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Installation and Knowledge Transfer Process Factors of Solar Energy Production for Northern Communities in Thailand

Prungsak Uttaphut
Assistant Professor, Department of Electrical Technology,
Faculty of Industrial Technology, Suan Sunandha Rajabhat University,
Bangkok 10300, Thailand.

Abstract
Thailand has the remote highland which electrical system cannot access. Solar energy production system is an option for the community and people in remote areas to have electricity. Installation and Knowledge Sharing Process Factors of Solar Energy Production for Northern Communities in Thailand is accorded to development strategy according to The National Economic and Social Development Plan, The Fourth National Research Strategy - Green Growth. The problem statement is which factors are important to the installation and knowledge transfer process of solar energy production for northern communities in Thailand. The objective of the study is to find factors for prototyping of the installation and knowledge transfer process of solar energy production for northern communities in Thailand. From the result, electricity production from solar energy by solar cells has factors which affect efficiency and system lifetime for design such as the arrangement of solar cells and the incline for receive ray from the sun, the maintenance of equipment such as solar cell panels cleaning and battery. These factors need knowledge and understanding of electrical system for the management in communities. For the remote northern area in Thailand, knowledge accessibility, technical and personal maintenance knowledge will be a benefit for people in the highland. They will get knowledge of suitable factors for installation of solar energy production in the level of communities. The data is historical data for 3 years, 2015-2017. The important factors consist of used electricity management problem as Table 6 with the cumulative frequency of 77. The next is a shortage of maintenance budget and the lack of integration with government agencies in the electrical system maintenance as Table 7 with the cumulative frequency of 59. Technical issues at the installation area, charging controller, and battery system by preventive maintenance as Table 4 with the cumulative frequency of 40. Technical issues at of equipment, solar cell panels, cable, and support structure of solar cell panels by preventive maintenance as Table 3 with the cumulative frequency of 22. The last is Technical issues of invertor and lighting protection by preventive maintenance with the cumulative frequency of 15 respectively.

Keywords: Installation Factor, Knowledge Transfer Process, Solar Energy Production for Communities, Northern Thailand.

INTRODUCTION

In the present, solar cells are widely used around the word especially after power shortages crisis due to fossil fuels is non-renewable energy and global environmental crisis. From 1973, there was an effort to find newly substituted energy sources. After that, the use of solar cells increased several times because solar energy is the high potential renewable energy and Green Energy which does not impact the environment so it can relieve the global warming. The use of solar cell or Photovoltaic can be used in remote areas or areas without electricity. In Thailand which is a developing country, some local areas still lack electricity however installing traditional transmission cable need to be evaluated economic worth because remote areas have a low density of population. Therefore, too low electricity use is not worth for the investment. When considering the advantage of the photovoltaic system as a source of power in remote areas, economic value is higher and good for social development. The features are the size can be designed based on the electricity demand, the efficiency is quite constant and not depends on the size, less maintenance cost due to less equipment but it might need preliminary knowledge for maintenance and use for the best-distributed performance.

Usage condition of Photovoltaic system which suitable for remote areas is Telecommunications Equipment, TV, and communication radio. In remote areas, most people are agriculturists so the application of Photovoltaic system can increase the productivity such as pumping by solar energy solar radiation maps that provide the information of solar potential in Thailand. It is found that the average daily solar radiation per year is 18.0 MJ/m2- day. From this, Thailand has highly potential in solar energy and "Thailand's Solar Energy Potential Map" is developed as figure 1 [1].

However, the design of Photovoltaic system needs information such as solar cell incline, solar cell size, and battery size for energy accumulation in a low-intensity condition such as early morning and evening and the most important condition is system design for ease of the application and maintenance. Therefore, components should be low as possible for ease of users in remote areas because solar energy production equipment has natural degradation along the application. For example, Si solar cell both of single and poly-crystalline has efficiency degradation rate 0.7% per year approximately as figure 2 [2]. Moreover, other components equipment which are electrical equipment such as battery, charge controller, or inverter degenerates because of different causes as well. This research aims to find factors for prototyping of the installation and knowledge transfer process of solar energy production for northern communities in Thailand.

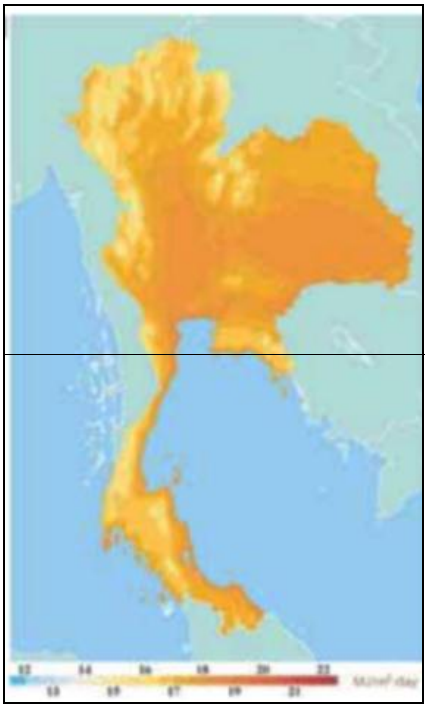

Figure 1: Thailand's Solar Energy Potential Map (average daily solar radiation per year) [1]

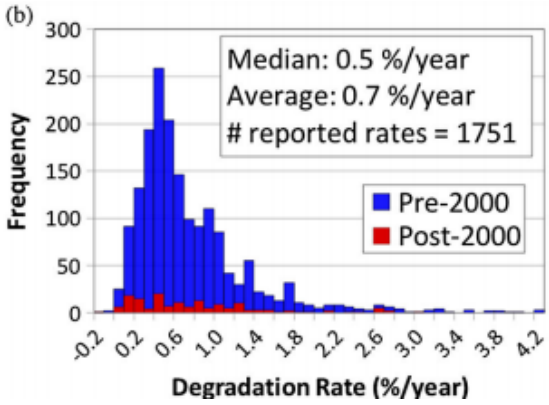

Figure 2: Efficiency degradation rate of Si solar cell panel per year [2]

Research areas have the characteristic of northern topography which has high and complex continuous mountain ranges. Most are in direction of north-south and north west-south east. Areas between mountain ranges are Valley Plain which are important sources of rivers that lead to southern Thailand. The scope of areas covers mountain areas which the proportion between highland and lowland of 4:1 that cover Chiang Rai, Mae Hong Son, Phayao, Chiang Mai, Lamphun, Lampang, Nan, Phrae, and Uttaradit. The central area is the range which is continuously complicated. Usually, this range is called Phi Pan Nam Range which separates flow to north and south which cause rivers that flow to the north such as Fang, Kok, and Ing. For rivers which flow to the south, they are Ping, Wang, Yom, and Nan which the important rivers are going to flow to Chao Phraya River. Between these ranges are Valley Plain and Fluvial Plain which spread in many areas. These are locations are northern communities. The solar energy potential of northern areas depends on the amount of incident solar radiation of each area. The higher amount means the higher potential of solar energy application as Table 1 [1]. It is obvious that the areas with higher solar irradiation are the lower part of northeast mostly. Moreover, northern provinces also have high potential because H is higher than 17 MJ/m2 - day which counted as high such as Chiang Rai, Chiang Mai, Tak, and Nan.

Table 1: Comparison of solar irradiation from Thailand's solar energy potential map [1]

Station	Province	H (map) MJ/m^2	H (measurement) MJ/m^2	Difference (%)
1	Bangkok	17.9	17.5	2.2
2	Kanchanaburi (TMD)	18.0	18.4	2.0
3	Kanchanaburi (Thong Pha Phum)	17.1	17.3	0.8
4	Khon Kaen	17.9	18.5	3.0
5	Khon Kaen	17.3	17.9	3.2
6	Chumphon	17.5	17.5	0.1
7	Chiang Rai	17.0	17.1	0.6
8	Chiang Mai	17.2	18.0	4.8
9	Doi Inthanon National (Mae Klang)	17.0	16.8	0.8
10	Doi Inthanon National (Radar)	17.0	16.1	5.3
11	Doi Inthanon National (Office)	17.0	15.4	9.1
12	Trang	16.9	17.9	5.8
13	Trat	17.2	17.1	0.3
14	Tak	16.7	16.5	1.3
15	Nakhon Phanom	17.4	17.4	0.5
16	Nakhon Ratchasima	18.1	18.1	0.1
17	Nakhon Sawan	18.3	17.9	2.2
18	Narathiwat	18.8	18.6	1.0
19	Nan	17.2	17.3	0.3
20	Prachuap Khiri Khan	18.7	18.5	1.1
21	Prachinburi	17.9	17.6	1.7
22	Phitsanulok	17.9	18.2	1.8
23	Phetchabun	17.6	17.8	1.1
24	Phrae	17.1	17.6	2.9

METHODS

Sample

The sample of this research is selected according to research objectives. They consist of northern areas which have small hydroelectric power plants that cooperate with Electricity Generating Authority of Thailand (EGAT) and people in communities. Moreover, government agencies support using prototype solar power and taken care by EGAT. From these criteria, there are totally 8 communities as samples with 19 solar energy production system sets. There are 1,913 users for all areas as follows;

1) Ban Nam Peang Din Community, Ban Pha Bong, Mueang Mae Hong Son District, Mae Hong Son 1 set with 320 users.
2) Yogi Cave Buddhist place Community, Ban Na, Sam Ngao District, Tak 1 set with 15 users.
3) Ban Mae Kampong Community, Mae On District, Chiang Mai 2 sets with 403 users.
4) Ban Khun Klang Community, Ban Luang, Chom Thong District, Chiang Mai 1 set with 319 users.
5) Ban Hin Lat - Ban Na Hai Community, Ban Na, Sam Ngao District, Tak 7 sets with 320 users.

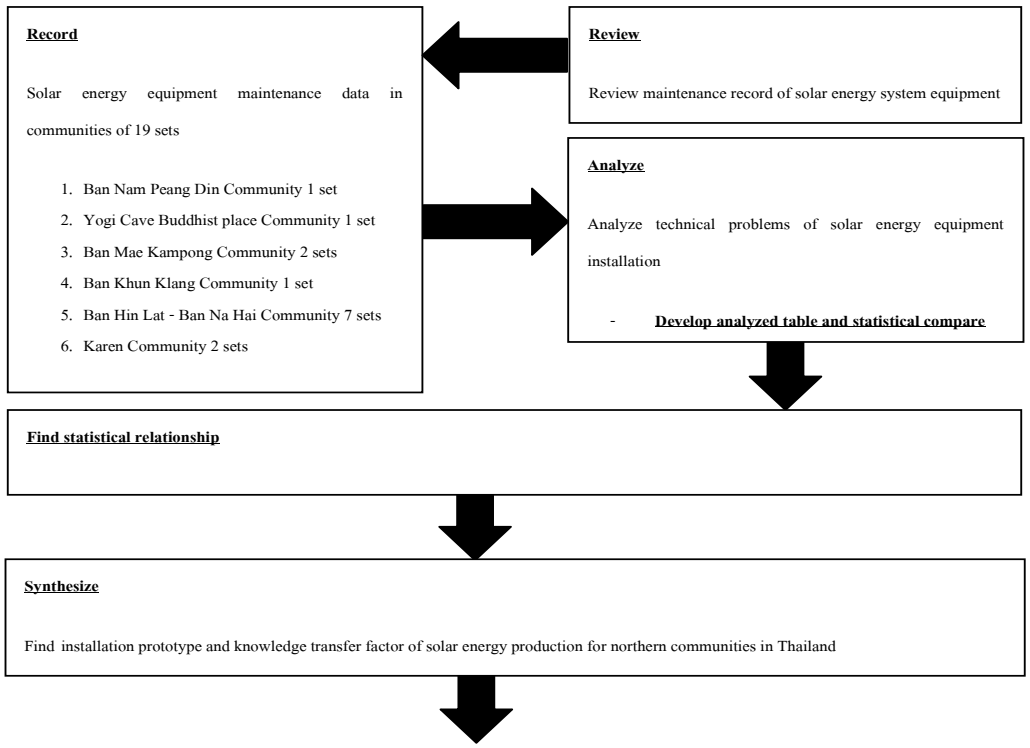

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Figure 3: Data analysis sequences

6) Karen Community, Chom Thong District, Chiang Mai 2 sets with 106 users.
7) Ban Um Wap Community, Ban Na, Sam Ngao District, Tak 4 sets with 328 users.
8) Phra That Kaeng Soi Temple, Ban Na, Sam Ngao District, Tak 1 set with 102 users.

Research tool

Survey, in-depth interview, and analysis by data collection from Power Plant Maintenance Division, Bhumibol Dam.

Data collection

Secondary data from preventive maintenance of Power Plant Maintenance Division, Bhumibol Dam consists of cable system and solar cell panel system including field survey and in-depth interview with staffs and people in communities. The researcher analyzes and synthesizes the result.

Data analysis sequences

The data analysis sequences are shown in figure 3.

1) Review solar energy equipment maintenance record
2) Analyze technical problems of solar energy equipment installation
3) Find the relationship between technical problem frequency and significant management
4) Synthesize installation prototype and knowledge transfer factor of solar energy production for northern communities in Thailand

DATA ANALYSIS RESULT

From data analysis in 1) and 2), there are important technique and process to solar energy system installation for northern communities in Thailand as follows;

Using solar energy system needs maintenance especially when the lifetime is longer. The efficiency will degenerate especially in remote areas which lack of staffs and tools for maintenances and continuous maintenance. Therefore, it is difficult to analyze problems or the maintenance fast and appropriately. It is the challenge of the researcher to design and transfer maintenance program which can be done under the limitation of staffs and tools in remote areas. The degenerations of solar energy system can be classified into many sections as follows;

Problems and degeneration of solar energy system

1) Equipment degeneration

1.1) Solar Cell Panels is the main component of the solar

energy system. The maintenance of this item is the most important factor in the system. Causes of panel degeneration are;

- Panels Cracking can be occurred by many causes such as physical causes from other objects, wind force, a mistake in production or transportation. When the time passes, cracks will expand and affect the efficiency of solar cell panels.
- Panels discoloration is frequently found and affects the efficiency of the panel. It reduces the amount of incident light and solar irradiation. Another cause is it affects the wavelength that the panel can absorb.

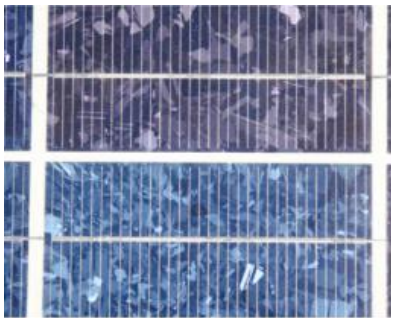

Figure 4: Example of discoloration panel

From figure 4, the color of solar cell panel changes to violet that means violet light will not be absorbed by the panel. This affects the efficiency of the panel. The causes of this issue are material quality, high temperature, moisture, or the installed location is near the sea.

- Hot spots, it is the misunderstanding that solar cell will perform better in the high-temperature condition. In fact, the efficiency depends on the solar irradiation and high temperature may be a cause of Hot Spot which damages the panel. It can be tested by a equipment called IR Gun (Infrared Gun) as figure 5.

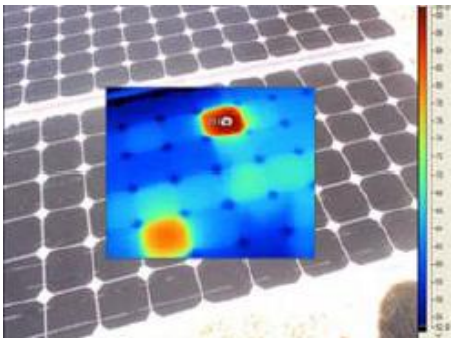

Figure 5: Hot Spots on solar cell panel [2]

1.2) Inverters are an important electrical equipment in a solar energy system which inverts current from the panel as direct current as alternating current. In the present, there is the development of Micro Inverters to use and tend to be more popular continuously. In the past, the lifetime of inverters are 10 years with 3 years and the error is lower than 3 years. In the present, inverters are developed in many perspectives especially the lifetime. The target is the lifetime which equals or longer than the design period of the solar cell system.

1.3) Monitoring Failure, the modern inverter usually has a monitor to show Volts and Current of outcome electricity. Moreover, the data from the inverter can be checked and stored as data itself. While the old inverter needs a routine inspection to check the continuity of the data and the record needs to be done by the inspector manually.

1.4) Panel Orientation and Grid, the orientation is the first step before solar energy system installation which the angle and degree of the panel have to be inspected for the maximum and longest duration of the light receiving. For sun tracking solar cell, this step may be not much important because it can change the angle along with the sun itself. However, for the fixed one, the installation has to be done by calculating Azimuth for the maximum current.

2) Degeneration by the environment

2.1) Snow, from the study, the degeneration of efficiency is the result of snow up to 15 % in Truckee, California, USA and 0.23-2.7 % in German. The average annual loss factor is 3% approximately [4]. Therefore, snow is the problem which reduces the efficiency of solar cell. However, this problem happens in just some locations. For the solution, if it is a residential level, the panel can be scrubbed as long as the panel is not damaged. For the power plant, it cannot be solved in that way. It has to be waiting for the snow to melt itself.

2.2) Soiling, dust and sand are very important problems because they need the very high cost to clean. In a big power plant, it may need to be cleaned 2 times per year which the cost is thousands USD. From the data of Mejia and Kleissl [2], from 186 solar power plants, the loss rate is 0.01% per day approximately. It is found that the panel with incline smaller than 5 degrees has dust accumulation 5-time more when compared with the panel with incline bigger than 5 degrees. Therefore, if the area is dusty, the panel should incline more than 5 degrees. Although the received amount of radiation is lower but the lifetime is longer because the maintenance period will be expanded.

2.3) Wind, this is similar to dust. It happens in the particular area. In general condition, solar cell panel needs to resist the wind force (50+ mph). However, in the real situation, the wind may not accord to the design and it may damage the panel by crack or falling. Therefore, the expertise of designers and installer are important.

Maintenance

1) Panel Cleaning is very important to maintain the efficiency of the electricity generation. The proper cleaning should be done in the morning while the panel is moist by dew because dust can be cleaned without damage to the panel. The most popular way is water spraying which adds some cleaning

substance that has some properties such as reduce surfactant of the panel or can melt itself without environmental impact. This cleaning process can lift the efficiency up to 98 % when compared with the new panel.

2) When to clean, in general, the proper time is not fixed. However, it has a guideline that is when the cost of energy loss is more than the cost of panel cleaning. Generally, the prediction of produced electricity amount is difficult because of many factors such as various angle of incidence. The prediction needs area information for a specific period and the longer period means the more accurate information. For example, a software called "NREL PV Watts Software" is used to predict the proper time to maintenance and cost of the cleaning which from the employee. In general, the employee will estimate the cost and visit the site to estimate the exact cost of cleaning (average cost is 2.50 USD per Kw.) [2].

DISCUSSION AND CONCLUSION

From the data analysis in 3) and 4), the relationship between technical problem frequency and significant management and synthesis of installation prototype and knowledge transfer factor of solar energy production for northern communities in Thailand can be discussed as follows.

From data collection of a solar energy system responsible person for the general feature, technical issue, management issue in northern areas, there are 8 installed location of solar energy system as Table 2. From this table, the problems or issues can be classified into 2 types, technical issue and management issue, as follows.

Technical issue

The technical issue which related to solar energy equipment that degenerates along the time and improper use can be shown as Table 3-5. From the above synthesis, the technical issues which the most frequently found are Battery and Inverter respectively. These 2 equipments have the most damage and degeneration because they are electronic equipment which responsible staffs lack of knowledge. Moreover, it is because of the degeneration, misuse, or excess capability of the equipment. For other issues, they are not frequently found when rectified and repaired according to proper maintenance periods such as damaged solar cell panel, damaged cable, rusted supporting structure of the panel and lightning protection equipment.

Management issue

Management issues are related to maintenance management of solar energy system. The issues may be caused by the preliminary knowledge lacking of staffs to maintain the efficiency as Table 6-7. From the above synthesis, the management issues which the most frequently found are Lack of maintenance budget and No knowledgeable maintenance staff respectively. Therefore, it is difficult to find expertise staff which causes other issues such as overload using that shorten the lifetime of the panel and lack of taking care by installed departments. When the system is damaged, people in remote areas are difficult in living. It is obvious that in the remote areas such as Ban Hin Lat - Ban Na Hai, Karen, and Ban Um Wap where are remote in the mountains and Bhumibol Dam where can be accessed by boat have the outstanding and clearer management issues than others. Therefore, local people should be provided the knowledge about the management to solve these issues.

Table 2: Information of location, owner, and type of studied solar cell

List	Installed location	Location	Owner	Type of solar cell panel	Stand Alone	Grid
1	Ban Nam Peang Din	Ban Pha Bong, Mueang Mae Hong Son District, Mae Hong Son	Community	Poly-Crystalline Silicon		I
2	Yogi Cave Buddhist place	Ban Na, Sam Ngao District, Tak	Tha Pui Tok Temple	Poly-Crystalline Silicon	I	
3	Ban Mae Kampong	Mae On District, Chiang Mai	Community	Poly-Crystalline Silicon		I
4	Ban Khun Klang	Ban Luang, Chom Thong District, Chiang Mai	Community	Poly-Crystalline Silicon		I
5	Ban Hin Lat - Ban Na Hai	Ban Na, Sam Ngao District, Tak	Community	Poly-Crystalline Silicon	I	
6	Karen	Chom Thong District, Chiang Mai	Community	Poly-Crystalline Silicon	I	
7	Ban Um Wap	Ban Na, Sam Ngao District, Tak	Community	Poly-Crystalline Silicon	I	
8	Phra That Kaeng Soi Temple	Ban Na, Sam Ngao District, Tak	Phra That Kaeng Soi Temple	Poly-Crystalline Silicon	I	

Table 3: Information of location and technical issues of Solar cell panel, Cable, and Supporting structure of the panel Solar cell panels which detected in Preventive Maintenance during last 3 years

List	Installed location	~ 1 month				~ 6 months				~ 6 months			
		Solar cell panel				Cable				Supporting structure of the panel			
		2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
1	Ban Nam Peang Din		I	I			I			I			
2	Yogi Cave Buddhist place	I					I						
3	Ban Mae Kampong	I				I				I			
4	Ban Khun Klang		I			I							
5	Ban Hin Lat - Ban Na Hai	I				I				I			
6	Karen		I			I					I		
7	Ban Um Wap		I			I					I		
8	Phra That Kaeng Soi Temple		I				I						

Table 4: Information of location and technical issues of System Installed area, Charge controller, and Battery which detected in Preventive Maintenance during last 3 years

List	Installed location	~ 1 month				~ 6 months				~ 6 months			
		System Installed area				Charge controller				Battery			
		2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
1	Ban Nam Peang Din	I				I				II	I	I	
2	Yogi Cave Buddhist place		I					I			I		
3	Ban Mae Kampong					I	I			II	I	I	
4	Ban Khun Klang									I			
5	Ban Hin Lat - Ban Na Hai					I		I		II	II	I	
6	Karen		I			I		I		II	II	II	
7	Ban Um Wap						I	I		II	II	I	
8	Phra That Kaeng Soi Temple									I			

Table 5: Information of location and technical issues of Inverter and lighting protection equipment which detected in Preventive Maintenance during last 3 years

List	Installed location	~ 1 month				~ 6 months			
		Inverter				lighting protection equipment			
		2015	2016	2017	2018	2015	2016	2017	2018
1	Ban Nam Peang Din	I				I			
2	Yogi Cave Buddhist place			II	I				
3	Ban Mae Kampong		I						
4	Ban Khun Klang				I				
5	Ban Hin Lat - Ban Na Hai	I			I				
6	Karen	I		I			I		
7	Ban Um Wap	I						I	
8	Phra That Kaeng Soi Temple	I							

CONCLUSION

From the analysis and synthesis, electricity generation by solar cell panel is affected by many factors. These factors affect the efficiency and lifetime of the system. For example, the design technique such as panel orientation and grid or incline of the panel to receive the solar radiation. Another is the maintenance technique of equipment such as solar cell panel cleaning and taking care of batteries. These factors need knowledge and understanding of electrical system and management system to manage the solar energy system for remote northern areas. The accessibility of this maintenance information may be limited for both of technique and personal which are the interesting challenge for knowledge design to transfer the knowledge to local people for the benefit of solar cell panel maintenance and electrical system management to get the best efficiency as it supposes to be. The installation and knowledge transfer process factors of solar energy production for northern communities in Thailand by using

Table 6: Information of location and management issues of Overload, No System administrator, and No knowledgeable maintenance staff which detected during last 3 years

List	Installed location	Overload				No System administrator				No knowledgeable maintenance staff			
		2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
1	Ban Nam Peang Din	II				I				II	I		
2	Yogi Cave Buddhist place	II	II	I		I				I			
3	Ban Mae Kampong	I											
4	Ban Khun Klang	I											
5	Ban Hin Lat - Ban Na Hai	II	II	II		II	II	II	I	II	II	II	
6	Karen	II	II	II		II	II	II	I	II	II	II	
7	Ban Um Wap	II	II	II		II	II	II	I	II	II	II	
8	Phra That Kaeng Soi Temple	I				I				I			

Table 7: Information of location and management issues of Lack of maintenance budget and Lack of integration with other departments which detected during last 3 years

List	Installed location	Lack of maintenance budget				Lack of integration with other departments			
		2015	2016	2017	2018	2015	2016	2017	2018
1	Ban Nam Peang Din	I			I	II	II	I	
2	Yogi Cave Buddhist place	II	I	II	I				
3	Ban Mae Kampong	I							
4	Ban Khun Klang	I			I	II	I		
5	Ban Hin Lat - Ban Na Hai	II	II	II	I	II	II	I	
6	Karen	II	II	II	I	II	II	I	
7	Ban Um Wap	II	II	II	I	II	II	I	
8	Phra That Kaeng Soi Temple	I	I	I	I				

data during the last 3 years, 2015-2017, can be summarized that there are important factors as follows Electricity use management issue as Table 6 with the cumulative frequency of 77 times. The second is Lack of maintenance budget management issue and Lack of integration with other departments as Table 7 with the cumulative frequency of 59 times. Next is the technical issues of system installed areas, charge controller, and a battery system which detected in Preventive Maintenance as Table 4 with the cumulative frequency of 40 times. Next is technical issues of equipment which consist of solar cell panel, cable, and supporting structure of panel which detected in Preventive Maintenance as Table 3 with the cumulative frequency of 22 times. The last is technical issues of Inverter and lighting protection equipment which detected in Preventive Maintenance with the cumulative frequency of 15 times respectively.

SUGGESTION

Electricity is the basic utility. In the present, remote areas cannot be installed transmission cable so they need solar energy system. Without the solar energy system, schools cannot provide satellite communication applications for distance education for student and people do not have the lighting during the night. These affect the development and social opportunities. Therefore, in case installed solar energy systems can work at the full capacity with the longer lifetime due to the proper maintenance be real users, it will meet the requirement of the need to develop life quality of people in remote areas where difficult to access. Moreover, it is the fundamental right of human resource development in Thailand. The routine maintenance of solar energy system can expand the lifetime of the system and reduce the maintenance cost according to the concept of "Preventive Maintenance". However, the knowledge transfer of solar energy system maintenance needs system administrators who ready for knowledge from the training, sacrifice, stamina, and spirit. From the remark, sometimes, people who attend the training of solar energy system maintenance are local people representatives, political officers, or local officers who relocated to other departments or areas over time. this affects the maintenance of the solar energy system in the long term. Therefore, it is better to be the people who have the homeland which have the solar energy system who ready to take care of the system and transfer the knowledge to others in the same community further.

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