The Design and Development of Photovoltaic Electrical Generating System Experimental Set

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ABSTRACT

This paper is to present the research results and development of the Photovoltaic Electrical Generating System Experimental Set. The experimental set is appropriate to use for training and teaching included the topics of PV stand-alone system, and PV grid-connected system Research tools are consisted of experimental set, worksheet, and the expert evaluation form. The sampling group is ten first year electrical engineering student of Rajamangala University of Technology Suvarnabhumi Nonthaburi. The expert evaluation results show that this experimental set help enrich knowledge and skills about the PV electrical generating system installation in its highest level. Consequently, it is very appropriate to use for training and teaching in high level. The analyzing results from sampling group found that the efficiency of the PV Electrical Generating System experimental set is equal to 84.5 percents as according the research hypothesis. Consequently, the sampling identified this experimental set enables them to get knowledge and skills about the PV generating system in the high level. Moreover they give a recommendation this that experimental set is appropriate for training and teaching in the high level.

Keywords : Experimental Set, Efficiency, PV Electrical Generating System.

1 INTRODUCTION

Since 1998 Thailand' s consumption of energy has been increasing every year, because we have used gas, fuel, oil, coal and electricity increasing 1.6 %, and have consumed energy from alternation energy increasing 5.3 % [1]. The solar energy potential in Thailand is very good potential. The study of Silapakorn University and Department of Alternative Energy Development and Efficiency (DEDE) found that the solar energy potential in Thailand is about 5 kWh/m^2-day in average. The research form National Statistical Office of Thailand (TNSO) found that Thailand have around 5.6 x10^9 m^2 vacant area. If we use that area to install PV panel to generate electricity, we will have energy more than the total consumption of Thailand which is around 100x 10^3 GWh/year [2]. From this information, it shows that the solar potential in Thailand is very important. We should not overlook it because the solar energy resource in Thailand is enough for the future.

The PV generating system that was installed in Thailand is separated into two types; it is stand-alone system, and grid-connected system. There are more than 200,000 of stand-alone systems around Thailand from 2005 to 2007. The mega-project is "Electric Service Acceleration Project by Solar Home System in Thailand (Solar Home System) the total capacity is around 28.8 MW. The grid- connected PV system was installed not to big scale; most of them are demonstration system. For example the roof top grid-connected project (phase 1 about 10 houses, phase 2 is about 50 houses) etc. The total installed capacity of grid-connected system in Thailand is around 3.38 MW. (2007) as shown in Figure 1.

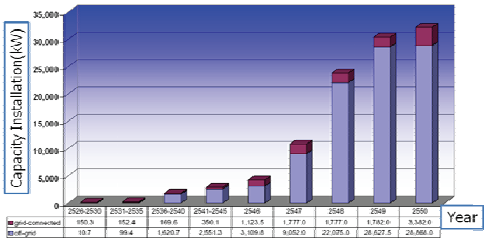

Figure 1: The installed capacity of photo voltaic Electrical generating system in Thailand

In the present Thailand can produce and export the PV module, inverter, charger and controller. Trend of the PV electrical generating system will be decreasing in cost. That means that the growth rate of the PV industry and related business will be increasing. The PV electrical generation system will need engineer, technician, installer in design process, installation process, and maintenance process. The problem is that the people who are ready to work in the PV industrial and related business not enough. Most are technicians and workers lack knowledge and skill about the PV generation system. It is about, How to fix the basic problem? How to maintain the PV module, inverter, charger, battery and the PV system? How to choose the appropriate PV module to match winch other electrical equipment? Now we don't have the school or institute for teaching and training, about these knowledge and skill. That's why the author has some ideas to design and construct the photovoltaic electrical generating system experimental set. Then use it for teaching or training people who need to develop their knowledge and skill. Author hopes this way will be one of the many ways to help them, to get skill and knowledge about the photovoltaic system. Then they can use it to apply in related jobs, and apply to develop their community. To

correct the problem of lacking of technician and skilled worker in the PV industry and related business. So this studies to help Thailand to suggest the possible way to sustainable development in the future.

2 PV ELECTRICAL GENERATION SYSTEM

The PV electrical generating system is separated into two types; there are stand-alone system, and grid-connected system. So the stand-alone could separate in to three sub systems. 1) Stand- alone with battery, 2) Stand-alone without battery, and 3) Hybrid system. The grid-connected system could be separated into two sub systems, 1) PV power plant, and 2) PV home as shown in figure 2.

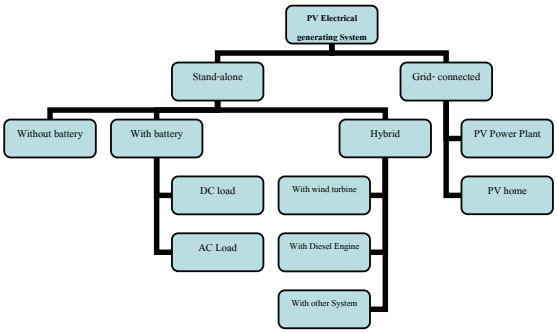

Figure 2: PV electrical generation system diagram.

2.1 Stand-Alone System

Usually the stand-alone system is preferably used in the rural area, where there's no transmission line. The stand-alone system is needed to use with battery for storing the electrical energy. The applications of stand-alone system are remote weather station, solar home system, remote radio transmitter station, buoy, etc. The PV stand-alone system consisted of PV module charger and controller (DC load) charger and inverter (AC load) and battery storage as shown in figure 3 and 4.

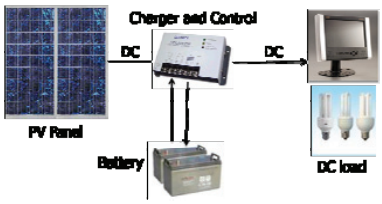

Figure 3: PV stand-alone system supply to DC load (with charger and controller)

2.2 Grid-Connected System

In the areas that have transmission line to supply the electricity, the PV grid-connected system is very appropriate. It is effective because the PV grid-connected system should be supply at day time which can help

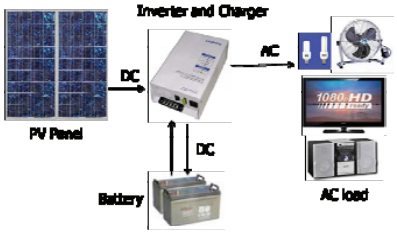

Figure 4: PV stand-alone system supply to AC load (with charger and Inverter)

to reduce at peak demand. The PV grid- connected system consisted of, PV module(or PV array), grid-connected inverter, junction box, DC and AC main switch, distribution switch, and kilowatt-hour meters as shown in figure 5.

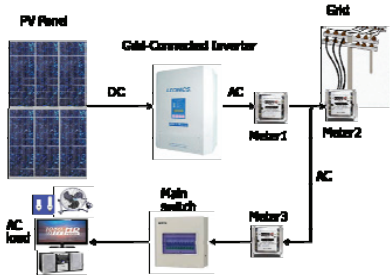

Figure 5: The PV grid-connected system diagram

3 METHODOLOGY

The research goal is to design, construct, and find the efficiency of the PV electrical generating system experimental set. Then let the experts evaluate them. After that take them to tryout with sampling group.

3.1 Population and sampling group

3.1.1 Population is Thai people who are interested in PV system.
3.1.2 Sampling group is ten first year electrical engineering student of Rajamangala University of Technology Suvarnabhumi Nonthaburi. The way to sampling is specifically chosen sampling group.

3.2 Research Process

There are four steps in this research process. It is designed and constructed, the experts' evaluation, tryout, and finding the efficiency of the experimented set as shown in figure 6.
3.2.1 Design and Construction
3.2.1.1. Idea of the design
Author created six concept ideas of designing the PV electrical generating experimental set. It will be appropriate to apply is teaching and training as follows;
1. Appropriate to demonstrating and experimenting by the panel concept.

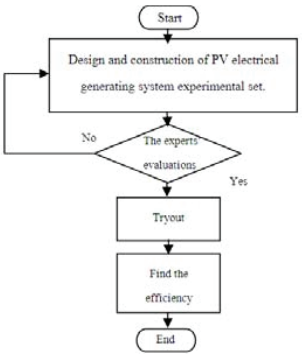

Figure 6: The flow chart of research process

2. Trainee could be wiring in three different systems;

A. PV stand-alone system supply to the DC load.

B. PV stand-alone system supply to the AC load.

C. PV grid-connected system.

3. Use the real devices, and try to use the product of Thailand.

4. Operating test, and measuring the real electrical parameter.

5. Use the real load in the house.

6. The experimental set could be developing the skill and knowledge of trainees as well.

3.2.1.2 Construction of the experimental set

The author searched about the product catalog of any electrical equipment that is used in the experimental set. For example stand-alone inverter, grid-connected inverter, battery, charger and controller, and PV module also. The detail of these equipments is shown in table1.

Equipments	Specification	Supplier
1. PV Module	Model : ND – L3E6ET Pmax 123 W Voc 21.3 V Isc 7.9 A Vpmax 17.2 V Ipmax 7.16 A	SHARP–THAI, THAILAND
2. Charger and Controller	Model : SOLARCON SET INPUT = 12 V – 22 V (12 A) OUTPUT = 12 Vdc/10A INDICATOR = LED	LEONICS, THAILAND
3. Charger and Inverter	Model : APOLLOS – 120 A INVERTER INPUT : 12 Vdc (10 – 16 Vdc) MODE OUTPUT : 150 W 220 Vac ± 3% ,50 Hz ± 0.1% CHARGER INPUT : 12 Vdc (0 – 23 Vdc) MODE OUTPUT : 12 Vdc /10A , EFF : > 80% PROTECTION :Overload / Over Temperature Reverse Polarity/Over Charge / Over-discharge	LEONICS , THAILAND
4. Grid-Connected Inverter	Model : SOLARDIN 600 Input : 40 – 125 Vdc / 550 Wdc Output : 550 W / 8A / 230 Vac / 50 Hz Type : Grid-Connected Protection : IP 23	MASTERVOLT, NETHERLAND
5. DC – load	2 x 10 W. Fluorescent Lamp	THAILAND
6. AC – load	2 x 10 W. Fluorescent Lamp 2 x 11 W. Compact Fluorescent	Phillip , THAILAND
7. Protective devices	2 x 2 pole 10 A circuit Breaker 2 x 2 pole 15 A circuit Breaker	Panasonic , THAILAND
8. Battery	Model : LFP1226S : 12 V 26 Ah/10Hr : Rechargeable : Sealed Lead Acid	First Power THAILAND

Table1: Specifications of equipment that are used for experimental set.

3.2.2 Evaluation from Experts

Experts are professors who teach or do research related to the photovoltaic system. Author chose five experts. Expert evaluates the photovoltaic experimental set, and laboratory manual. After that we will bring the evaluation results to develop the complete photovoltaic experimental set.

3.2.3 Tryout

Tryout to the sampling group. They are ten students of the first year electrical engineering student of Rajamangala University of Technology Suvarnabhumi Nonthaburi. Author explained the objectives and guided them about the photovoltaic experimental set. Then teach them about theory of PV stand-alone, and grid-connected system.(100 min) After that separate students into groups of two. Each group will do experiment in 150 minutes per worksheet, there are two worksheets. Next do assignments after worksheet then author recorded the score.

3.3 Statistic

3.3.1 The expert's evaluation

To evaluate the quality and the appropriate of the experimental set. The evaluations from is five rating scale. Then use equation (1) to find out the average recommendation from experts. [4]

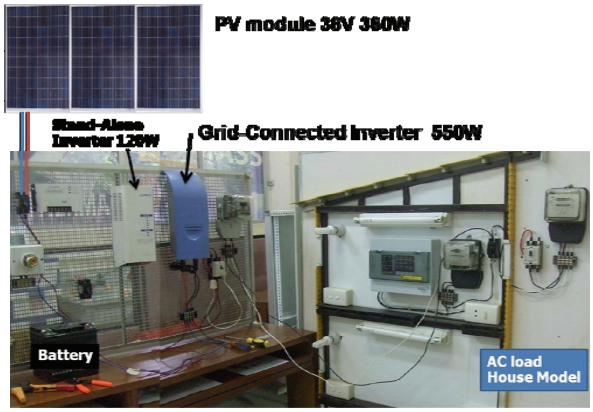

Figure 7: The Photovoltaic Electrical Generating System Experimental Set


Figure 8: Student workshop on the Photovoltaic Electrical Generating System Experimental Set

$$\bar{x} = \frac{\sum x}{N} \quad (1)$$

When $\bar{x}$ = Average score
$\sum x$ = Total score
N = Number of data set

3.3.2 Analyze the efficiency of experimental set

The equation that is used for find the efficiency as shown in equation (2).

$$E = \frac{(\sum x / N)}{A} \times 100 \quad (2)$$

When E = Efficiency in percentage was obtained from worksheet in experimental period
$\sum x$ = Total score from completing Laboratory
N = Number of students
A = Full score from worksheet

4 RESULTS AND DISSCUSSION

4.1 Results

The evaluation results from five experts as shown in table 2. Experts' overall opinion about of the photovoltaic electrical generation system experimental set in average is 4.06. That means they have strongly agreed. Then they agree that this experimental set helps to enrich the knowledge about the stand-alone, and grid-connected photovoltaic generating system, and it helps to develop the installation skill of the photovoltaic generating system.

Item	$\overline{X}$	SD	Meaning
1. Experimental set	4.15	0.208	Strongly Agree
2. Worksheet	3.96	0.383	Agree
Average	4.06	0.30	Strongly Agree

Table 2: The opinion from five experts

They strongly agree about the worksheets, they are presented content and experiment procedure clearly, Then they agree that this experimental set is very appropriate to used for teaching and training.The efficiency result of the experimental set as shown in table 3.

ITEM	N	$\sum x$	A	$\overline{X}$	E (%)
Worksheet 1	10	86	10	8.6	86
Worksheet 2	10	83	10	8.3	83
Average	10	84.5	10	8.45	84.5

Table 3: The efficiency result of the experimental set

4.2 Discussion

Author found that the efficiency of the photovoltaic electrical generating system is equal to 84.5 percents. It is according to the research hypothesis.

However, author has two disagreements against experts. There are 1) the experimental set developed by the local equipment (or buy in local), and 2) Trainee should be connecting/wiring in the real circuit, equipment, and measuring results. So, more than 90 percent of equipment is local equipment except only for the grid-connected inverter imported from the MASTERVOLT Company in Netherland. Because it is small size (550W) inverter. It is more appropriate than local inverter (It is 2.5 kW over size unsuitable to experimental set), and cheaper than local inverter (around 3 times). Next, when the sampling groups work on the worksheets, they will have to wire/connect cables to any real electrical equipment, and measuring voltage and current by digital multimeter.

The sampling group suggests that the Photovoltaic Electrical Generating System Experimental set should be developing the knowledge and skills. Then it is right to use in teaching and training.

5 CONCLUSIONS

The Photovoltaic Electrical Generating system that the author developed is beneficial in teaching and training students, installers, electricians, and other people that are interested in the topic. It can also help to enrich the knowledge and the installation skill of photovoltaic electrical generating system, including the stand-alone, and the grid-connected system. This is one of the ways to prepare the manpower. Then increase the potential about the installation skill of installers, electricians, and technicians. To support the photovoltaic and related industrial in Thailand. University should cooperate with industry to develop the standard training course, then give the certificate to the qualified to photovoltaic installer in the future.

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