A Comparative Study of Solar Street Lighting System in Different Lamps

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ABSTRACT

This paper presents a comparative study of solar street lighting system in three different lamps. Namely, a fluorescent lamp (36 W), a low pressure sodium lamp (18 W) and a high pressure sodium lamp (50 W) have been used for installation in each mast to deter mine the appropriate system to install in a rural area of Thailand. All three systems have been mounted with the same module type and wattage at the Rajamangala Institute of Technology (main campus), Thanyaburi district, Pathumthani province of Thailand. The design of a control circuit was experimentally done in this work. Protection of the battery from damage from deep discharge and overcharge by a controller was also considered. The batteries, which have a low self-discharge and maintenance free, have been situated inside the water proof battery boxes including measuring meters to show the values of current and voltage that to be generated from the solar modules. An operation of solar street lighting system can be divided into 2 periodof time, namely, at 18.00-22.00 hours and 05.00-06.00 hours. The life cycle cost analysis is the appropriate method for comparing three different lamps. The present worth of each system can be compared and the least cost option selected. A LCC analysis is based on the key assumptions (year 2002). The costs of in stallation and operation and maintenance were esti mated by multiplying the capital cost of PV arrays with 0.2 (20%) and 0.02 (2%) respectively. The results of comparative study the solar street lighting system with a fluorescentlamp has been the appropriate system for installation in a rural area of Thai land when the cost of lamps, system performance and possibility for purchasing the components of the system have been considered. The results of this study are able to provide useful information for rural electrification planners and PV engineers to choose the optimum system for installation in a particular rural village of Thailand. They should be applicable in other countries that are situated the same latitude angle with a similar climate.

Key words : Solar Street Lighting.

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1. INTRODUCTION

The electric lamps that have been working on solar energy system in a rural area can represent a nonpolluting alternative source compared to the conventional lighting. They are highly economical in places without an electrical network as neither cabling nor main's connection is necessary. An autonomous lighting system is to provide lighting in isolated sites. According to a typical rural environment, stand-alone PV public lighting systems can be mainly applied as lighting for dangerous points or intersections, pedestrian crossings, ferry stations, access to the villages or the towns, public places, bus stops (school buses), camping sites, areas for activities and so on.

In the design of a PV public lighting system the following items should be considered: (1) lamps for public lighting system, most lamps used in PV public lighting systems are low pressure sodium lamps, high pressure sodium lamps and fluorescent lamps. Although the colour of the light emitted from the low pressure sodium lamps is golden-white, they operate at a wavelength close to the peak sensitivity of the human eye and provide the highest luminous efficiency compared with other lamps. Generally, the wattage of lamps that are widely used is 18, 26 and 35 W for street lighting lamps. They provide luminosity of 1800, 3320 and 4800 lumens respectively [1,2]. A street lighting for fluorescent lamp with 36 W is normally recommended because it provides a somewhat higher efficiency (lumens/W) than a lamp with 18 W. Furthermore, the lamps should be strong but lightweight and the housing must be sealed to IP65 by a high quality Neoprene gasket. The lens should be vandal resistant and hinge down from stainless steel hinges for easy maintenance. Some manufacturers will provide a high efficiency inverter within the housing designed specially to operate 18 W or 26W low pressure sodium lamps. (2) Battery and Box, a water proof battery box is commonly used, and closed with special anti-theft screws. This makes it difficult to access for maintenance of the battery with regular addition of water. Maintenance-free batteries with valve-regulated sealed are strongly recommended. This is because they will never require water. Even though lead-acid batteries are commonly used for PV public lighting systems, nickel-cadmium batteries are also used in some special circumstances. The nickel-cadmium batteries are more expensive than lead-acid type. These batteries are designed for deep cycle and low self discharge as needed for this PV application. (3) Control Unit, this is one of the most important parts of the system. The main features of this part of the system are voltage regulation to protect battery against over charging and deep discharges, and the possibility of programming the length and periods of the operation of the lamp. In addition, a special function can be operated to recognise the different length of day and night throughout the year and adapts itself to the seasons automatically. A conventional solar-driven street lamp tends to fail at least for some nights in winter. This is because it consumes a fixed quantity of energy every day until the battery is completely discharged. From that moment on, the lamp can spend in the night only the amount of energy it gained during the day. In long periods with bad weather this can lead to total breakdown for at least some nights. As a result, some manufacturers have designed a special function called an "intelligent management system", based on a micro processor, which constantly compares the irradiation and the charging condition of the battery to calculate the optimum control sequences [3]. Reducing the lighting times in the periods with bad weather prevents a total breakdown. Furthermore the management system will save energy in times when no light is required.

2. SYSTEM COMPONENTS

2.1 Street lighting lamp

The first step of the design requires knowledge of the selection of street lighting lamps to use for comparing that is the main point of this research. Due to the fact that the solar street lighting systems must be installed for comparative study at main campus of Rajamangala Institute of Technology, Pathumthani province in Thailand. The main aims of this research is to determine the most suitable system for installation in a rural area of Thailand. Three different lamps were selected to use in this research. Namely, a low pressure sodium lamp of 18 watts, a high pressure sodium lamp of 50 watts and a fluorescent lamp of 36 watts have been used for testing. Technical data of these lamps can be seen in references [1] and [2].

2.2 PV (photovoltaic) module

There are 3 masts that have been mounted. Each of them consists of 2 PV modules which are connected in parallel for supplying the electric power to load. The PV module # BPTS 1270HP was used. The its characteristics are as follows:

Rated power:	70 watts @ 25°C.
Voltage @ max. power	17 volts
Current @ max. power	4.16 amps
Short circuit current	4.70 amps
Open circuit voltage	21.2 volts
Dimension	50 cm x 120 cm
Weight:	50 kg

The height of each mast is 5 metres that to be mounted at Rajamangala Institute of Technology (RIT), main campus, Pathumthani province of Thailand. Design of solar module sizing is mainly basedon the climatic data on inclined surface at latitude angle of Pathumthani province and daily load demand. Accordingly, the solar modules have been mounted on the top of a mast that having a slope of angle is about 14°, this is the latitude angle of Pathumthani province, facing to the south of a compass.

2.3 PV lighting controller

The PV street lighting system consists of a control unit or PV lighting controller, a charge controller, a universal timer, an inverter, a battery and a PV panel. The PV lighting controller is the heart of the energy management system. This is because it controls the energy of the battery and the way it is spent on the different parts of the system. The design of a control circuit was experimentally done in this research. An operation of the solar street lighting system can be divided into 2 period of time, namely at 18.00-22.00 hours and 05.00-06.00 hours. The charger is responsible for the charging and the protection of damage of the battery from over depth of discharge. The operating voltage of the system has been 12 V. One of the PV lighting controllers, the product from Morningstar Corporation Company, was used as a control unit of the PV street lighting for testing. Block diagram of the control unit can be shown in Fig. 1.

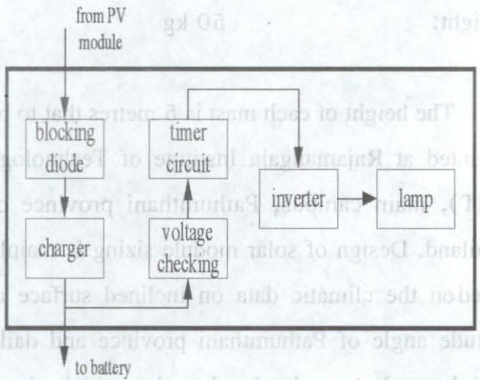

Figure 1 : Block diagram of a control unit part.

2.4 Battery

In this project, the battery with maintenance free type has been used. Rated ampere-hour and an operating nominal voltage are 100 Ah and 12 volts respectively.

3. LIFE CYCLE COST ANALYSIS

The life cycle cost analysis (LCC) is the appropriate method for comparing three differentlamps. The initial costs and all future costsfor the entries operational life of a system are considered. To make a meaningful comparison, all future costs and benefits have to be discounted to their equivalent value in today's economy. All future costs and benefits are discounted to the present worth or present day values. The present worth of each system can also be compared and the least cost option or the most suitable system for installation in Thailand selected. A LCC analysis is based on the key assumptions (year 2002). The costs of installation and operation and maintenance were estimated by multiplying the capital cost of PV arrays with 0.2 (20%) and 0.02 (2%) respectively. The results of an analysis for three different street lighting lamps are shown in Table I.

4. EXPERIMENTAL TESTING

In this project, the luminous efficacy of each lamp, this is quotient of the luminous flux emitted and the power consumed [4], was determined to know which type of the lamp the best is. A comparison of the luminous efficacy of the each lamp was done. In fact, a square matrix that has a dimension of 13 metres x13 metres was divided to measure the horizontal illuminance at a point under luminaries. Each point has equally 1 metre of distance, it can be seen from Fig 2. By choosing the centre point of measuring that has been between the bottom of the luminaires and the surface luminance of the road is selected. This is based on 5 metres of the mounting height. Accordingly, a significant data was found that the luminous efficacy of the fluo rescent lamp has been the best for this experimental testing.

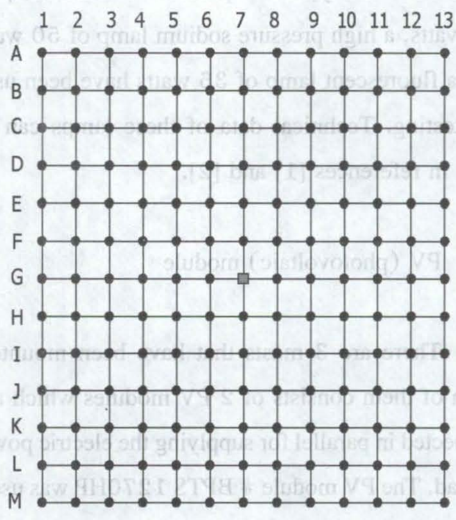

Figure 2 : A square matrix for testing the luminous efficacy of the lamps

The illuminance value (E_p), its unit is lux , at the point of marking in the square matrix can be measured by a lux meter. Then the value of an average illuminance (E_{av}) over the area of the square matrix can be calculated from $E_{av} = (E_{p1} + E_{p2} + ... + E_{pn})/n$, where n is the total number of points in the square matrix. Table II shows the comparison of the illuminance value, the value of luminous flux of the lamp and the luminous efficacy in different lamps.

5. CONCLUSIONS

This research has been found that the average illuminance in lux of the fluorescent lamp at design location, Pathumthani province of Thailand, has a highest value compared to the low-pressure sodium and high-pressure sodium. On the other hand, the lifetime of the fluorescent lamp has a shortest time compared to other lamps [4]. Nevertheless, the aim of this project is to determine the appropriate system to install in a rural area of Thailand when the cost of lamps and system performance are compared. Table III shows a comparison of characteristic of each lamp in different parameter. Although the input current consumption of the low pressure sodium lamp was least, the total capital cost of the low pressure sodium lamp for installation was highest compared with other lamps. The main problem for using a low pressure sodium lamp (18 w) and a high pressure sodium lamp (50 w) with DC ballast sets in Thailand is to very difficult to purchase. Especially, there have not been absolutely available in many local shops of Thailand. In addition, the cost per lamp of a low pressure sodium lamp and a high pressure sodium lamp has been very more expensive than a fluorescent lamp (see Table III). This was a reason why the AC ballast sets and inverters were needed when the low pressure sodium and high pressure sodium lamp were used in this project. In contrast, a fluorescent lamp and the DC fluorescent ballast of 12 volts or 24 volts that to be used for a circuit of fluorescent lamp can be widely purchased in many local shops of Thailand. Accordingly, The results of comparative study the solar street lighting system with a fluorescent lamp was the appropriate system for installation in a rural area of Thailand when the cost of lamps, system performance and possibility for purchasing the components of the system have been considered. The results of this study are able to provide useful information for rural electrification planners and PV engineers to choose the optimum system for installation in a particular rural village of Thailand.

Table I : The results of analysis in different lamps

Type of Lamps	Period of Analysis (years)	Total LCC (Baht*)	Annualised LCC (Baht/year)	Levelised Energy Cost (Baht/kWh)
Low Pressure Sodium (18 w)	20	96,039	12,141	198
Linear Fluorescent (36 w)	20	87,568	11,070	158
High Pressure Sodium (50 w)	20	95,541	12,079	144

* 42 baht ≅ 1 US $

Table II : The results of calculation.

Lamp	Wattage of lamp (watts)	E_{av} (lux)	Luminous Flux (lumens)	Luminous Efficacy (lumen/w)
Fluorescent[1]	36	4.36	628	17.44
High pressure Sodium[2]	50	0.5	72	1.44
Low pressure Sodium[3]	18	1.30	187.2	10.40

1. with DC ballast, 2. with AC ballast, 3. with AC ballast.

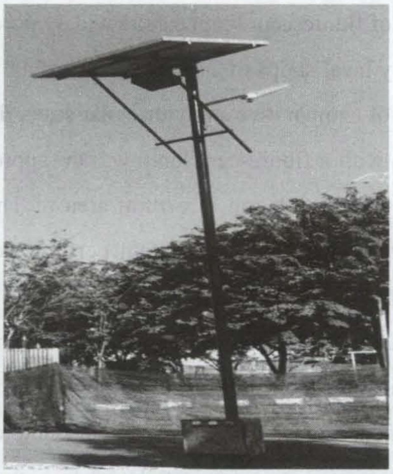

Figure 3 : Solar street lighting system with a fluorescent lamp

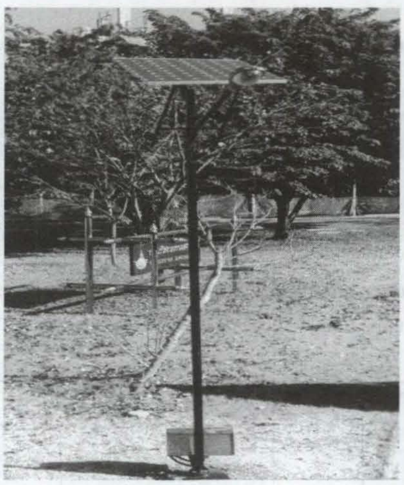

Figure 4 : Solar street lighting system with a low pressure sodium lamp

Figure 5 : Solar street lighting system with a high pressure sodium lamp

Table III: Conclusions of the comparative study of solar street lighting system in three different lamps.

Features	Fluorescent (36 W)	Low pressure Sodium (18 W)	High pressure Sodium (50 W)
Input I_{dc} used (A)	4	3.5	4.8
Nominal V_{dc} (V)	17	17	17
Nominal I_{dc} (A)	8	8	8
E_{av} (lux)	4.36	1.3	0.5
Cost/lamp (baht)	60	1,200	2,100
Ac ballast (baht)	non	2,500	900
Dc ballast (baht)	340	not available	not available
Inverter Used	no	yes	yes
Inverter 100 w (baht)	Non	400	400
Battery 100 Ah (baht)	4,800	4,800	4,800
Lamp Housing (baht)	400	1,000	2,000
Solar module 2x70 W (baht)	60,000	60,000	60,000
Lamp available in rural area	yes	no	no

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7. REFERENCES

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