
Reset	All parameters and inputs reset to default values. LEDs flash in a reset pattern.
Normal	When voltage and current are detected, the unit begins auto-ranging. Armed for fault detection and inrush event detection.
Intermediate	Two-minute timeout period after fault current detection.
Temporary Fault	If voltage and current are detected after an Intermediate State delay, the unit is rearmed for fault detection and inrush event detection. LEDs flash in a temporary pattern. A reset countdown is executed here for a temporary fault.
Permanent Fault	If no voltage or current is detected after a two-minute delay, the LEDs flash in a permanent pattern. A reset countdown is executed here for a permanent fault.
IR Lockout	Three-minute timeout period after a loss of current or voltage is detected.

Source SEL Overhead Auto RANGER (AR-OH/AR360) Instruction Manual



Source: SEL Overhead Auto RANGER® (AR-OH/AR360) Instruction Manual)

Figure 9-1-3-1.4 How to install an overcurrent indicator on a pole

3) Method to detect sections with frequent faults using an overcurrent indicator

An overcurrent indicator has already been installed at each substation (34.5/13.8 kV) of the Nekken transmission line. In addition to these, this project will install similar types of overcurrent indicators will in sections of the power transmission line passing through the jungle (about 40 locations).

Under these conditions, a patrol will be dispatched upon the occurrence of every fault on the Nekken transmission line (including transient faults) to check the overcurrent indicator and identify the section that caused the fault. These data will be filled in the record sheet (Figure 9-1-3-1.5) and compiled on a monthly basis to detect sections with problems.

4) Change of the workflow in the event of a fault

PPUC only recognizes permanent faults as long power outages. When such a fault occurs, a team of Line Workers (PDD) carry out the restoration work and prepare a report. In this workflow, PDD receives no information relating to transient faults. Information on transient faults is only known to the operators of the power stations and substations.

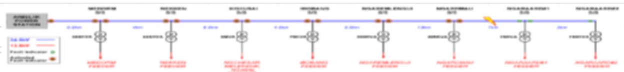
To detect sections where faults frequently occur, the operators of the power stations and substations would have to inform the Line Workers (PDD) every time a fault occurs and dispatch them out on patrol. To create the data shown in Figure 9-1-3-1.5, therefore, the workflow has been changed to ensure that the operators of the power stations and substations promptly inform the Line Workers (PDD) of even transient faults.

5) Data accumulation on a trial basis

Since overcurrent indicators have already been installed in eight locations on the Nekken transmission line, sections with frequent faults can be detected in the system even in its current status. With the abovementioned change in the workflow for the notification of fault information, training on how to collect the data will have to be provided.

Until more overcurrent indicators are procured, the JICA Survey Team will continue to provide instructions on the collection of data from the existing overcurrent indicators. The procedures taken by the Line Workers (PDD) in this trial are described in Figure 9-1-3-1.6.

PALAU PUBLIC UTILITIES CORPORATION
Power Distribution Division (SYSTEM CONTROL DIVISION)
Record OF POWER INTERRUPTION of Nekken Line



No	TIME						Fault Section Indicated by Overcurrent indicator																	
	DATE	CB TRIP	CB CLOSE	DURATION (min)	Kind of Fault	CAUSES & Relay Indication	Aimerik APP-CB		Medorm SS1		Medorm SL1		Nekken SS2		Nekken SL2		Koknsai SS3		Koknsai SL3		Ibobang SS4		Ibobang SL4	
1	2017.11.29	15:49	15:50	1	Transient	Over current 1.5kA,Phase-C, Unknoun		1																
2	2017.11.30	8:10	9:00	50	Permanent	Over current 1.5kA,Phase-A, Tree touch						1												
3	2017.12.01	12:00	13.2	80	Permanent	Customer call, Fuse Blown								1										
4																								
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22																								
23																								
24																								
25																								
	SUM (Fault)							1		0		1		1		0		0		0		0		0

The Information of Transient, Fault from Operator (All information in Red column)

Count for 34kV Line faulit(Primary of Trans. (Yellow colomn)

Fill in "1" into the column(Section between SL1(Flash and SS2(No Flash)---- Border of Flash condition

Count for 13kV Line faulit(Secondary of Trans (Green colomn)

Figure 9-1-3-1.5 Record sheet indicating sections where faults have occurred

Training (Activity) for Detecting Sections with Frequent Faults
2. Follow up fault indicator status after every transient outage. Fault indicators have been installed at 16 locations along the Nekken 34.5 kV transmission line. The collection and recording of all relevant SCADA information (protection device, nature of trip) and fault zones (as based on the fault indicator status) after every transient fault over time will help PPUC build up a 'picture' to aid in the identification and rectification of "unknown" transient faults on the Nekken line. The collection of this data over time will also enable PPUC to map the reliability of sections of the line and improve network reliability by further directing resources to areas in need. For instance: a. A transient fault occurs on the Nekken line, followed by a successful reclose. b. The power station operator contacts the line crew dispatcher and informs him of the details of the transient fault. c. The line crew dispatcher instructs the line crew to identify the section of the line where the fault occurred. d. The line crew uses fault indicators to identify the section of the line where the fault occurred. e. The line crew follows the section of the line in detail, looking for the possible cause of the fault. f. The line crew reports the findings, including the section of the line and possible sources of the fault. g. Reports are entered into a spreadsheet or database. h. Monthly and quarterly reports are generated to observe the trends in the incidence and locations.

Source: Evaluation of the PPUC Power Transmission & Distribution System Due to Numerous Unknown Tripping Events, ISS REF#: 13808)

Figure 9-1-3-1.6 Procedures for section identification work after a transient fault

9-1-3-2 Facility maintenance and management technology (Pilot Project 3)

In transferring technology related to facility maintenance and management, SCD is the counterpart. Note, however, that there are some problems in the implementation, as mentioned above.

(1) Creation of maintenance guidelines for power transmission/distribution lines

Though SCD recognizes the need for preventive maintenance, no standards for facility patrol and inspection have been developed. In response, the JICA Survey Team has created a "TRANSMISSION & DISTRIBUTION OVERHEAD LINE MAINTENANCE GUIDELINE" (draft) to set out the basis for facility maintenance and management. Figure 9-1-3-2.1 shows part of the GUIDELINE.

The guideline specifies the inspection items and cycle required for maintaining a certain level of reliability in the main components of the power transmission/distribution lines. A maintenance plan that takes this guideline and the present status of the equipment into account should be formulated and implemented.

The GUIDELINE (draft) prepared is only a draft recommended by the JICA Study team. The exact specifications, cycle, and other details need to be revised into what PPUC's department in charge thinks is appropriate. From this viewpoint, the JICA Survey Team is currently asking the SCD Manager to consider opinions on revisions for the GUIDELINE (draft).

3. RECOMMENDED SCHEDULES FOR PATROL

Table: Maintenance Standard (Patrol)

No.	Equipment / Items	Points to be checked / noted	Remarks	Frequency
1	Overhead Distribution Line (13.8 kV and Low voltage)	Defect points of all facilities, including clearance from trees	Take corrective action according to the criteria	Yearly
2	Underground Distribution Line (13.8 kV)	Terminal box for cable, excavation work by other companies	Take corrective action according to the criteria	Yearly
3	Overhead Transmission Line (34.5 kV)	Defect points of all facilities, including clearance from trees	Take corrective action according to the criteria	Yearly
4	Underground Transmission Line (34.5 kV)	Terminal box for cable, excavation work by other companies	Take corrective action according to the criteria	Yearly

Figure 9-1-3-2.1 TRANSMISSION & DISTRIBUTION OVERHEAD LINE MAINTENANCE GUIDELINE (draft)

(2) Creation of patrol checkpoint manual

The JICA Survey Team has created a "Checkpoint Manual" (draft) containing know-how on the checkpoints and criteria for judging the degree of deterioration when conducting facility patrols and inspections. Figure 9-1-3-2.2 shows part of it.

The contents of this manual (draft) are mainly based on the experience of JICA study team. The draft, therefore, should be revised to reflect actual state of PPUC's equipment, PPUC's experience, etc. for application to PPUC's practical operations. From this viewpoint, the JICA Survey Team is currently asking the SCD Manager to consider opinions on revisions for the GUIDELINE (draft).

Arm

Checkpoint		Defect Criteria	Treatment
State of arm fitting	Rotation of the fitting band	Rotated by more than 30 degrees.	Issue a repair form if the bind wire is broken and replace the bind wire immediately.
	Slanted	Slanted by more than 10 degrees.	
	Twisted (loose arm bolt)	A bolt can be seen between the pole and the arm.	
Condition of the arm	Rusted	More than 60% of the arm is rusted.	Issue a repair form.
	Deformed	Bent.	
	Rotted (wooden arm)	The edge is worn away or overed with moss.	

Figure 9-1-3-2.2 "Checkpoint Manual" (draft)

(3) Creation of the Patrol and Inspection Report (form)

After conducting a patrol and inspection, the results should be recorded and analyzed to prepare for equipment replacement and the next maintenance work. SCD, however, has yet to develop an organization to either undertake this work or create a record form. In response, the JICA Survey Team created a Patrol and Inspection Report form (Figure 9-1-3-2.3) and instructed SCD to apply it in its actual work.

	Report and Record for (Periodic) Patrol and Inspection							
	LINE Name			Date			Person in charge	
No.	Location (Pole ID)	Equipment	Rating	Year of manufacture	Situation about Deterioration	Approach for Maintenance	Photo No.	Comment(Remarks)
Example of description	AA1	Transformer	50kVA Fuse(4A ?)	1998	✓Heavy Rust of tank ✓Chipping of Bushig or Insulator ✓Oil Leakage ✓Over heating(Temp?) ✓Lack of Arrester ✓Inappropriate Fuse ✓Over heating of connection	✓Replace? ✓Repairing Parts? ✓Re-painting? ✓Check under the Shortened interval		✓Select typical word
Example of description	AA2	Pole	✓Concrete or Steel ✓Length: 14m ✓Stlength:500kg	2001	✓Crack of Concrete ✓Rebar exposure ✓Large Inclination ✓Large bend ✓Clearance from other objectives ✓Abnormal arrangement ✓Wooden arm or Heavy Rust? ✓Broken strand ✓Chipping of Insulator ✓Over heating of connection	✓Replace? ✓Repairing Parts? ✓Re-painting? ✓Check under the Shortened interval		✓Fill in proper word freely or ✓Select typical word
	AA2	Stay (Guy Wire)						
	AA3	Switchgear			✓Chipping of Insulator ✓Over heating of contact ✓Operation mechnism			

Figure 9-1-3-2.3 Patrol and Inspection Report (form)

(4) Implementation cycle for preventive maintenance work (PDCA cycle)

The preventive maintenance of facilities is achieved through facility maintenance and replacement/repair work. Facility maintenance and replacement/repair work are performed for the purposes of "ensuring public safety" and "preventing power outage by faults." The work consists of finding faulty facilities through patrols, inspection, and measurement and then controlling and replacing/repairing them as priority dictates.

Patrol, inspection, and measurement works are to be carried out based on the TRANSMISSION & DISTRIBUTION OVERHEAD LINE MAINTENANCE GUIDELINE and Patrol Checkpoint Manual, mentioned in the previous section. To maintain the power transmission/distribution facilities at an appropriate level of reliability on a continuous basis, we should grasp the signs of deterioration of facilities from the data obtained in these works and draw up an appropriate replacement/repair plan. Furthermore, the replacement/repair work should be implemented steadily based on that plan.

Figure 9-1-3-2.4 presents the series of works that need to be carried as a cycle.

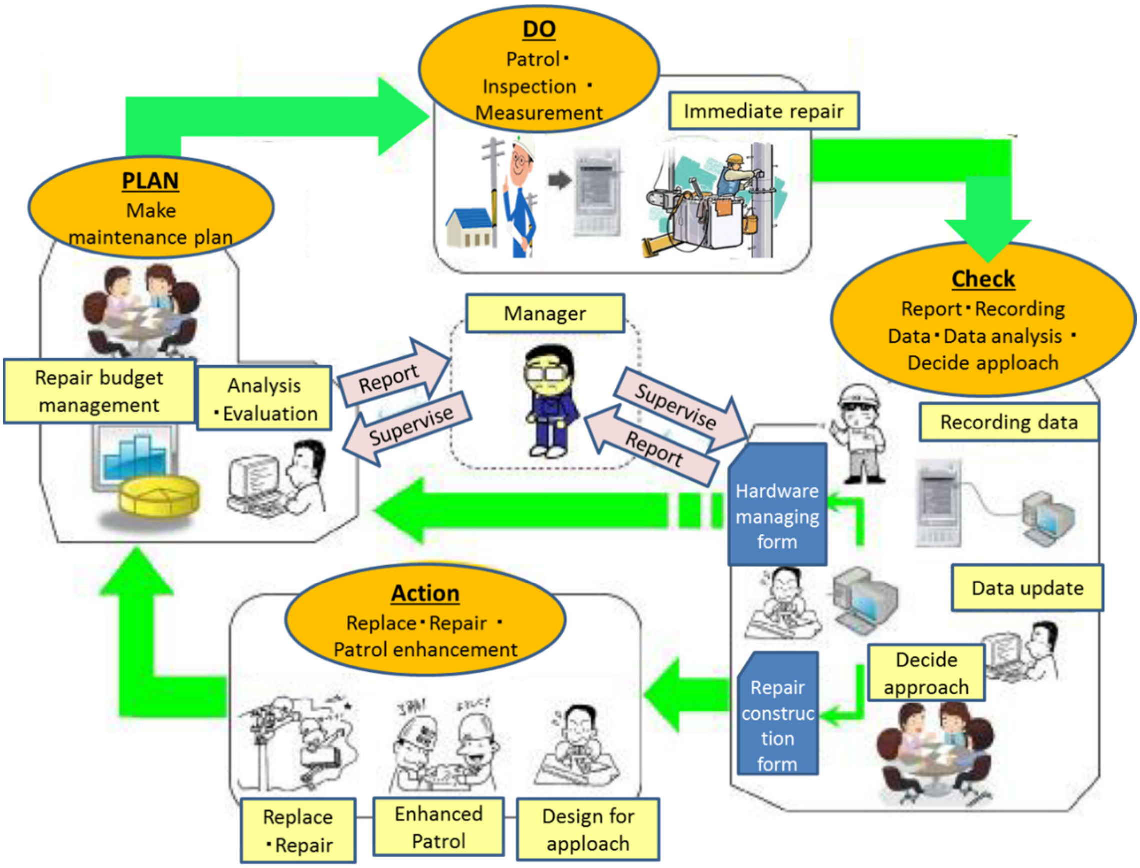


Figure 9-1-3-2.4 Cycle of preventive maintenance works

The key points of the works carried out in the cycle of preventive maintenance works are summarized in Figure 9-1-3-2.4.

In Pilot Project 3, we created "TRANSMISSION & DISTRIBUTION OVERHEAD LINE MAINTENANCE GUIDELINE" and "Patrol Checkpoint Manual." The JICA Survey Team will also be transferring technologies applied in the cycle of preventive maintenance works shown in Figure 9-1-3-2.4 and Figure 9-1-3-2.5.

PLAN	**Formulation of the equipment maintenance pla** ✓ In order to secure the accuracy of equipment data base, first, update the data based on the result of past patrol / inspection / repair record. ✓ Based on the result of the last patrol / inspection analysis of previous cycle, formulate the maintenance plan for the next cycle.

DO

Grasping the condition of the equipment

Grasp the condition of equipment such as abnormality or deterioration (eg, the situation of poles peeling off and the rust of the transformer) and confirm the consistency between the site situation and equipment data registered in the database .

Patrol	Inspection/Measur ment	Outage report
By visual check of the current equipment condition, judge the soundness of the equipment up to the next patrol.	✓Inspection: Examine each part of the target equipment precisely using five senses as visual inspection or using function testing tools etc. ✓Measurement: In order to grasp the condition of deterioration by operation period etc., investigate the equipment using a measuring instrument.	Report outages of permanent / transient fault

Check	✓ Consider the action based on the result of patrol / inspection / measurement. ✓ Result (evidence) of patrols / inspection / measurement shall be recorded for a certain period regardless of the presence or absence of defects. ✓ By accumlation and trend analysis of fault data etc., detect the progress situation or the area of equipment degradation. Through the process, grasp the priority point/area of maintenance.

Action

repair

Carry out the following repair (as precautionary measure) according to the situation or degree of deterioration.

replacement	repair(including painting)	increment of frequency of patrol/inspection
✓ Replace the equipment promptly if risk of outage or public disaster seems high. ✓ If the urgency is low, replace it in the plan.	Minor defects are repaired on the site	✓ In case the degree of deterioration is large but not so bad for planned replacement ✓ Such place as fast growing trees are approaching

Figure 9-1-3-2.5 Key points of the preventive maintenance work cycle

9-1-4 Implementation of the Pilot Project

9-1-4-1 Tree management technology（Pilot Project 1）

(1) Measures to cope with vines

1) Grasp of the actual status of vine growth and selection of vine guard installation sites

A. Installation of vine guards

The JICA Study Team purchased vine-guards (80 vine guards for utility poles and 90 for guy wires) for the Nekken transmission line in Nov. 2017. (Figure 9-1-4-1.1). The materials were attached to utility poles at the preselected candidate sites (installation work carried out by PPUC in Dec. 2017).

(a) Vine-guard for poles (b) Vine-guard for guy wire

Figure. 9-1-4-1.1 Vine-guard

B. Change after vine guard attachment

In Apr. 2018 (3 to 4 months after installation work), we investigated the status of vines climbing up and wrapping themselves around the utility poles and guy wires. The site surveyed for the sample check was located between the Aimeliik power station and Compact Road. This is a critical section, because the Nekken transmission line and Aimeliik-Malakal transmission line are co-located on the same utility poles. The vine guards proved to be effective: while vines had spread over the ground surface at the attachment point of the vine-guard, they did not climb up the utility poles or onto the guy wire.

Sample surveys were also done approximately 6 months and 12 months after installation. Almost no wrapping of vine was seen in the places where the guards were attached, (Figure 9-1-4-1.2). Vine wrapped slightly around one guy wire, but the tip of the vine had already died and no further growth was expected (Figure 9-1-4-1.3).

Figure 9-1-4-1.2　Status of vine near a utility pole

Figure9-1-4-1.3　Vine winding around a guy wire

C. Effect vine guard attachment

Figure 9-1-4-1.4 shows an example of a vine near a utility pole that has not climbed up or wrapped itself around the equipment. The tip of the vine apparently dies when it contacts the vine guard, precluding any further growth (Figure 9-1-4-1.5). Figure 9-1-4-1.6 shows an example of vine that has grown but has not wrapped around the pole.

Fig. 9-1-4-1.7 shows a length of vine (about 1.7 m) wrapping itself around a discarded wire without climbing up an adjacent pole protected with a vine guard. A remarkable difference can between the cases with and without a vine guard attached.

Fig. 9-1-4-1.8 shows a vine wrapping itself around a guy wire without a vine guard. This wine grew about 3 to 4 meters over the period between Nov. 2017 and Apr. 2018. The vine guards seem to be effective in preventing the rapidly growing vines from wrapping themselves around the equipment.

Figure 9-1-4-1.4　A vine spreading

Figure 9-1-4-1.5 Dead tip of a vine

Figure 9-1-4-1.6 A vine prevented from climbing the equipment

Figure 9-1-4-1.7 A vine guard preventing growth

Figure 9-1-4-1.8 Growth on guy wires without a vine guard

D. Growth speed of vine and patrol frequency

Considering the speed of the vine growth (3-4 meters / 6 month) and the sufficient effects of the vine guards confirmed by the site observations, a patrol interval as long as 6 months seems appropriate for the patrol visits to the sites where vine guards are attached.

In the situations shown in Figure 9-1-4-1.7 and Figure 9-1-4-1.9 (a), however, there turns out to be some risk that the vine will climb up through the detour route. For such places, it will be necessary to determine the appropriate position to attach the vine guards.

PDD is carrying out a general tree patrol for the 34.5 kV transmission line in every month. The points of vine guard attachment can therefore be patrolled during the general tree patrols.

(A) Growth through the detour route of a pole

(b) Winding around a guy wire

Figure 9-1-4-1.9 Status of vine growth (no vine guard attached)

E. Establishment of utilization of management materials

PPUC has started a once-monthly patrol to sites where vine guards are attached. Some of the results from the patrols are shown in Figure 9-1-4-1.10. Not much change was observed between before and after vine guard attachment, so only the date of the patrol is filled out in the sheet. Periodic work to manage vine contact is being established in this way.

PALAU PUBLIC UTILITIES CORPORATION

POWER DISTRIBUTION DIVISION

Management table of vine prevention material

Line/Location:		NEKKEN SUBSTATION TO KOKUSAI SUBSTATION				Date:	2017/11/28	Supervisor:	ROBERT P/	
Pole No.	Location/ID	Equipment (Pole or Guywire)	Clearance from Conductors						Growing	Eff Ma
			Date 1st survey	Length from hardware	Date 2nd survey	Length from hardware	Date 3rd survey	Length from hardware	Length/week	
83-B		POLE	2017/11/28	34FT	9-Jan-18					
86-B		POLE	2017/11/28	28FT	9-Jan-18					
97-B		GUY	2017/11/28	42FT	9-Jan-18					
94		POLE	2017/11/28	43FT	9-Jan-18					
107		GUY	2017/11/28	38FT	9-Jan-18					
119		POLE	2017/11/28	28FT	9-Jan-18					
128		POLE	2017/11/28	38FT	9-Jan-18					
129		POLE	2017/11/28	28FT	9-Jan-18					
131		GUY	2017/11/28	38FT	9-Jan-18					
132		POLE	2017/11/28	35FT	9-Jan-18					
142		GUY	2017/11/28	15FT	9-Jan-18					
144		GUY	2017/11/28	10FT	9-Jan-18					

Figure 9-1-4-1.10 Table for managing vine guard attachment points

Note, also, that the pole number, a basic piece of information for checking the target equipment, has been lost in most poles. As a consequence, the patrol work can be difficult for various unspecified persons to manage. This is a general problem in PPUC's power transmission and distribution facilities. The problem will have to be resolved as soon as possible in order to perform continuous and precise facility management and accurate system operation.

(2) Use of overcurrent indicators to detect sections that frequently come into contact with vegetation (grasp of the fault occurrence trend)

An overcurrent indicator flashes when an overcurrent caused by a fault passes through the line. These indicators are to be installed the Nekken transmission line (target site for this pilot project) in order to detect sections with frequent faults. Candidate installation locations for the indicators on the Nekken transmission line were confirmed with PDD (December 2017).

1) Procurement and installation of overcurrent indicator

Overcurrent indicators arrived in Palau in August 2018 and were received by PPUC. PDD installed them on the Nekken transmission line. In the 6th survey in Oct. 2018, the JICA Study Team checked the site with PDD on site and confirmed that the overcurrent indicators were properly installed (number installed on the Nekken transmission line: 19 sets × 3 phases = 57 pieces). Figure 9-1-4-1.11 shows an example of overcurrent indicators installed on overhead lines.

Previously there were 16 sets of overcurrent indicators installed on the Nekken transmission line, dividing the line into 16 sections (including 8 substation sections) to detect faults. With the addition of the newly installed indicators, the line is now divided into 35 sections and the system for grasping the fault occurrence trend is enforced.

Figure 9-1-4-1.11 Example of overcurrent indicators installed (line around Kokusai substation)

2) Results on the detection of sections with frequent faults and the status of work implementation

In the period between Nov. 2017 and Apr. 2018, only two faults occurred in the Nekken transmission line. In one case, a patrol was sent out to check the indicator according to the prescribed procedure (the cause was contact with a windblown branch, Fig. 9 -1-4-1.12). In the other case, no trip information was transmitted from the substation operator to the lineman, so no patrol was dispatched.

Figure 9-1-4-1.12 Windblown branch (cause of a fault)

Next, we checked the situation in the period between March to July 10th, 2018.

Five transient faults (causes: unknown) and one general fault (cause: contact with wildlife) occurred in this period. Compared with the situation before November 2017, transient faults had drastically decreased to a number too low to enable any detection of sections subject to frequent faults. The steady implementation of tree trimming and vine guard attachment is thought to have helped prevent faults in the Nekken line.

PDD, however, dispatched a patrol to identify the cause for only one of the five transient faults mentioned above. In the remaining four cases, the power plant operator provided no information on the faults occurred to PDD. The work rules for patrols of overcurrent indicators were not well established. We responded by advising the power plant operators to inform PDD of all faults occurring without fail, including transient ones.

The number of faults in the Nekken transmission line has been drastically decreased. It appears, however, that there have yet to be established rules for patrols of overcurrent indicators when faults occur.

9-1-4-2 Facility Maintenance and Management Technology (Pilot Project 3)

(1) Implementation of periodical inspection

1) Implementation of periodical inspections for preventive maintenance

One of the technology transfer items we proposed in this project was the implementation of line work using the PDCA cycle for preventive maintenance. In response to this proposal, PPUC conducted a periodic inspection of the trunk lines for the transmission and distribution lines in Feb. to Mar. 2018.

To implement the inspection, the SCD Manager formed a team of four people to examine the facilities in detail with telescopes. In the process, they also measured the temperature rises of various equipment (pole transformers, electric wires, connection points) with an infrared camera.

Table 9-1-4-2.1 shows the trunk lines inspected.

Table 9-1-4-2.1 Trunk lines examined in the periodic inspections

Facility	line name
34.5 kV transmission line	Aimeliik - Airai
13.8 k V distribution trunk line	Airai-Koror
	Malakal-Koror
	Meyuns

2) Inspection results

As an example of inspection results, Figure 9-1-4-2.1 shows the report on the inspection described in the previous section. Table 9-1-4-2.2 partially lists the inspection results attached to the report. The 'Remarks' column in the report contains descriptions of defects found in the utility poles. The 'Recommendation' column summarizes measures to be taken in the future. The comments entered suggest actions (repair/replacement, detailed inspection, etc.) that PDD should take as the next step of PDCA cycle.

Based on the form shown in Table 9-1-4-2.2, the JICA Study Team proposed a revised report format that would enable PPUC to keep track of the status of actions until the defects were completely eliminated (Table 9-1-4- 2.3).

3) Establishment of an operation cycle corresponding to the PDCA cycle

Table 9-1-4-2.4 (a) and Table 9-1-4-2.4 (b) are expanded views of the latter halves of Tables 9-1-4-2.2 and 9-1-4-2.3, respectively. The processing status of the defects pointed out in the inspection report is managed using the status check table (Table 9-1-4-2.4 (b)) added after Table 9-1-4-2.4 (a). This form is stored in a common server where it can be accessed and updated by related persons in SCD and PDD as necessary. Hence, the work process for this form is established.

Judging from situation described above, it appears that the preventive maintenance work in the form of an PDCA cycle is being established.

However, preparatory steps such as permissions for power interruption and material procurement still hinder the early implementation of the repair work.

PALAU PUBLIC UTILITIES CORPORATION
Malakal, Koror

System Control Division

February 22, 2018

For : **James Mengeolt**
SCD Manager

From : **Michael S. Allejos**
SCD Engineer

Subject: Airai – Koror Main Power Pole Survey

I. Background: Due to the frequent unscheduled outages we experience. SCD conducted Power Pole survey to the main line to find something that may potentially cause interruption to the main feeders.

II. Findings:

Most of the hardware are polluted and some are starting to rust / rusted due to the location they were situated.

Items which requires immediate repair:

Type	LANDMARK - PLACE/THINGS	REMARKS	RECOMMENDATIONS
A	nt of KB Shell	Tilted X-arm / Trimming	Correction of Structure
A	w/ DT for Shell	Trimming	Trim Mango Tree
A	w/ 1- 10kva DT (Bill Board of Koror State)	buzzing / hotspot on secondary connector	Check loose connection in secondary connectors
A	w/ 1 DT for ED Construction	buzzing / hotspot on secondary connector	Check loose connection in secondary connectors
E	w/ 3 lateral line to Rock Crusher	trimming / 1 blown lightning arrester	Trim Trees / replace arrester
A	front of Rock Crusher	trimming	Trim trees near to line
E		trimming / polluted 34.5kv insulator	Trim trees near to line
A		vegetation on X-arm	Remove vegetation on Cross arm
B		13.8kv middle pin insulator w/ chip	Replace Pole Top Insulator
E		vegetation on X-arm	Remove vegetation on Cross arm
A		vegetation on X-arm	Remove vegetation on Cross arm
A	w/ 1-25kva DT	vegetation on X-arm	Remove vegetation on Cross arm
C	w/ 3 DT to Fun Palau (near Shell Villa)	polluted insulator/vegetation on X-arm	Remove vegetation on Cross arm
A	after LBS	polluted insulator / Trimming	Trim trees near to line
B		polluted insulator / Trimming	Trim trees near to line
A	w/ 3 DT for Pump @ Intersection to Ngermid	Tilted X-arm	Correction of Structure
A	w/ 3 FCO to Ngerias	polluted insulator / 1 arrester chipped	Replace Pole Top Insulator
A	w/ 1 lateral line to PIDC DT	polluted insulator / chipped spool insulator for neutral	Replace Spool Insulator
A	w/ 3-37.5kva DT (Mobil Top Side) & 3 Lateral to Ngeremai	broken 1 Arrester	Replace Arrester
A	w/ 3 FCO to T-Dock & Dead End from IDID	1 Hot line clamp to T-Dock w/ Hotspot & rusted bolt FCO	Check loose connection / Retighten / replace HL clamp
A	w/ 3-37.5kva DT (L' Amerena)	Hot spot on secondary lead w/ split bolt connector (middle)	Check loose connection / Retighten / replace split bolt
A	w/ 1-25kva DT (front of DHS2 Store)	DT blown arrester / Need Trimming of Mango, near to lines	Replace Arrester
A	w/ 1 DT after Franco	burned secondary lead/ arrester not connected/ trim vines	replace secondary lead & cut vines
A	(Bethlehem)	for Trimming Acacia Tree	Trim Tree near to line
A	w/ 3 FCO to KES (Ngerbeched) & 3 FCO to PCC	chipped bell insulator (right side) / trim PCC Line	Replace Chipped insulator / Trim Line to PCC
A	w/ 1 DT to PCC Cafeteria	blown arrester	Replace Arrester
A		34.5kv neutral line loose tie wire	re-tighten neutral line

Figure 9-1-4-2.1 Example of a periodic inspection report

Table 9-1-4-2.2 Report form on the results of a periodic inspection

Meyuns Line				
Pole	Type	LANDMARK - PLACE/THINGS	REMARKS	RECOMMENDATIONS
1	E	w/ 1-50kva DT (back of Judiciary)	ok	
2	A	w/ 3-37.5kva DT for Rock Island Café	blown arrester / burned secondary lead	replace arrester & burned seccondary lead
3	E	jumper to Meyun's line	ok	
4	A	RIC parking area	ok	
5	A	w/ 1-100kva DT (MS Wash Land)	tie wire removed on middle insulator	re-install tie wire for insulator
6	A		ok	
7	A	w/ 1-50kva DT (HE Budget Mart 3)	ok	
8	B	w/ 3-37.5kva DT for Ulodong Bldg.	blown arrester	replace blown arrester
9	C	intersection at Rainbow Mart	guy wire need re-tension	re-tension guy wire
10	E	in front of UMI	mango tree near to line	trim mango tree near to line
11	E	w/ 2-25 & 3-50kva DT - front of Professional Bldg.	ok	
12	A	w/ 2-50kva DT - Meda Garden & Meda Terrace	ok	
13	A	w/ 1 lateral to HA Tire Shop	coconut leaves near to lateral line	trim coconut leaves
14	B	w/ 1-DT & 1 lateral - after HA Tire shop	tilted x-arm / chipped insulator / vegetation near to lateral	structure correction / replace chipped insı
15	B	w/ 3-10kva DT - front of Blue Bay Gas station	tilted x-arm	structure correction
16	B	w/ 1-25kva DT - Presidents House	polluted insulators	
17	A	steel pole - Meyuns causeway	all rusted	double check integrity of hardwares
18	A	steel pole - Meyuns causeway	all rusted / tilted x-arm	structure correction
19	A	steel pole - Meyuns causeway	all rusted / tilted x-arm	structure correction
20	A	steel pole - Meyuns causeway	all rusted / tilted x-arm	structure correction
21	A	steel pole - Meyuns causeway	all rusted	double check integrity of hardwares
22	A	steel pole - Meyuns causeway	all rusted	double check integrity of hardwares
23	A	steel pole - Meyuns causeway	all rusted	double check integrity of hardwares
24	E	Meyuns causeway Store	ok	
25	C	w/ Capacitor bank - Pacific Family Clinic	ok	
26	A	w/ 4-25kva DT for Belau Hospital	ok	
27	C	w/ 3-DT to Pie Printing	ok	
28	C	w/ jumper to hospitals pole for underground primary	ok	
29	C	w/ 3 laterals to satellite office & 3FCO to Meyuns	ok	
30	A	w/ 1-75kva & jumper to 3-37.5kva - Kemur laundromat	tilted x-arm & insulator	structure correction
31	A	w/ 3 FCO to Pres. Sattelite office	1FCO holder signs of flash over / chipped insulator	replace FCO holder
32	A	w/ 3 FCO to Kalau Gym	ok	
33	A	w/ 1-50kva DT - Dylan's house	ok	
34	A	w/ 1-50kva DT, LBS & unused ACR - Melusch	polluted insulators	

Table 9-1-4-2.3 Draft revision of the report form

Malakal - Koror Line								
		Corresponding Division ↓						
		SCD ↓					PDD ↓	
Pole No.	Pole Type	LANDMARK - PLACE/THINGS	REMARKS	RECOMMENDATIONS	Urgency (By what time)	Date Requested	Date Accomplished (Planned for Address)	Status / Remarks
1	E	from S/S at MPS	34.5kv insulator w/ signs of flash over	Double Check Integrity of Hardwares				
2	E	gate @ MPS	13.8kv & 34.5kv Insulators w/ signs of flash over	Double Check Integrity of Hardwares				
3	B		34.5kv pin insulator w/ signs of flash over / 13.8kv Insulator bolt rusted	Double Check Integrity of Hardwares				
4	A	front of Car Quest	starting to rust	Double Check Integrity of Hardwares				
5	A	front of Shipyard	rusted steady clevis for neutral / spool about to detached	Double Check Integrity of Hardwares / Repair & replace steady Clevis and spool				
6	B	PNQ	all rusted bolts and nuts / w/ signs of flash over	Double Check Integrity of Hardwares				
7	C	CTSI	all rusted bolts and nuts / w/ signs of flash over	Double Check Integrity of Hardwares				
8	A	w/ line to Sams tour (intersection)	rusted bolts & nuts Pin insulator and Cross arm	Double Check Integrity of Hardwares				
9	A	six80	rusted bolt 34.5kv pin insulator	Double Check Integrity of Hardwares				
10	A	intersection	all rusted bolts and nuts	Double Check Integrity of Hardwares				
11	E	Cove Resort (w/ 34.5kv line to Fisheries)	rusted bolt for steady clevis	Double Check Integrity of Hardwares				
12	A	Cove Resort	rusted bolt insulator	Double Check Integrity of Hardwares				
13	B	Neco Yamaha	34.5kv insulator w/ signs of flash over / 13.8 rusted bolt	Double Check Integrity of Hardwares				
14	B	w/ capacitor bank (Neco Shop)	chipped pole top insulator	Replace chipped pole top insulator				
15	A	Neco Shop Gate (w/ 13.8kv underground & lateral	all rusted	Double Check Integrity of Hardwares				
16	A	w/ 1-75kva Dt (Coral Reef Research Foundation)	tilted cross arm & insulator / rusted bolt	Double Check Integrity of Hardwares / x-arm correction				
17	C	w/ 3-100kva DT (Sea Passion)	blown Arrester & rusted DT	Replace blown arrester				
18	C	Malakal Causeway	all rusted	Double Check Integrity of Hardwares				
19	A	Malakal Causeway	all rusted	Double Check Integrity of Hardwares				
20	A	Malakal Causeway	all rusted	Double Check Integrity of Hardwares				
21	A	Malakal Causeway	all rusted	Double Check Integrity of Hardwares				
22	A	w/ underground to Palau Vacation Hotel	all rusted	Double Check Integrity of Hardwares				
23	B	w/ 2 lateral to Fishermans Grill	all rusted	Double Check Integrity of Hardwares				
24	A	w/ DT to Pier 7	all rusted	Double Check Integrity of Hardwares				
25	A	entrance to Long Island	all rusted	Double Check Integrity of Hardwares				
26	A	Long Island Causeway	all rusted	Double Check Integrity of Hardwares				
27	A	Long Island Causeway	all rusted	Double Check Integrity of Hardwares				
28	C	Long Island Causeway w/ Guy wire.	all rusted	Double Check Integrity of Hardwares				
29	A	Long Island Causeway	all rusted / chipped 13.8kv middle insulator	Double Check Integrity of Hardwares / Replace chipped pole top insulator				
30	A	Bridge	all rusted	Double Check Integrity of Hardwares				
31	A	Bridge	all rusted / w/ signs of flashover L3	Double Check Integrity of Hardwares				
32	A	after Bridge	rusted insulator bolt & steady clevis	Double Check Integrity of Hardwares				
33	A	w/ 3 lateral to Palau Conservation Society & DT t	rusted insulator bolt & steady clevis / 34.5kv bolt loose	Double Check Integrity of Hardwares / Tighten bolt for 34.5kv insulator				
34	A	front of Shell	rusted insulator bolt & steady clevis	Double Check Integrity of Hardwares				

Table 9-1-4-2.4 Report form on inspection results

(A) Inspection Results

Pole No.	Pole Type	LANDMARK - PLACE/THINGS	REMARKS	RECOMMENDATIONS
1	E	w/ 1-50kva DT (back of Judiciary)	ok	
2	A	w/ 3-37.5kva DT for Rock Island Café	blown arrester / burned secondary lead	replace arrester & burned seccondary lead
3	E	jumper to Meyun's line	ok	
4	A	RIC parking area	ok	
5	A	w/ 1-100kva DT (MS Wash Land)	tie wire removed on middle insulator	re-install tie wire for insulator
6	A		ok	
7	A	w/ 1-50kva DT (HE Budget Mart 3)	ok	
8	B	w/ 3-37.5kva DT for Ulodong Bldg.	blown arrester	replace blown arrester
9	C	intersection at Rainbow Mart	guy wire need re-tension	re-tension guy wire
10	E	in front of UMI	mango tree near to line	trim mango tree near to line

(b) Column for checking the status of actions taken

Urgency (By what time)	Date Requested	Date Accomplished (Planned for Address)	Status / Remarks
		OK	
			Schaduled: 7/23/2018
		OK	
		OK	
			Schaduled: 7/23/2018
		OK	
		OK	
			Schbduled: 7/23/2018
			Schcduled: 7/23/2018
			Scheduled: 7/23/2018

4) Overall status of preventive maintenance work in PPUC (current situation)

Through the implementation of the patrol for maintenance described in the preceding paragraph, we grasped the status of the preventive maintenance efforts undertaken by PPUC. The cycle of inspection is classified according to the size and position of the equipment. An outline is shown in Table 9-1-4-2.5.

Table 9-1-4-2.5 Implementation status of preventive maintenance

	Size of Facility	Cycle of Inspection/Repair	Details on Implementation
(A)	Area-wide	Period of about 30 years (Planned renovation)	Equipment that has been in place in the area for about 30 years is assumed to be heavily deteriorated by rust and in need of repairs on a region-wide basis.
(B)	Main line	An annual cycle, as specified in the "MAINTENANCE GUIDELINE"	In view of the large impact on reliability, periodic inspections are carried out on a 1- to 3-year cycle.
(C)	Branch line	Whenever necessary	This work is carried out whenever necessary for purposes such as finding the causes of frequent faults and taking countermeasures.

A. Planned renovation of area-wide facilities

The power facilities in Palau are widely installed near the coastline, which makes them susceptible to degradation due to the rusting of iron materials over a wide area. To cope with the deterioration, PPUC is planning to replace any equipment in the area constructed around 30 years ago or earlier (excluding concrete poles and pole transformers).

The main replacement targets are wires, arms, and insulators. The existing wire is being replaced with new copper wire in sections with many disconnection repair points or sections where the rusting of the steel core ACSR (Aluminum Conductors Steel Reinforced) has progressed. The arm brackets (including the mounting bolts) are also being replaced because of progressive rusting, and the existing ceramic type insulators are being replaced with a lightweight polymeric type. PPUC is thus promoting facility improvements by replacing the older equipment with new equipment with specifications suitable for Palau's environment.

The planned replacement work began in Mar. 2018, when the budget was secured. Replacements for the Peleliu area and Melekeok (capital) area were carried out first. The Melekeok region took the highest priority, as the facilities were aging (installed in 1987), located near the coastline, and considerably rusted. The next replacements are planned in the Airai substation area (where the facilities are old, with many wooden poles and steel tubular poles), and then in the Asahi substation area (where the facilities are old and the conductor capacities are insufficient).

B. Periodic inspection and repair of the main line

Periodic inspections and repairs of the main line were carried out in this project based on the proposal from the JICA Study Team. The main line was selected for the periodic inspections in light of its importance for the overall system. A fault occurring in the main line has a very large influence. Periodic inspections have yet to be performed, so it will be necessary to reinforce the structure to implement periodic inspections as a regular operation in the future.

It will be necessary to get permission for the scheduled power outages required to repair the defects identified in the periodic inspections. This permission will be difficult to obtain for the trunk line, however, given the large impact that trunk line outages would have. The implementation plan up to the completion of the replacement work will thus have to be examined.

C. Branch line repairs

A fault of a branch line is detected as a fault due to a blown fuse. As PDD is able to identify faults frequently occurring on the branch line, it carries out inspections on such faults and carries out repair work as necessary.

As described above, basic efforts for preventive maintenance are carried out in PPUC. It will be not easy, however, to carry out preventive maintenance in a systematic or stable fashion with the existing restrictions of budget, human resources, organizational structure, etc.

5) Status of facility management material (Management data)

As described below, PPUC has yet to prepare materials (data) to easily grasp the construction specifications and quantities to be implemented at each step of the construction process from the planning/designing stage to completion. Management materials necessary for the operation and maintenance of facilities are neither prepared nor updated. To safely and adequately carry out the operation and maintenance of the facilities, it will be necessary to develop an operational system for reliably preparing and updating these materials (e.g., facility construction standards, construction design documents, power transmission and distribution diagrams, etc.).

A. Procedure for repair work

The repair works proceed in the following steps.

① Issuance of a materials list by SCD (Table 9-1-4-2.6)

② Explanation of the outline of construction in the meeting before construction (Figure 9-1-4-2.2)

In the example given, this explanation is a simple presentation of only the form of a pole fitting on a white board sketch. Concrete specifications such as the installation position of the equipment and height of the ground are not shown.

Facility construction standards prescribing these specifications are not prepared. This information is conveyed through oral communication by OJT.

③ The listed materials are picked up from the warehouse, and the construction work is carried out.

④ Construction completion report (Figure 9-1-4-2.4)

The completion of construction is reported in a daily report form (sentences describing the work content) of the type shown in Fig. 9-1-4-2.3. No information on the equipment specifications after construction is described.

B. Procedure for new construction

① Application for power supply from customers

② Design for budget estimation (Figure 9-1-4-2.3)

In order to estimate the budget for customers, the designer (Surveyor) conducts a field survey, determines the positions and types of utility pole (Figure 9-1-4-2.4 plots the poles on Google Earth), and prepares a material list (Table 9-1-4-2.5). Even in this design, no materials describing the details of the construction are prepared. PDD (person in charge of construction implementation), meanwhile, is only sent the material list and not any design documents.

③ Pickup of the listed materials are picked from the warehouse and execution of the construction work

When implementing the construction, a surveyor visits the site and instructs the work crews on the utility pole positions.

④ Construction completion report

PDD sends SCD a construction completion report. Distribution line maps, etc. should be updated when adding facilities for new construction, but this has not been implemented in recent years. The person in charge of updating the data is also unclear.

Table 9-1-4-2.6 List of materials for construction (excerpt)

Name : Ngaraard State Gov/CIP	**Work Order #:** 2017-002942
Location: Ngaraard	**Date Requested** : 01/10/2017
Phone No. (680) 775-61131(Masubed)	**Date Completed** : 06/16/2017
Residential___ Commercial___ Government _X	**Prepared by: Surveyor**

SURVEY;	***DATE:***	***TIME:***
STATUS:	2017年6月12日	10:00am

Complete

Description of Work Requested:

New Installation of power poles.

Customer request new power poles installations. Erect (26) power pole's, and string HV line...

Bring climbing gear and Ladder.

Equipment.	No.	Hrs.
Pick Up Truck	2	160
Bucket Truck	2	160
Auger Truck	1	160

Crew.	No.	Hrs.
Line Man	6	160
Operator	3	160
Meter Tech		

No.	Item Code/No.	Description	Qty.	Out	In Stock
1	301-7051-AAC 336	WIRE TULIP AAC 336.4-19	2739'		✔
2	301-7051-#2-7 PRIMA	WIRE BARE STR CU #2-7 HRD	2739'		✔
3	301-6301-6525AS	GRIP FOR NEUTRAL WIRE	6		✔
4	301-7051-50X300	Armore wire/ Binder tap solid, soft 1350-0 Al. alloy size mils: 50X300	160'		✔
5	**301-7086-13M-19CM**	**POLE CONCRETE (42.64'x 7.)**	15		✔
6	**301-6053-CAN-FBD-17T**	**Pole Band 13m (CAN-FBD-17T)-170-265mm**	32		✔
7	**301-6104-0327**	**CLEVIS,STEADY INS.**	16		✔
8	**301-6401-P53-2**	**INSULATOR,SPOOL**	16		✔
9	**301-6901-6813**	**WASHER SQUARE 2 1/4 x 2 1**	108		✔
10	**301-7101-1.8M**	**CROSSARM STEEL-DJA-94015-13**	26		✔
11	**301-OLD-6051-UABD-412**	**BOLT U-BOLT FOR CROSSARM**	8		✔
12	301-6051-P8868	BOLT DOUBLE ARMING 5/8 X	36		✔
13	**301-6053-DJA-9415-13**	**STEEL ARM BRACE**	26		✔
14	**301-6051-M16-120**	**BOLT C W/NUT FOR ARM BRAC**	27		✔
15	**301-OLD-6401-34KV-LP40**	**INSULATOR LINE POST**	18		✔
16	**301-6051-11612A**	**LAPP MOUNTING STUD FOR LINE POST (5/8X7 1/2 W/SQ NUT)**	18		✔
17	301-6051-STAP B&NUT	STRAP TWIST W/BOLTS & NUT	5		✔
18	301-OLD-6401-INS.WHTE	INSULATOR BELL WHITE NGK	24	✔	
19	301-6103-GDW2010	DEADEND AUTOMATIC	6		✔

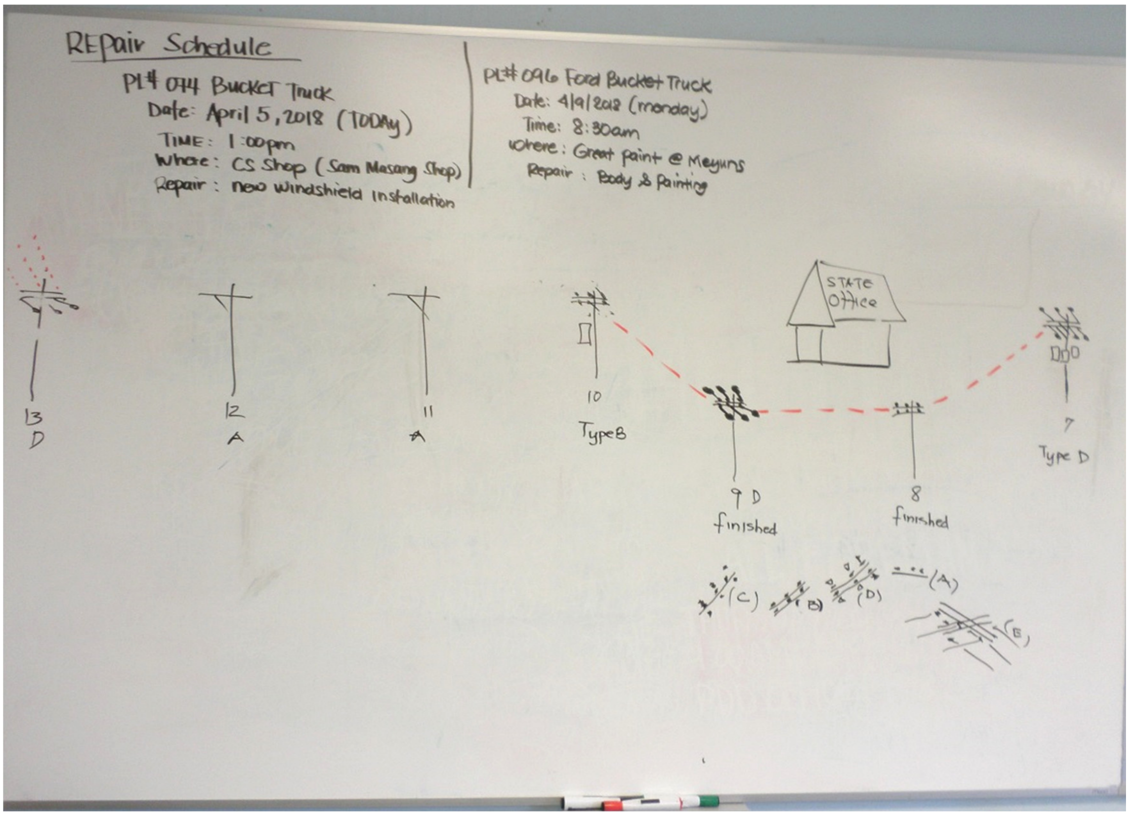


Figure 9-1-4-2.2 Design drawing used for repair work (shown at a pre-construction meeting)

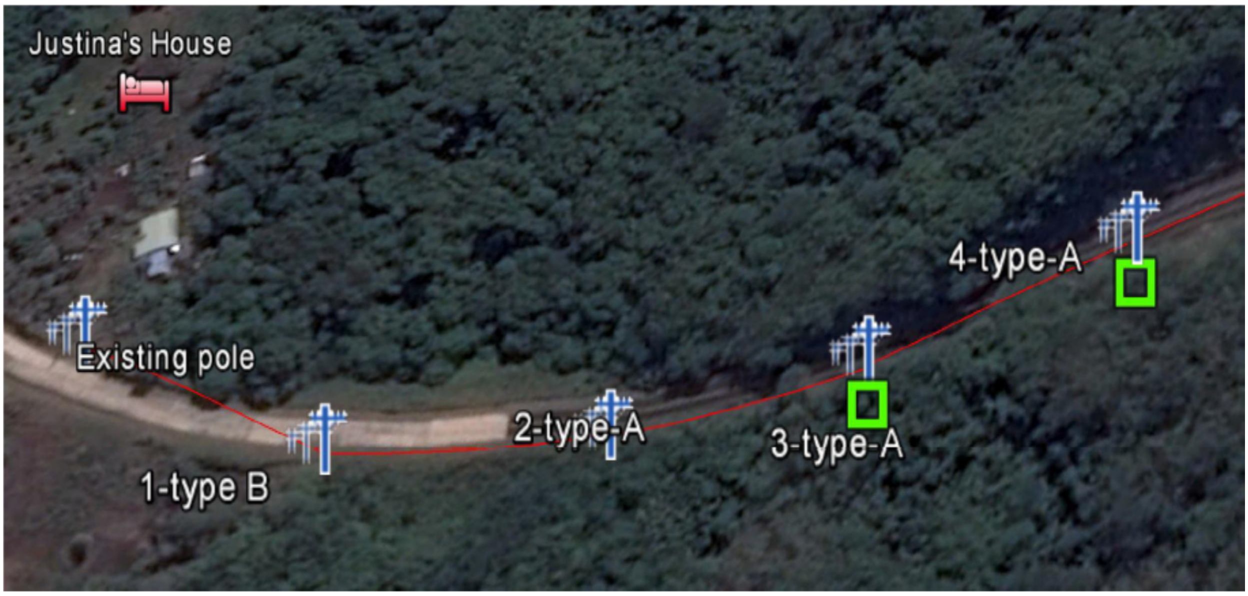


Figure 9-1-4-2.3 Design drawing of 13.8 kV line extension work (new construction work)

PDD March 2018 Report

April 6, 2018

Page 2

MELKEOK SYSTEM UPGRADE

Monday, March 05, 2018

Cut and trim trees at the new designated area to erect new power poles. Project in-charge, Spesungel & Gabriel with operators erected a 2 – 13 m power pole and 1 - 34' wooden pole in front of Melkeok State Office. After erecting them, they prepared the poles by installing all of the hardware for upgrading purposes. The poles were erected ahead of schedule to get the task out of the way and concentrate on the main task of transferring the primary lines only. 34' wooden poles are used for the secondary line.

Workers present:

Joseph Spesungel	Foreman
Ronald Gabriel	Foreman
Osbourne Siksei	H. E. Operator
Burt Maidesil	H. E. Operator
Masao Umedib	Certified Lineman

Equipment:

Auger Digger Truck	PL#56
Bucket Truck	PL#96
Tacoma Pick Up	PL#21

Friday, March 09, 2018

A meeting on the system upgrade projects in Peliliu and Melkeok was scheduled to start on Monday, 3/12/2018. All PDD employees attended. Manager Hilton gave a brief description of the projects and when the projects would commence. The foremen in-charge of the projects took over one by one and explained the work performed.

Monday, March 12 to 16, 2018

Foreman Gabriel and Acting Foreman Spesungel set all the materials, hardware, and tools with their crews. The mechanics performed a vehicle inspection to make sure that all of the trucks to be used for the operation were in good running condition.

Wednesday, March 14, 2018

An overtime request letter was sent to the CEO for approval of work on Saturday or Sunday only, so as not to interrupt the schools and daily functions in Melkeok State on week-days. The weekend scheduling for the Melkeok Upgrade work was also ideal, as a weekend power outage from 9:00 am to 4:00 pm would make it possible to include a full work force of all of the linemen, streetlight workers, tree trimmers, and mechanics. The overtime request was approved by the CEO, so the project will continue on Saturday.

PDD March 2018 Report

Figure 9-1-4-2.4 Completion report on replacement work in Melekeok (excerpt)

9-1-4-3 Technology transfer (activities other than pilot projects)

Among the technology transfer activities focused on the power transmission and distribution system, the following activities were conducted in addition to the pilot projects. The following pages present the activities in detail.

(1) Introduction of the power distribution efforts in a Japanese Power Company

· Attendees: 5 persons from the PDD department
· Date: 2018/Oct/6 and 7
· Content: A lecture on the following items

Concrete examples of efforts focused on facility formation and operation in Japan (The Kansai Electric Power Co., Inc.) were explained in this lecture to improve the participants' knowledge.

1) Outline of domestic distribution equipment in Japan (introduction)

Before covering specific countermeasures against wildlife and corrosion, this lecture outlined the distribution facilities in Japan (Kansai) and explained the concept of facility formation, maintenance operation, and the status of power outages in order to extend the participants' understanding of the differences in facility forms, supply area sizes, and environments between Palau and Japan.

2) Countermeasures against contact with wildlife

Power distribution facilities such as electric wires in Japan are insulated as an essential countermeasure against faults caused by contacts with other objects such as wildlife. The supply reliability has been greatly improved as a result. Faults caused by wildlife damage still occur, however, at points where the insulation has deteriorated, etc. To manage the problem, patrols are dispatched to grasp, manage, and repair the insulation deterioration points in Japan. We explained the above-described circumstances in Japan and the efforts taken and presented examples of countermeasures to prevent contacts with birds and animals.

Two important questions were asked and answered in the Q&A.

Q: The medium pressure distribution voltage in Japan was shown to be 6.6 kV. Is this the voltage to ground or from phase to phase?
A: The voltage is phase to phase.
Q: Are the devices introduced for birds and animals made of metal?
A: They are made of resin.

3) Efforts for measuring corrosion

This lecture explained the idea of facility construction against corrosion due to salt damage according to the geographical environment. Several instances of corrosion and equipment countermeasures (painting of the arm) were presented as examples. Procedures for managing maintenance and operation such as accumulating the patrol results, ranking the deterioration status for each facility, and replacement criteria were explained to extend the participants' understanding of preventive maintenance efforts.

An important question was asked and answered in the Q&A.

Q: Is there any prospect that special painted arms will be introduced as a corrosion countermeasure?
A: We are now studying the effects of this corrosion countermeasure. In the future we plan to introduce countermeasures in consideration of the benefit-cost balance.

4) Efforts to improve disaster tolerance

Earlier sections introduced examples of damage caused by natural disasters experienced by the domestic power distribution department such as typhoons and earthquakes. The lecture explained the status of measures in facility formation and operational aspects. On the facility formation side, the lecturer presented an overview of facility reinforcements for damage prevention, the adoption of low-wind-pressure wires on high-voltage lines, the installation of flood-prevention devices at substations, and the interconnection line linking distribution lines to minimize sections with power interruptions. On the facility operation side, the lecturer explained the importance of maintaining and improving work skills and presented an example of emergency power transmission by provisional equipment and generator cars for the early restoration of power failure sites.

An important question was asked and answered in the Q&A.

Q: Is the insulator washed with the line power being interrupted?
A: It is washed in live line.

Figure 9-1-4-3.1 The lecture

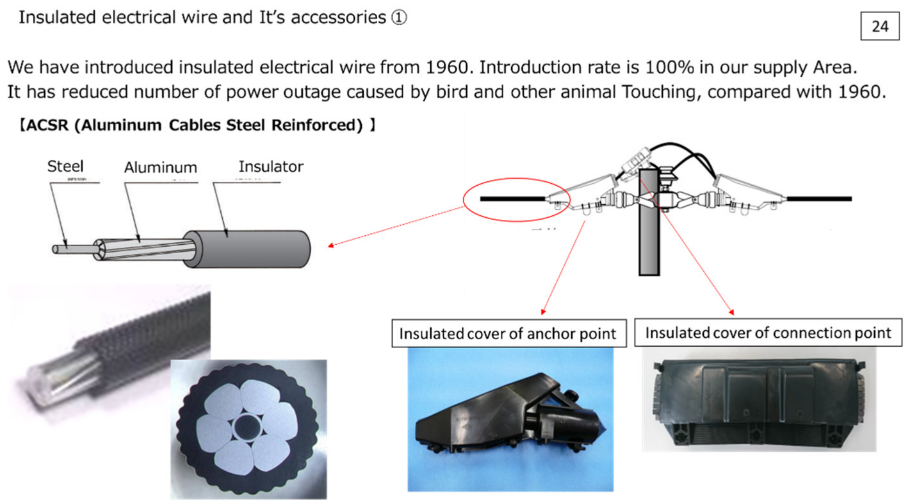


Figure 9-1-4-3.2 Lecture material (countermeasures against wildlife)

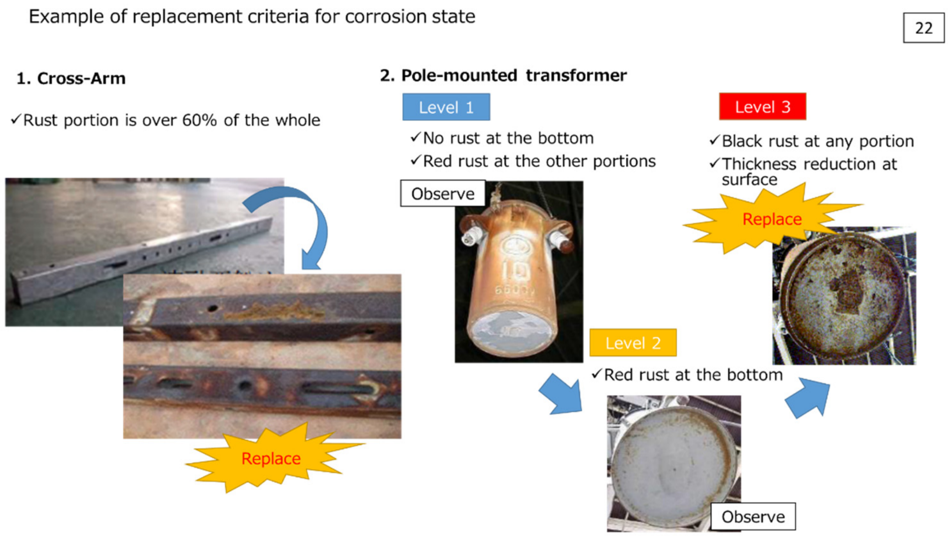


Figure 9-1-4-3.3 Lecture material (countermeasures against corrosion)

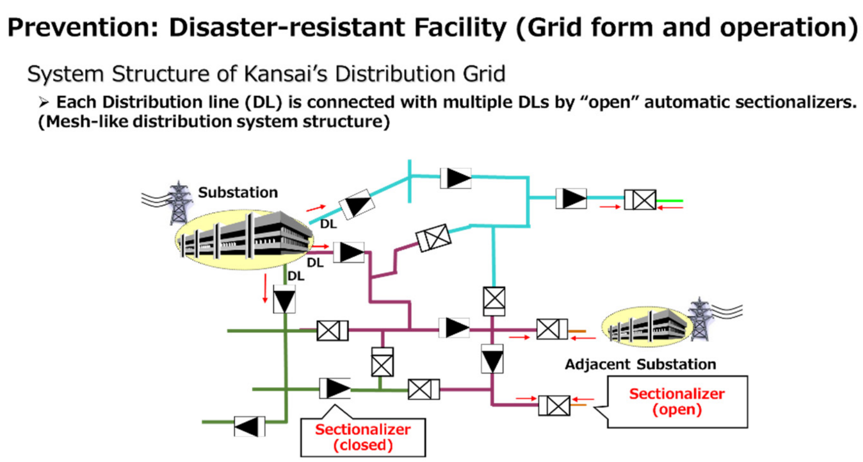


Figure 9-1-4-3.4 Lecture material (disaster resistance)

(2) Guidance on the use of fault data in the power distribution department

- Background:
  Faults were constantly being reported in PDD. There seemed to be some room for improvement, however, in the classifications used and the accuracy of the descriptions in the reports. Without improvement, the reports could not be expected to suffice as fault records with analyzable data. Therefore, the following items were covered as guidance for the improvement and use of the PDD fault data records.
- Attendees: 2 persons from the PDD department
- Date: 2019/Jan/24, 28, 31 (1 hour on each date)
- Content:

1) Confirmation and classification of the fault report records of PDD

The following items were confirmed and classified using PDD's fault record reports from 2018.

- ⎈ Confirmation of protection open points of faults (fuses, circuit breakers, etc.)
- ⎈ Classifications of the fault causes and damaged equipment (Figure 9-1-4-3.7)

2) Preparation of demonstration data for fault data analysis

As demonstration data, a list of fault records incorporating the above-described classifications and points confirmed was created. (Figure 9-1-4-3.8)

- ⎈ Introduction of the tabulation method

The demonstration data created (Figure 9-1-4-3.9) was used to provide practical guidance on the method for totaling the number of faults in the pivot table used to assist the analysis work on the fault records.

Figure 9-1-4-3.5 Data confirmation work

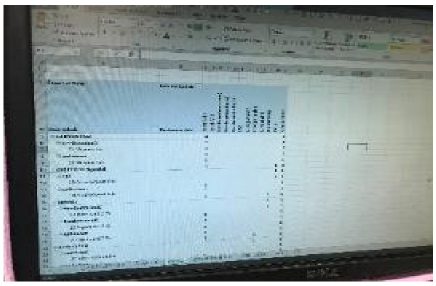


Figure 9-1-4-3.6 Guidance on the tabulation method

[Category]

（1） Cause of fault

Cause of fault	Detail
Wild touch	animal(bird)
	animal(fruit bat)
Corrosion	corrosion
Public	car
	Customer side
Power plant	power plant
Vegetation	tree(bamboo)
	tree(bettel nut)
	tree(blown leaf)
	tree(coconut)
	tree(mango)
	tree(vine)
Unknown	unknown

Note:
These keywords are based on the outage of outage data in 2018

(2) Damaged equipment

Mainly Damaged equipment	Detail
Pole	Pole
Line	Line(jumper) Line(primaly) Line(static)
Hardware	Hardware(crossarm) Hardware(u-band) Hardware(u-bolt)
Fuses	fuse(D/L) fuse(T/L) Fuse bottle(D/L) Fuse bottle(T/L)
Arrester	Arrester
Insulator	Insulator
Switch	LBS
Transformer	Transformer
Underground	Cable
Customer	Customer equipment
No damage	No damage

Figure 9-1-4-3.7 Classifications of the causes of faults and the equipment damaged

Date	Work Time			(↓input) Serial No.	Class	①Area(TL/Fdr/SS)	②CB/Fuse opened	③cause of fault	④ equipment
	Start	Finish	duratio						
1/10	5:00	7:30	2:30	41	DL Fuse	11 Airai-Koror Fdr	Ngermid MAIN FCO	tree(bamboo)	Line(primaly)
1/10	20:00	23:00	3:00	134	DL Fuse	22 Ngaraard 2 SS	SS 13kV fuse(Ngaraar	unknown	fuse(D/L)
1/13	7:30	10:30	3:00	144	DL Fuse	22 Ngaraard 2 SS	Choll	unknown	fuse(D/L)
1/13	10:30	12:30	2:00	23	DL Fuse	10 Airai-Airport Fdr	2nd FCO to Ngerikiil	unknown	fuse(D/L)
1/14	5:00	10:30	5:30	23	DL Fuse	10 Airai-Airport Fdr	2nd FCO to Ngerikiil	car	Pole
1/14	11:30	2:30	15:00	135	DL Fuse	22 Ngaraard 2 SS	Betania	unknown	fuse(D/L)
1/14	12:30	16:00	3:30	30	DL Fuse	10 Airai-Airport Fdr	MAXX FCO	corrosion	Line(static)

Figure 9-1-4-3.8 List of fault records (demo data (excerpt))

行ラベル	animal(bird)	animal(fruit bat)	car	corrosion	customer	power plant	tree(bamboo)	tree(bettel nut)	tree(blown leaf)	tree(coconut)	tree(mango)	tree(vine)	unknown	Total
⊞01 NEKKEN TL				2									4	6
⊞02 A-M TL				1		2								3
⊞10 Airai-Airport Fdr			1	3									7	11
⊞11 Airai-Koror Fdr		1		3			1			1		1	5	12
⊞12 Meyuns Fdr				1						1			1	3
⊞15 Medorm SS				1									2	3
⊞16 NEKKEN SS										1			2	3
⊞17 Kokusai SS		4		3	1					1			16	25
⊞19 Ngremlemgui SS											1		1	2
⊞20 Ngardmau SS										1			2	3
⊟22 Ngaraard 2 SS														
Betania								1		1			4	6
Choll				1									2	3
Main NGR													1	1
Ngbuked									1					1
Ngurang	1												4	5
SS 13kV fuse(Ngaraard 2 sub)													1	1
Total	1	5	1	15	1	2	1	1	1	6	1	1	52	88

Figure 9-1-4-3.9: Example of a pivot table (example of tabulation by substation and fault cause)

9-1-5 Effects of the Technology Transfer (Through Pilot Projects)

9-1-5-1 Qualitative effect

In the technology transfer for power transmission and distribution lines in this project, we set up two pilot projects and worked to reinforce the management system for the maintenance of the facilities. The pilot projects were designed to address urgent problems pertaining to the reliability of the electricity supply in PPUC.

① Pilot Project 1: Measures for trees were implemented to reduce the unknown causes of faults on the Nekken transmission line.

② Pilot Project 3: To introduce concepts of preventive maintenance into facility maintenance and management work for the distribution lines in the Koror town area and establish the implementation.

The following pages describe the qualitative effects obtained through the above pilot projects.

(1) Effect obtained through Pilot Project 1

1) Implementation of vine guards and the establishment of a management system

Judging from the circumstances and past experience, the faults with no known causes along the Nekken transmission line were likely to have been caused by contacts with trees. Therefore, PPUC began reinforcing its tree trimming team and patrol work systematically in May 2015. These measures for trees have been carried out as planned until now.

There was a possibility, however, that faults were caused by vines, which grew faster than general plants. We therefore proposed introducing vine guards. At the same time, we proposed periodic patrols to the installation sites and follow-up on the effects to determine the effective patrol interval and establish this patrol work.

The patrols and follow-up confirmed that the attached vine guards effectively prevented the vines from wrapping around the utility poles and guy wires. In the vine patrol work, we also prepared a management table (Fig. 9-1-3-1.2) and established a system for continuously managing problem sites using this table.

2) Construction of a system using overcurrent indicators to detect sections susceptible to frequent contact with trees

Tree trimming is planned in all sections of the 34.5 kV transmission lines, including the Nekken line. In cases where the tree growth is faster than expected or the trimming is delayed, however, the occurrence of transient faults (reclosing succeed faults) due to tree contact can increase again. To address this likely problem, we added overcurrent indicators to detect sections where frequent faults occur by accumulating data on transient faults. Through the activities of Pilot Project 1, we have constructed the work procedure shown below.

①Segmentation of detection section by adding overcurrent indicators

Initially there were 16 sets of overcurrent indicators to detect line faults between substations in the Nekken line. Nineteen additional sets of overcurrent indicators were installed to enable the detection of fault occurrence in smaller sections. In this way, we have established a system on the facility side to enable the detection of sections where faults frequently occur on the transmission line.

② Improvement of the system to explore the causes of faults

Patrols were not usually carried out to identify the causes of transient faults (faults of unknown causes) in the Nekken transmission line. To identify the fault locations and causes and link them to appropriate maintenance measures, we began conducting patrols to specify the same even for transient faults.

For that, it will be necessary to coordinate the exchange of information between the power plant operator and Line Workers (PDD). Together with improving this communication, we have established a rule for the transient fault patrol procedures carried out by the Line Workers (PDD) (Figure 9-1-3-1.6).

③ Preparation of an analysis form for detection of frequent fault sections

We prepared a management sheet (Fig. 9-1-3-1.5) to record the fault sections and causes detected in the patrol work described above. The pattern of fault occurrence is shown when the number of faults recorded for a certain period (e.g., 1 month) is totaled.

(2) Effect obtained through Pilot Project 3

In order to continuously carry out preventive maintenance, it will be necessary to constantly implement a PDCA cycle (Fig. 9-1-3-2.4) in the regular work. The following items necessary for carrying out each stage of work in this cycle were prepared.

1) Preparation of standards related to facility maintenance work

We prepared a set of facility maintenance guidelines (Figure 9-1-3-2.1: “TRANSMISSION & DISTRIBUTION OVERHEAD LINE MAINTENANCE GUIDELINE”) stipulating the policies and philosophies of the patrol and inspection work.

We prepared a checkpoint manual (Figure 9-1-3-2.2 “Checkpoint Manual”) for periodic patrol. This manual can be utilized by the SCD staff or Line Workers (PDD) for the accurate detection of defects in a facility.

It will be necessary to revise the contents of these standards to adapt them to the actual conditions in PPUC. Information such as the equipment fault data, the data obtained through the patrols, etc. should also be reflected.

2) Preparation of an inspection patrol report and repair status management form

In the PDCA cycle of preventive maintenance work, information at each business stage needs to be exchanged and shared between related sections. Based on this necessity, we prepared a form for reporting the results of periodic patrol work and a repair status management table (Table 9-1-4-2.3).

The details of Table 9-1-4-2.3 are divided and shown in the former half (patrol result report table: Table 9-1-4-2.4 (a)) and in the latter half (repair situation management table: Table 9-1-4-2.4 (b)). This file is stored in a common server and updated by the related department each time the situation changes. In this way, a system that enables information-sharing on the status of patrols and repairs is established.

3) Implementation of periodic patrols

① Implementation of periodic inspections for preventive maintenance

Based on the system mentioned in the above section, PPUC conducted periodic patrol inspections of the trunks of the transmission and distribution lines (from Feb. to Mar 2018). Table 9-1-5-1.1 shows the target facilities inspected.

Table 9-1-5-1.1 Trunk lines inspected in the periodic inspections

Facility	line name
34.5 kV transmission line	Aimeliik power station - Airai substation
13.8kV Distribution Trunk line	Airai-Koror
	Malakal-Koror
	Meyuns

② Inspection results

Figure 9-1-4-2.1 shows an example of a report of a periodic inspection described in the previous section. The defects found in each utility are entered in the ‘Remarks’ column. The measures to be taken in the future are listed in the ‘Recommendations’ column. Suggestions on actions (repair/replacement, detailed inspection, etc.) PDD should take in the next step of the PDCA cycle are entered as comments.

③ Examples of equipment defects found

The following major defects are described in the report (Figure 9-1-4-2.1). These items are almost the same as those of the "Checkpoint Manual" described in the previous section. The inspection carried out is considered appropriate.

✓ Rusting of the iron materials (Figure 9-1-5-1.1)
✓ Loose bolts and nuts (Figure 9-1-5-1.2)
✓ Inclination of the arms (Figure 9-1-5-1.3)
✓ Damage of the arrester / cut-out (Figure 9-1-5-1.4)
✓ Chipping of the insulators (Figure 9-1-5-1.5)
✓ Disconnection of the grounding wire of the overhead ground wire / neutral wire (Figure 9-1-5-1.6)
✓ Broken wire grip (Figure 9-1-5-1.7)
✓ Temperature rise of the transformer · Overheating of a wire connection (Figure 9-1-5-1.8)
✓ Approaching tree growth (Figure 9-1-5-1.9)
✓ Disappearance of the utility pole number · Loss of the utility pole number tag

(a) Rusting arm brace

(b) Broken support hardware for the insulator by rust

Figure 9-1-5-1.1 Rust of iron materials

Figure 9-1-5-1.2 Loosening of the nut for the insulator

Figure 9-1-5-1.3 Inclination of the arm

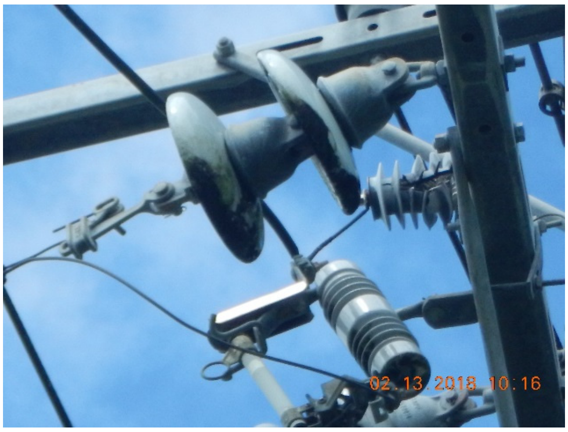


Figure 9-1-5-1.4 Equipment damage (arrester)

Figure 9-1-5-1.5 Chipped insulation

Figure 9-1-5-1.6 Disconnected grounding wire

Figure 9-1-5-1.7 Escape from the wire fixing grip

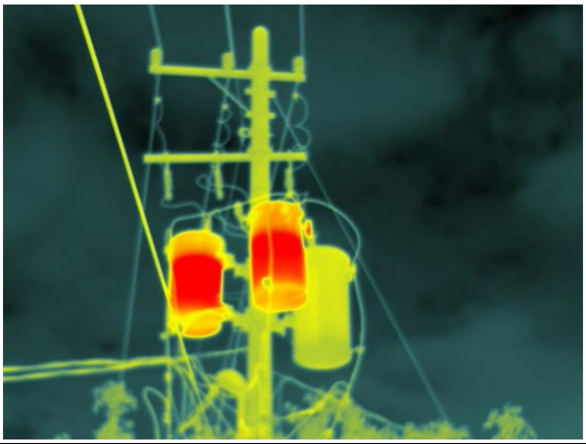


Figure 9-1-5-1.8 Temperature rise of the transformer

Figure 9-1-5-1.9 Approaching tree growth

9-1-5-2 Grasping the quantitative effect

Technology transfer for power transmission and distribution was implemented with a view to achieving improved maintenance work. Speaking in general, indicators to objectively compare the characteristics of different systems, such as SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index), can be used to quantitatively grasp the effects of these activities. Likewise, the accident rate per unit length (times / km· year) can often be adopted as a facility reliability index that is simpler to use than the one above mentioned. PPUC, however, does not keep or maintain the data necessary to obtain these indicators.

As the indicator for this project, we therefore decided to adopt the number of faults occurring in the transmission and distribution system as a direct measure for evaluating the reliability of the equipment. Specifically, we evaluate the effect based on the decrease in the number of faults in the transmission and distribution system during the period in which the technology transfer takes place.

(1) Background details on the reliability measures for the transmission and distribution system in PPUC

1) History of reliability measures for the 34.5 kV transmission lines

Table 9-1-5-2.1 shows the history of the reliability measures implemented for the 34.5 kV transmission lines, including the Nekken transmission line. Because faults in the 34.5 kV transmission lines occurred very frequently before 2015, the measures listed in the table were implemented as PPUC policies.

A breakdown analysis of the faults showed a high ratio of transient (short-term) faults. The two principal causes of the transient faults were identified as movement of the substation relays due to tree contact and the inappropriate coordination of protections. Countermeasures against both causes were taken.

Since the year 2015, trees trimming along the 34.5 kV transmission lines has been carried out once per year. As of 2018, tree patrols are also being conducted once yearly.

Table 9-1-5-2.1 History of measures taken for the 34.5kv transmission lines

Time	Status of measures implemented
1. 2015 / 5	**Start of tree trimming** (moving southward from Ngarrard2 substation)
2. 2016 / 4	Completion of trimming along the entire Nekken transmission line (Babeldaob Island)
3. 2016 / 5	Start of trimming between Aimeliik Power Station - Airai Substation
4. 2016 / 7	Completion of trimming between Aimeliik Power Station - Airai Substation
5. 2016 / 6	Correction of fuse ratings in the substations and distribution lines connected to the Nekken transmission system (**coordination of protections** for the fuses and substation relays)
6. 2017 / 9	Start of the JICA project
7. 2017 / 11	Installation of **vine guards**

Source: JICA Study Team

2) Status of 13.8 kV distribution line maintenance

PPUC had been not taking preventive maintenance measures for the 13.8 kV distribution lines based on patrol inspections. Damaged equipment was updated when the faults were restored

In the technology transfer under this project, we explained the necessity of preventive maintenance and proposed periodic patrols along the 34.5 kV transmission lines and the trunk lines of the 13.8 kV distribution system. The first periodic patrols were conducted in February and March of 2018.

3) Planned replacement of aged facilities

PPUC has implemented planned replacement work for facilities near the coast, where aging deterioration (particularly by rust) was expected. In FY 2017 (March 2018), replacement work was performed on the 13.8 kV distribution line in the area of Peleliu and Melekeok (capital).

(2) Change of the number of faults in the transmission system and trunk lines of the distribution system (analysis of SCD data)

PPUC keeps track of two kinds of fault data, one recorded by the system control division (SCD) and the other recorded by the power distribution department (PDD).

SCD counts the number of faults based on the number of substation relay operations in the transmission and distribution system. The data of a distribution system therefore include the detected data only when the cause of a fault is localized in a trunk line of the distribution system.

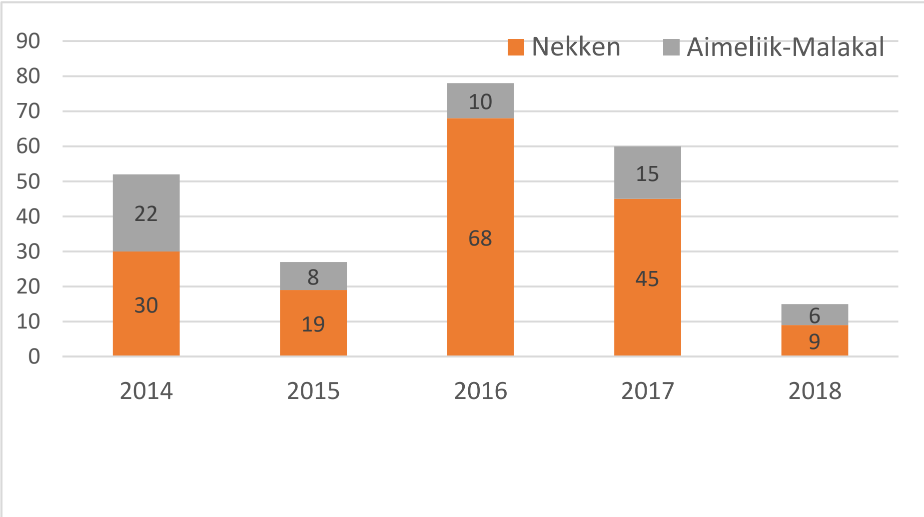
PDD counts the number of faults caused by blown fuses installed in the power line. PDD detects the occurrence of power faults based on inquiries from customers. The change in the number of faults based on the data recorded by SCD is shown below.

1) Fault in 34.5 kV transmission line

A. Change in the number of faults

Figure 9-1-5-2.1 shows the change in the number of faults detected by relay operations in the power transmission system operated by PPUC. There are two transmission lines: the Nekken line and Aimeliik - Malakal line. The number shown in Figure 9-1-5-2.1 is the sum of permanent faults plus transient faults.

The total number of faults has been around 30 to 80 during the period from 2014 to 2017. Then, it decreased sharply in 2018 (note: only nine months are counted for the period in 2018). The fault frequency in Nekken transmission line is much larger than that in Aimeliik-Malakal line.



Source: JICA Study Team (original data from PPUC)

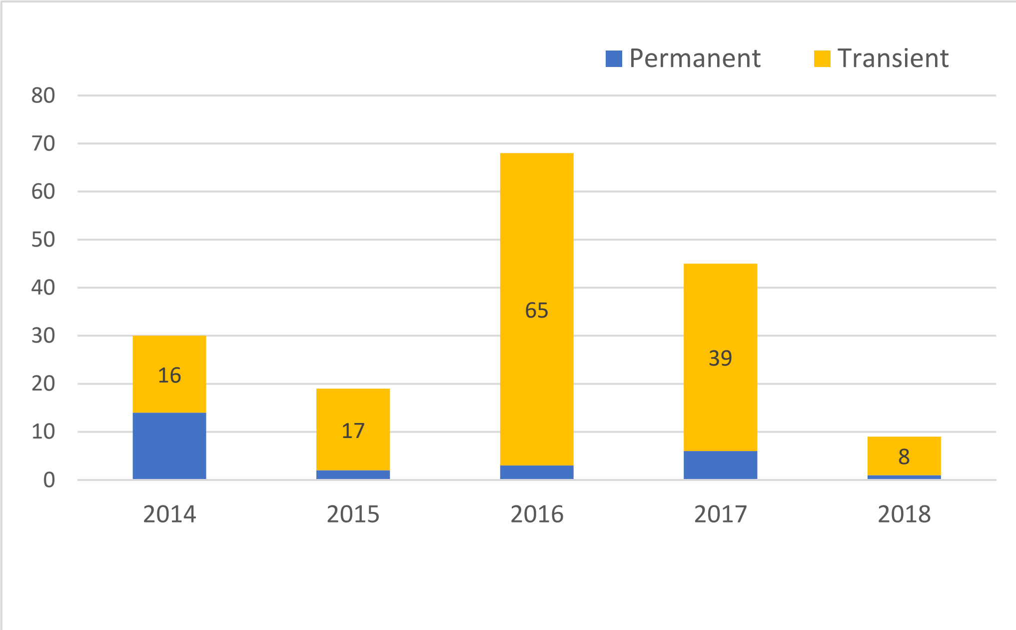
Figure 9-1-5-2.1 Change in the number of faults in 34.5kV transmission lines

B. Grasping the patterns of the faults occurring

The next two figures show breakdowns of the faults by transmission line (based on the overall total number shown in Figure 9-1-5-2.1): Figure 9-1-5-2.2 shows the number of faults in the Nekken line; Figure 9-1-5-2.3, the number of faults in the Aimeliik - Malakal line.

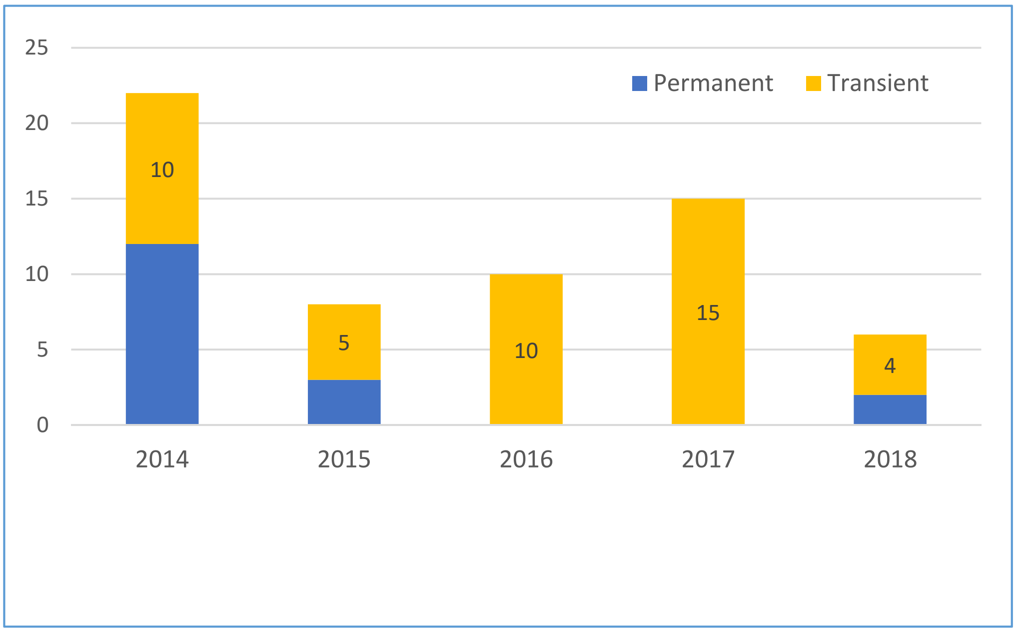
Faults occurred frequently in the Nekken transmission line, especially in 2016 and 2017, and most of the faults occurring were transient. In 2018, both permanent faults and transient faults drastically decreased (Figure 9-1-5-2.2).

Compared to the Nekken line, about half as many faults occurred in the Aimeliik - Malakal line. Transient faults were also more common, as observed in the Nekken transmission line. The number of transient faults drastically decreased in 2018.



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.2 Change in the number of faults in the Nekken line



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.3 Change in the number of faults in the Aimeliik - Malakal line

C. Relationship between measures implemented for the 34.5 kV transmission lines and the occurrence of faults

As mentioned above, PPUC's efforts to improve the reliability of the 34.5 kV transmission lines began in May 2015 and have been maintained to date with reinforcements added to the workforce. Meanwhile, this pilot project began in September 2017.

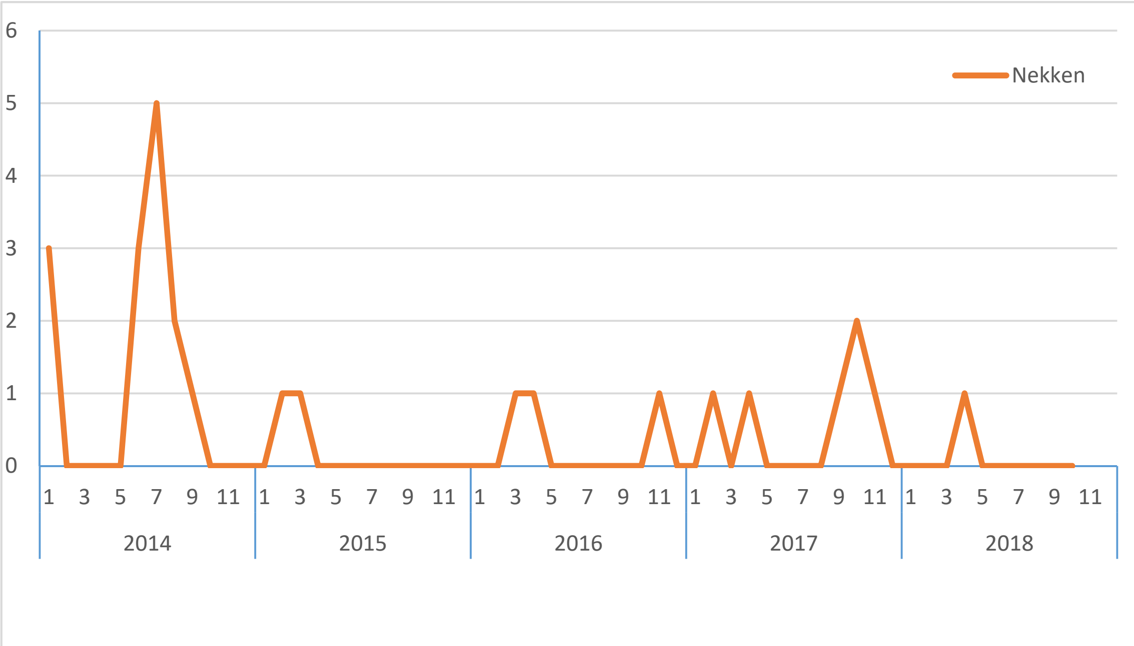
Because the various countermeasures were taken in the implementation stages from 2015 to 2017, the above-described reductions in the numbers of faults are thought to be transient effects.

Therefore, in order to grasp the change of the effect in detail, the changes by year shown in Figure 9-1-5-2.2 and Figure 9-1-5-2.3 are detailed as changes by month. Figure 9-1-5-2.4 shows the data of Nekken line. Figure 9-1-5-2.5 shows the data of Aimeliik - Malakal line.

In the Nekken line, permanent faults occurred once every three months in 2014 to 2015, and then sharply decreased. By 2018, the number of occurrences had dropped to once every 10 months (Figure 9-1-5-2.4 (a)). Transient faults occurred frequently in 2016 and 2017, but after December 2017 they only occurred about once a month (Figure 9-1-5-2.4 (b)).

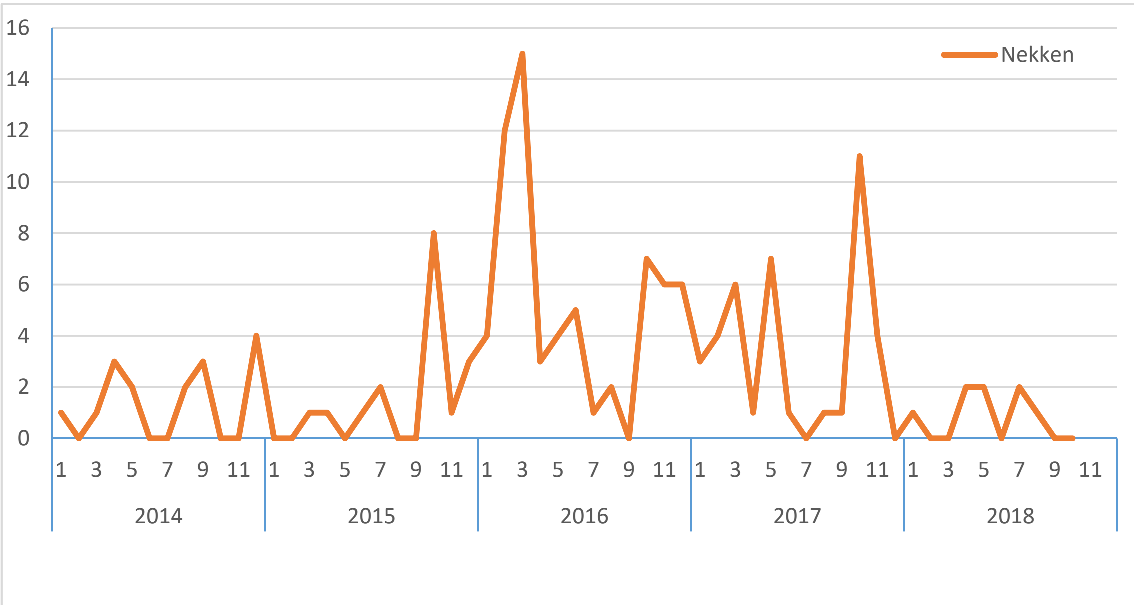
The first round of tree trimming along the Nekken line was completed in April 2016, but as of that month substantive effects had yet to appear. The second round of trimming was completed in November 2017, and vine guards were installed in the process (as a Pilot Project 1 activity). The effects of these two rounds of tree trimming and the vine guard installation seemed to manifest clearly from December 2017 (Figure 9-1-5-2.4(b)).

Permanent faults in the Aimeliik - Malakal line occurred frequently up to 2015 and dropped to very low numbers after 2016 (Figure. 9-1-5-2.4 (a)). Transient faults, meanwhile, were frequent in 2016 and 2017, then dropped in frequency to about once a month to once every 2 months after 2018. The effects of the two rounds of tree trimming also appeared in the Aimeliik - Malakal line at that point of time.



Source: JICA Study Team (original data from PPUC)

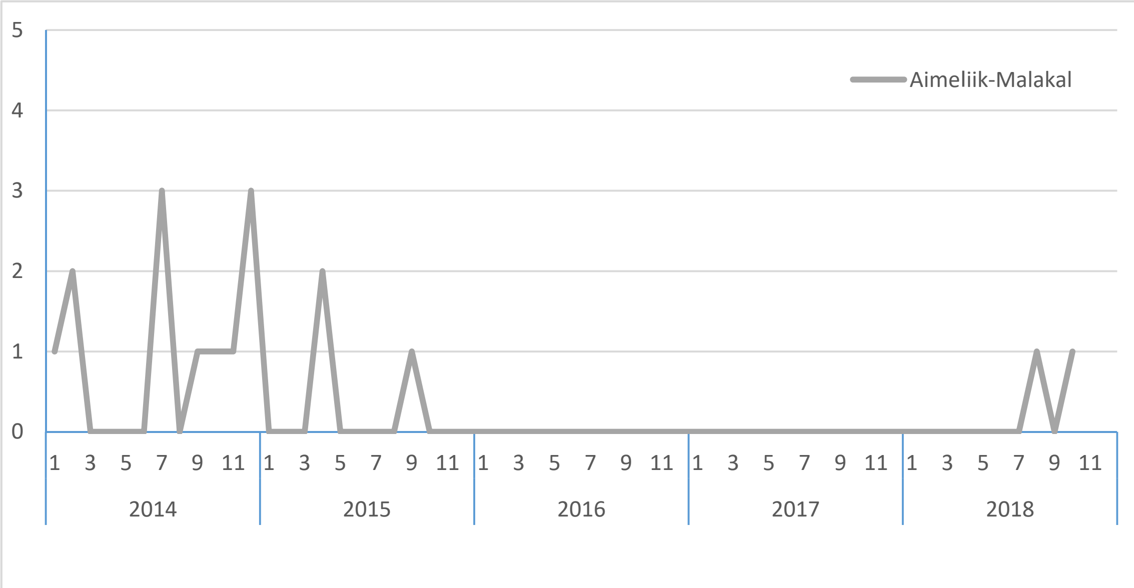
（a） Permanent faults



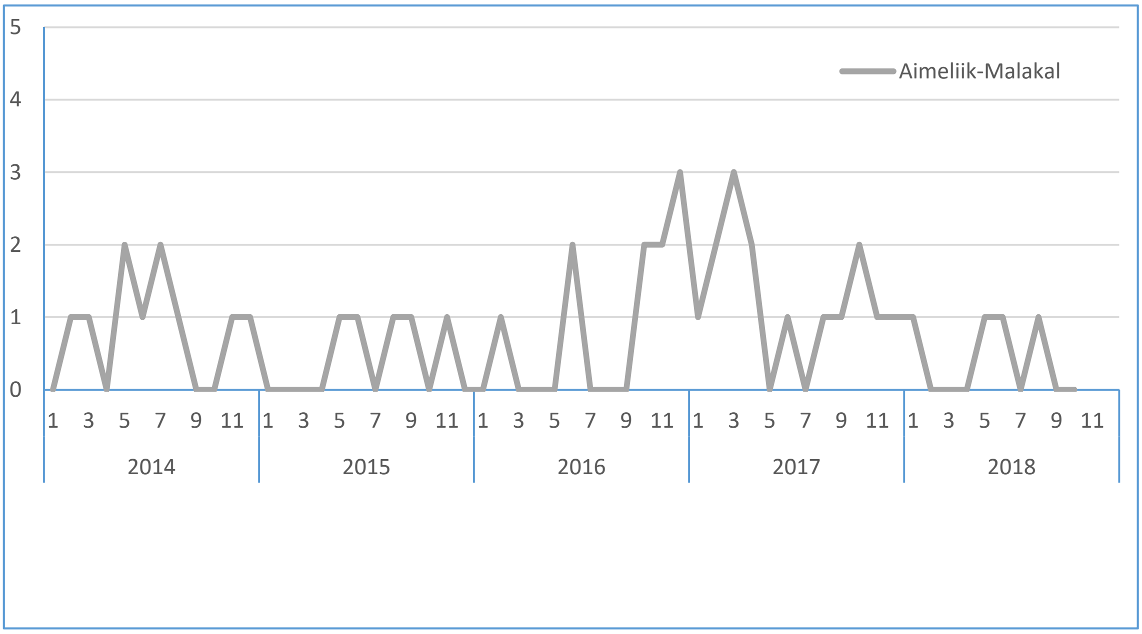
Source: JICA Study Team (original data from PPUC)

(b) Transient faults

Figure 9-1-5-2.4 Monthly change in the number of faults (Nekken line)



(a) Permanent faults



Source: JICA Study Team (original data from PPUC)

(b) Transient faults

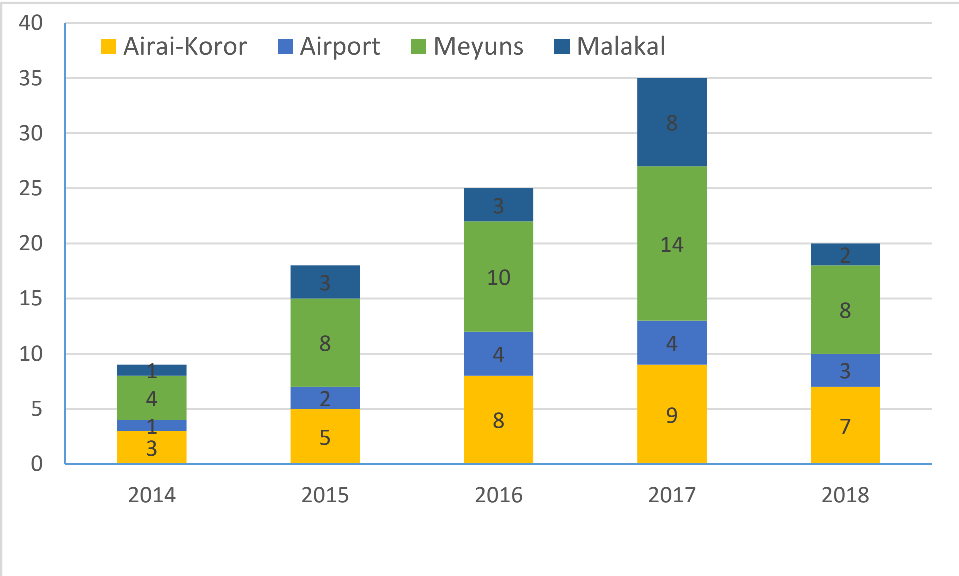
Figure 9-1-5-2.5 Monthly change in the number of faults in (Aimeliik-Malakal line)

2) Faults in 13.8 kV distribution lines

A. Change in the number of faults

Figure 9-1-5-2.6 shows the change in the number of faults detected by relay operations in the 13.8 kV distribution lines. There are four distribution lines in total: Airai - Koror, Airport, Meyuns, and Malakal. The number of faults shown is the sum of permanent faults and transient faults (cause unknown).

As shown in Figure 9-1-5-2.6, the number of faults increased by about 10 cases per year from 2014 to 2017. Among these four lines, faults occurred rather frequently in the Airai - Koror line and Meyuns line. The installation environments (in close proximity with many trees) and long lengths of these lines are likely to have contributed to the higher incidence of faults.



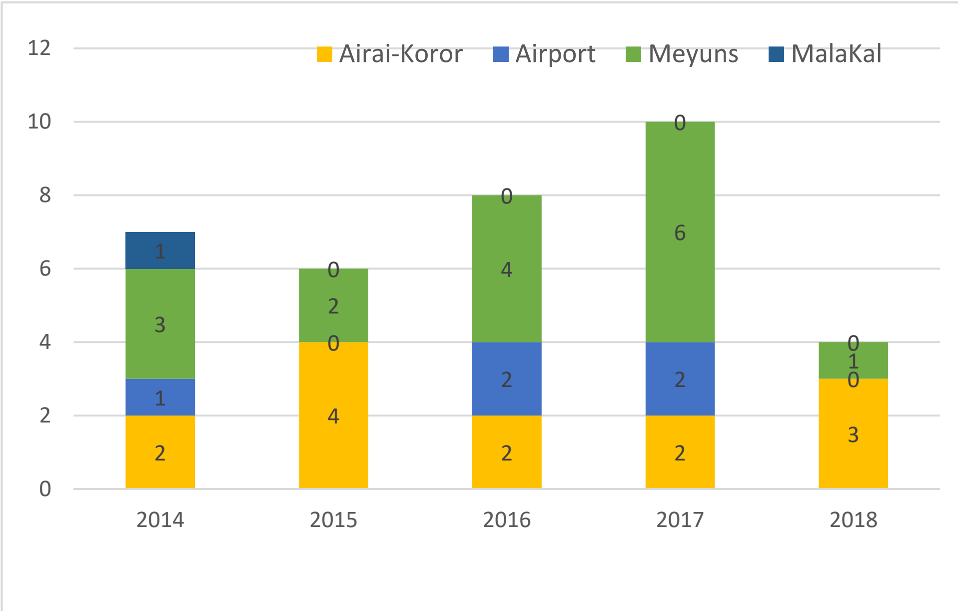
Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.6 Change in the number of faults in distribution lines (permanent faults and transient faults)

B. Grasping the patterns of the faults occurring

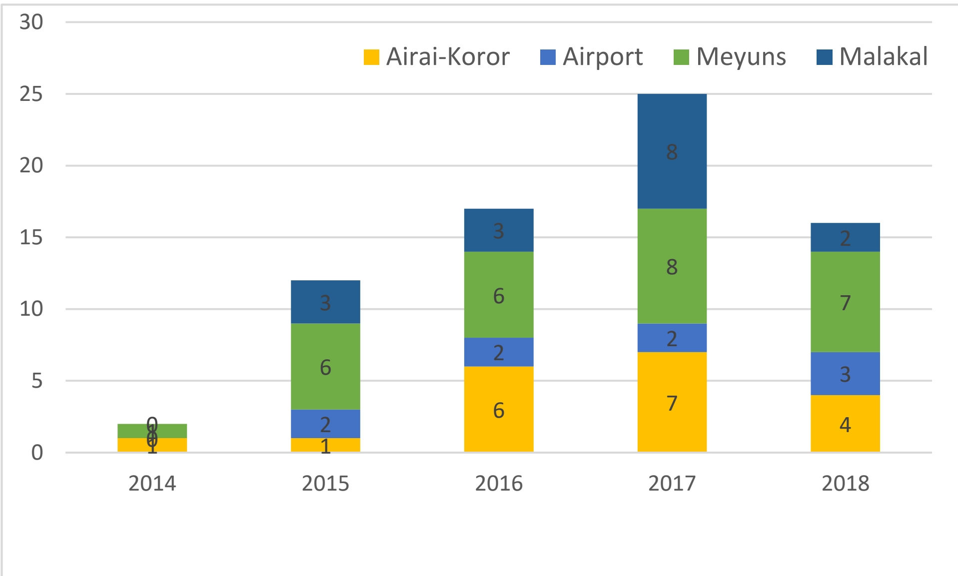
The total numbers of faults shown in Figure 9-1-5-2.6 are broken down into permanent faults (Figure 9-1-5-2.7) and transient faults (Figure 9-1-5-2.8). The breakdowns clearly show that the increases in the total numbers of faults from 2014 to 2017 were due to increases in both permanent faults and transient faults.

From the viewpoint of the distribution system as a whole, transient faults were about twice as frequent as permanent faults. Permanent faults were frequent in the Airai-Koror and Meyuns distribution lines.



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.7 Change in the number of distribution line faults (permanent faults)



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.8 Change in the number of distribution line faults (transient faults)

As shown in Figure 9-1-5-2.7, permanent faults were especially frequent in the Meyuns line up to 2017 but then drastically decreased in 2018. Almost the same tendency appeared in the Airai-Koror line throughout the whole period investigated, with several permanent faults occurring per year.

As shown in Figure 9-1-5-2.8, transient faults occurred at almost the same frequencies in the three distribution lines (Airai-Koror line, Meyuns Distribution Line, Malakal Line).

C. Relationship between countermeasures taken for the 13.8 kV distribution lines and the numbers of faults

As shown in the previous section, the number of faults in 13.8 kV distribution lines detected by relay operations increased from 2014 to 2017 and then declined in 2018.

The maintenance measures taken for the 13.8 kV distribution lines, meanwhile, were corrective repairs after each fault. As an initiative under this project, periodic patrols aiming for preventive maintenance were started in February 2018. Part of the repair work prescribed in the inspection results was carried out by August 2018.

Because of the arrangement and sequencing of the measures taken under this project over time, the results of this project have yet to manifest as a change in the number of faults. If regular patrols and repair work are carried out continuously in the future, the number of faults will gradually decrease from the level recorded in 2018.

(3) Change in the number of distribution line faults (analysis of PDD data)

The next analysis focused on the number of faults reflected in the data recorded by the power distribution department (PDD). The faults counted include those due to blown fuses installed in the distribution lines. PDD dispatches Line Workers to investigate the causes and perform restoration work. Therefore, these data are also believed to include the number of cases shown in Figure 9-1-5-2.7 (SCD data)

Only data after 2016 were obtained for analysis, so the results of the data analysis below do not cover faults in 2016 or earlier.

A. Changes in the numbers of faults

PDD summarizes fault data by region. The following seven regions are set.

a. Despedall (East Coast of Babeldaob): Distribution line area supplied from Kokusai substation
b. Keyukl (West Coast of Babeldaob): Distribution line area supplied from substations (8 places: table 6-1-1-2.1) under the Nekken transmission line
c. Malakal Feeder: Distribution line supplied from Malakal substation
d. Meyuns Feeder: Distribution line supplied from Malakal substation
e. Airai-Airport Feeder (Entire Airai): Distribution line supplied from Airai Substation
f. Airai-Koror Feeder (Airai Sub to PHS): Distribution line supplied from Airai Substation
g. Airai (Airai Sub to Ngerikiil and to Ordomel): Some branch lines of the Airai-Airport Feeder

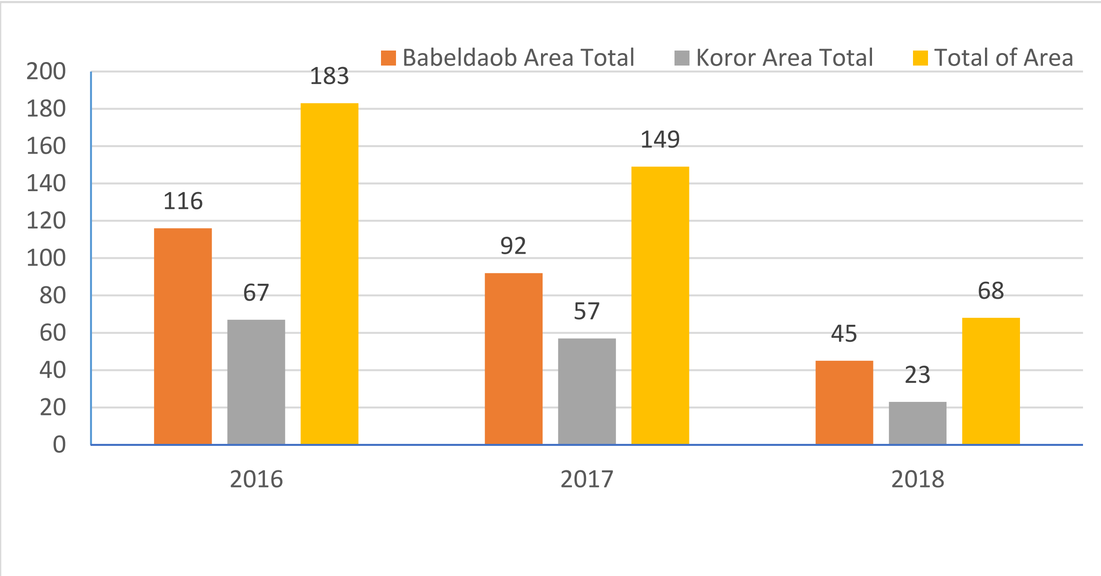
Figure 9-1-5-2.9 shows the yearly trends in the number of faults by area (Babeldaob Area and Koror Area). Here, the number of cases in the figure is summarized by the following formula.

- Babeldaob Area Total = a + b
- Koror Area Total = c + d + e + f + g

As this figure demonstrates, the number of faults has decreased since 2016 in both areas. The trend shown is completely opposite to the change observed in Figure 9-1-5-2.6. The number of faults in

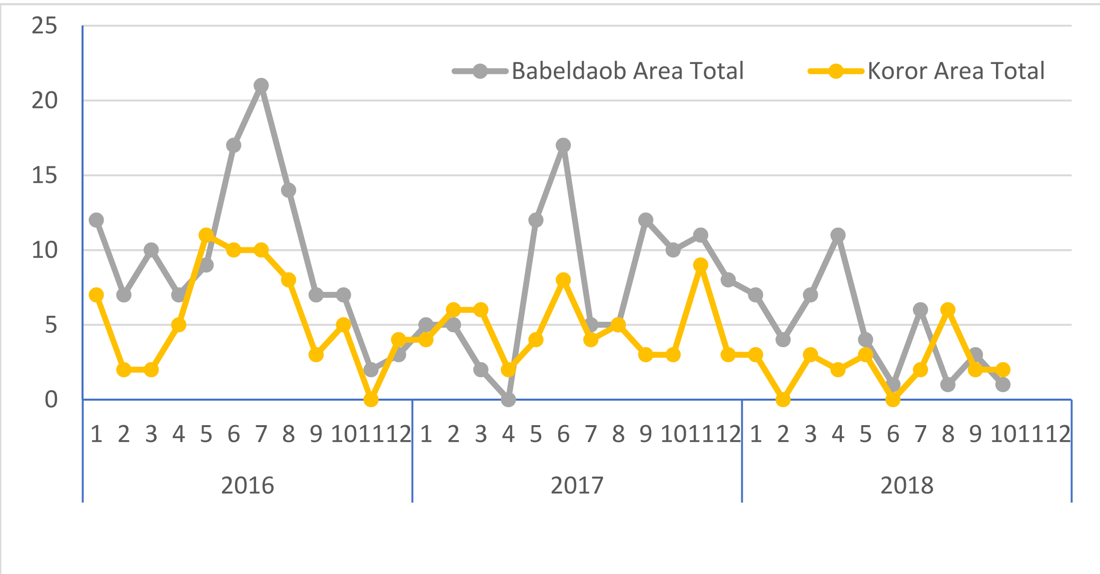
Figure 9-1-5-2.6, however, is much smaller than that in Figure 9-1-5-2.9. Hence, it may not be necessary to consider the difference between these two trends.

Figure 9-1-5-2.10 plots the monthly breakdowns of the yearly data shown in Figure 9-1-5-2.9. The monthly trend of the data also shows a decline in the number toward the end of 2018 in both the Babeldaob and Koror Areas.



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.9 Annual change in the number of faults in each area



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.10 Monthly change in the number of faults in each area

B. Grasping the patterns of the faults occurring

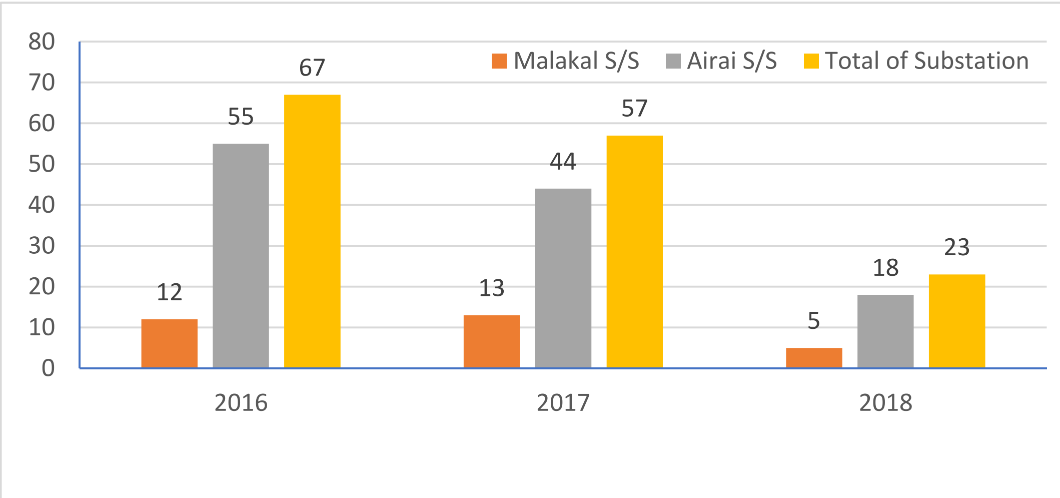
The comparison of the number of faults by region in Figure 9-1-5-2.9 shows that nearly twice as many faults occur in the Babeldaob Area than in the Koror Area, even though former has a much smaller power demand than the latter. Many stretches of the distribution line in the Babeldaob Area pass through the jungle, so the tree and wildlife contacts are thought to explain the high fault frequency in this area.

① Trends in town areas (Koror Area)

Figure 9-1-5-2.11 shows the annual change in the number of faults in each substation in the Koror Area. The number tends to decrease every year for each substation, and the decrease in 2018 is remarkable.

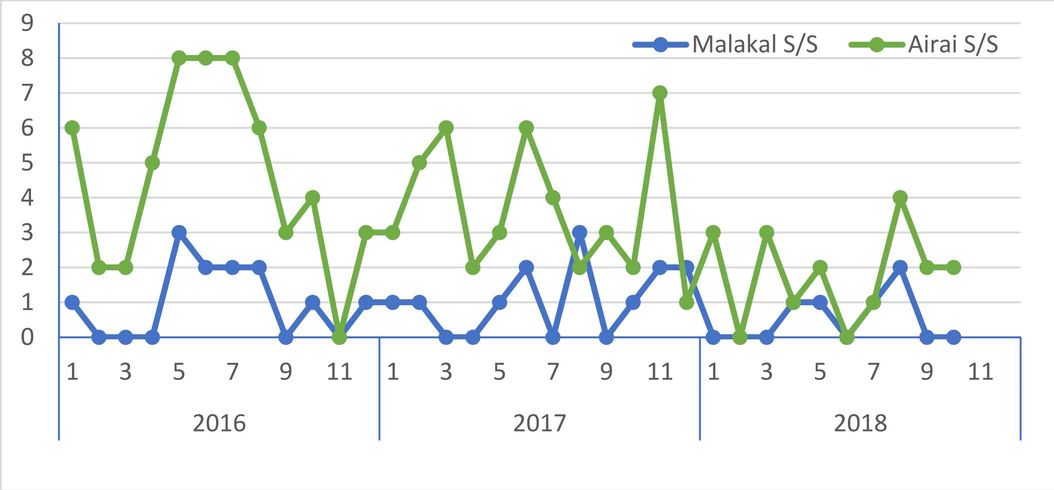
In the comparison between substations, faults occurred four times more often in the Airai substation area than in the Malakal substation area. The power lines in the Airai substation area span a longer total length and more often pass through stretches of jungle.

Figure 9-1-5-2.12 shows the monthly breakdown of the yearly changes in the numbers of faults shown in Figure 9-1-5-2.11. The number remains almost constant, at twice a month, in the Malakal substation area. In the Airai substation area, meanwhile, the number tends to decrease.



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.11 Annual change in number of faults in each substation



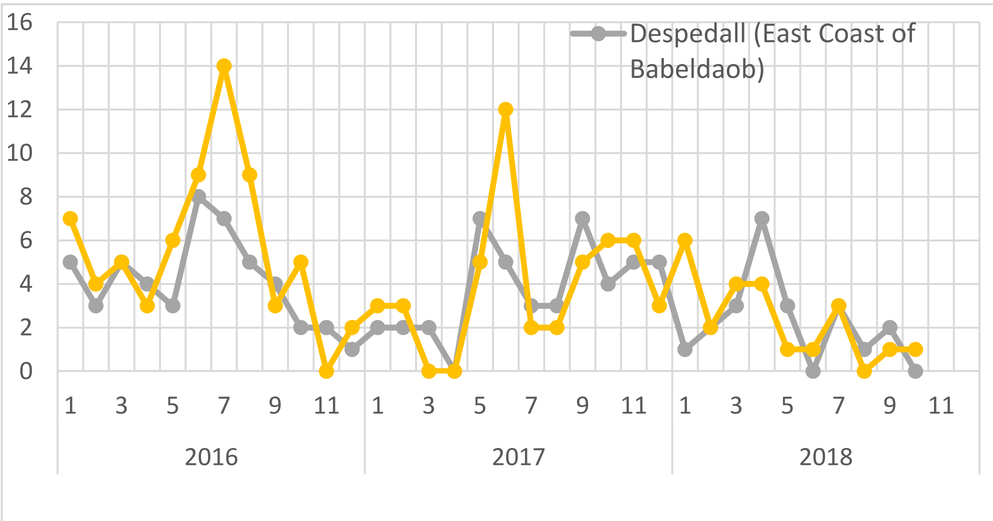
Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.12 Change in the number of faults in the Koror area

② Trend in the jungle Area (Babeldaob Area)

Figure 9-1-5-2.13 shows the monthly change in the Babeldaob Area. The Babeldaob Area is divided into two areas, Despedall (eastern coast of Babeldaob) and Keyukl (western coast of Babeldaob).

The monthly frequency of faults tended to decrease toward the end of 2018 in both areas. More faults occurred in the east coast area than in the west coast area in 2016 and 2017, but the numbers have been almost the same since 2018.



Source: JICA Study Team (original data from PPUC)

Figure 9-1-5-2.13 Change in the number of faults in Babeldaob (Supplied from Nekken T/L)

As described above, the faults occurring in the transmission and distribution lines of PPUC were analyzed from the viewpoints of 'temporal change' and 'region (corresponding to the status of facilities installed).' The effects of measures implemented were considered from the viewpoints of the temporal change in fault frequency and the timing of their implementation.

Because the data (facility data, fault reports, equipment inspection data, etc.) at present have yet to be sufficiently maintained, the results of the analysis are as described above. To take maintenance measures directly related to the causes of faults in the future, it will be necessary to objectively grasp the problems with equipment and the areas with problems in reliability. To attain this capacity, it will be necessary to prepare various data as described above and establish methods to analyze them.

9-1-6 Recommendations on Reinforcing the Transmission and Distribution Facility Maintenance and Management System

In this project we have introduced the concept of preventive maintenance and implemented examples of concrete measures through pilot projects with the aim of ultimately improving the reliability of the transmission and distribution facilities of Palau. The following two pilot projects were implemented.

- Measures to cope with trees nearby the 34.5 kV transmission lines
- Periodic patrol and repair of town area facilities

The chief measures to cope with trees nearby the transmission lines have been the establishment of a tree trimming team in 2015 and steady trimming operations since.

Regarding the periodic patrols of the facilities, the main task for preventive maintenance, a lack of personnel in departments, difficulty in obtaining budgets, and other impediments have hindered sufficient efforts so far.

Further, the necessary bases for the steady implementation of preventive maintenance work, such as the organization, the rules of business operation, the management of data, etc. have yet to be sufficiently established.

The following section describes the items required for the steady implementation of the preventive maintenance work by PPUC and the items that need to be intensively reinforced going forward within PPUC.

9-1-6-1 Reinforcement of the organization and human resources and clarification of business operations

As shown in the earlier descriptions of the work cycle of preventive maintenance (Figure 9-1-3-2.4) and the key points in the preventive maintenance work cycle (Figure 9-1-3-2.5), the preventive maintenance has to be implemented cyclically, with each PDCA work stage connected in an effectively flowing series (PDCA cycle).

To effectively connect each stage, proper data should be handed over to the relevant departments. It will also be important to analyze the data to narrow down the problems to be addressed by focused measures.

The types of maintenance work currently carried out in PPUC are roughly divided into three types (Table 9-1-6-1.1). The period for inspection and repair is divided according to the size and position of the equipment.

Type (A) is the replacement of certain aged facilities all at once. The planning department forms the plan for the replacement work. Type (C) is the repair of faults when necessary, based on experiences of PDD (information on frequently occurring faults and the equipment causing the faults). This is a kind of corrective maintenance. Type (B) is another approach based on the concept of preventive maintenance, but it has not been implemented so far.

Table 9-1-6-1.1 Implementation status of preventive maintenance

Type	Size of Facility	Cycle of Inspection/Repair	Details on Implementation
(A)	Area-wide	Period of about 30 years (Planned renovation)	Equipment in the area that has been in place for about 30 years or longer is assumed to be deteriorated by rust and in need of repair on a region-wide basis.
(B)	Main line	An annual cycle as specified in the "MAINTENANCE GUIDELINE"	Due to the large impact on reliability, periodic inspection is carried out in a 1- to 3-year cycle.
(C)	Branch line	When necessary	This work is carried out whenever necessary for purposes such as find the causes of frequent faults and taking measures against them.

Source: JICA Study Team

The maintenance work implemented in PPUC is carried out without constructing the above-mentioned PDCA cycle sufficiently.

In order to properly maintain the reliability of the system in the future, it will be necessary to shift the emphasis to the type (B) approach and properly combine it with the (A) and (C) approaches in a cohesive system. The releated departments (SCD and PDD) will need to clarify their roles and business operations for this purpose, and uncertainty in the scope of responsibility will have to be eliminated in the organization.

In conducting the above organization management, it will be necessary to allocate personnel in charge of data analysis, planning, and progress management. As no section responsible for data analysis and planning is yet established, the organizational structure is still ill-equipped to effectively rotate the PDCA cycle.

Another required step will be to arrange administrators to manage these works comprehensively. Figure 9.2-3.1, Figure 9.2-3.2, and Figure 9.2-3.3 show examples of the organizational structure and work flow for the maintenance work on the substation equipment under the control of SCD.

9-1-6-2 Multi-skilling of the Line Workers

The main section in charge of periodic patrols in PPUC is currently SCD, but the lack of personnel (busy work) and vehicles makes it impossible to carry out periodic patrols on a continuous basis. While the personnel in PDD engage in construction work and fault restoration work using vehicles every day, they do not conduct patrol work.

The style of organization as described is not a rational choice for conducting inspection work. However, increasing the number of personnel of SCD for inspection work is problematic in terms of cost. One idea for improving the situation is the multi-skilling of the PDD Line Workers. With improved inspection skills, PDD personnel could engage in inspection work on behalf of SCD in off-peak periods of operations.

Training for the multi-skilling of Line Workers would be necessary to realize this idea. It would also necessary to establish the report form. With these steps taken, periodical inspection could be conducted continuously without any rises in cost.

9-1-6-3 Establishment of standards and thorough information-sharing

The preventive maintenance work cycle in the organization can be made to funtion effectively if each concerned department recognizes objective rules on business in common. In PPUC, however, no such rules are codified as standards. The standards prepared and proposed in the various types of support extended do not seem to have been sufficiently utilized. Currently, some of the rules are inherited by the staff verbally through OJT.

In order to carry out preventive maintenance work continuously while keeping a certain level of quality, it will be necessary to prepare standards for the main works and enhance the knowledge for the work. Following are several examples of necessary standards. The contents of these standards have to be considered to ensure that they suitably fit the current situation of PPUC.

- Equipment planning standards (concepts for long-term plan formulation, planning methods)
- Construction standard for equipment (specification of structures, sizes, capacity, etc.)
- Electrical safety code or technical standard of power facilities
- Equipment maintenance standard (proposed as a "Maintenance Guideline")
- Operational rules for various tasks
- Criteria for judging degraded equipment
- Criteria for updating equipment (due to aging or overload)

9-1-6-4 Maintenance of facility management data and drawings

At the very least, the materials (data and drawings) for facility management must be maintained if preventive maintenance work (including system operation) is to be effectively performed in the above organization. These materials also have to be shared with the relevant persons and updated regularly. In PPUC, however, this point is fundamentally insufficient.

Table 9-1-6-1.2 shows basic data required for preventive maintenance work. In addition to preparing them, the organization and work flow for updating the data (e.g., new construction and replacement, etc.) must also be considered.

The pole numbers are a piece of basic information for confirming the equipment and managing the equipment data. The numbers, however, are too often insufficiently set, and most of the pole number plates do not remain at the sites. Objective data management is difficult in this situation. This is a problem to solve with top priority.

Table 9-1-6-1.2 Equipment management data to be maintained

	Documents & Form	Information to be stated		Purpose and usage of development
		Major Information	Detailed information	
1	Pole number (Setting number & Installing tags)			It is an indispensable indicator for objectively and continuously implementing the management of facilities and equipment for preventive maintenance work and facility planning work.
2	Single Line Diagram (34.5kV and 13.8kV)	It specifies the details of the configuration and form of each 34.5kV system /13.8kV system in a single line diagram. In the symbolized single line diagram, information on the main equipment is described. (as in right side column)	1.Length and conductor type of major section 2.The current capacity (limited current) of each section 3.Position of automatic sectionalizing switch / recloser (pole number) 4.Position of manual switch (pole number) 5.Position of cut-out for sectionalizing line (pole number), Capacity of applicable fuse 6.Relation of Interconnection between adjacent systems	・Fault point locating against Feeder faults, System operation during power restoration ・Original drawing for Scheduled outage plan and indication of current situation during power outage work ・System operation for Scheduled outage plan and indication of current situation during power outage work ・Calculation of fault current ・Grasping the configuration and form of each feeder of transmission system and high voltage distribution system ・Preparing relating documents in order to implement proper system operation and management.
3	Line Route Map	Details of the configuration and form of each 34.5kV line / 13.8kV line are indicated on the map. Information on the main equipment is described in the line diagram. (as in Right side column)	1.Length and conductor type of major section, and Installation year 2.The current capacity (limited current) of each section 3.Position of automatic sectionalizing switch / recloser (Pole number), Current capacity, and Year of manufacture 4.Position of manual switch / recloser (Pole number), Current capacity, and Year of manufacture 5.Position of cut-out for sectionalizing line (utility pole number), Capacity of applicable fuse 6.Position of transformer bank (pole number), connection type of the bank, transformer capacity, capacity and type of applicable fuse 7.Position of large load contract (Pole number), Customer name, Contract power	・Comprehensive grasp of transmission line / high voltage distribution line and facility management ・Expansion planning for substation (Power plant) and transmission and distribution feeder against increasing demand ・Basic data for design and construction planning ・Examination of countermeasures against emergency disaster
4	List of Line Switches	Information on switchgear including line sectionalizing cut-out (as in right side column)	1.Installed place(line name and pole number) 2.Switchgear type, Year of manufacture 3.Current capacity (Load current) 4.Inspection / repair record	・Basic information for equipment management and formulating maintenance plan
5	List of Transformer bank	Information on polemounted transformers supplying to customer (as in right side column)	1.Installed place(line name and pole number) 2.Connection type of transformer bank 3.Transformer capacty, Year of manufacture 4.Data of Connected customers (number of customers by type of contract)	・Basic information for equipment management and formulating maintenance plan ・Basic information for load management and equipment expansion design