Green Office Lighting with Hybrid Photovoltaics (PV) System At Office ofPertamina Oil Fuel Terminal (TBBM) Rewulu

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Abstract

Global warming ischallanging problem that need to be solved. One of the main challange in the global warming issueis reducing the carbon emitted to the atmosphere trough substituting fossil fuel by the green energy source.

The geographical position of Indonesia which is located in the equatorial regions gives great potential for utilization of solar energy. This research was conducted to combine a conventional electricity source provided by the PLN with a photovoltaics(PV) systemas a Hybrid PV system. In this system the PV system acts as main power, whilethe electricity from the PLN as a backup power in office of the Pertamina Oil Fuel Terminal (TBBM) Rewulu, Yogyakarta.

A Hybrid Solar Power System unit was designed to powermaximum 60 pieces of lamps with 9 watt power each. The designed system should be able to work 8 hours/day. The installed hybrid solar power system consists of 12 piece PV panel(@135watt peak), 80A MPPT solar charge controller, 2kW sine power inverter, 8 units 12V100Ah batteries, and a hybrid controller. It was designed with 80% efficiency due to loss of thePV system component.

The measurement of the system have been conducted on the July 14th-20th 2014. The result showed that the minimum energy produced in acloudy situation PV at 15th July was 4.1 kWh,whereas on a sunny day at 17th July was up to 8.6 kWh, and energy rate on one week was 6.38kWh. The energy consumption for the lamps was 5.3 kWh per day, so in the sunny day the hybrid system is be able to fulfillthe energy demand. However, in the cloudy day the PV system is be able to supply merely a part of energy needed. Total annual electric energy that can be produced by the system was 2.061kWh/year. It givesannualy1.494 metric tons CO_2reduction**.**

Keyword: Hybrid Photovoltaics Power System, Carbon Emission Reduction

1. Preface

Pertamina Oil Fuel Terminal Rewulu (Terminal Bahan Bakar Minyak- TBBM Rewulu) is one of the fuel terminal owned by PT. Pertamina (Persero) S & D Region IV, which is located in the Village Argomulyo, Sedayu subdistrict, Bantul, Yogyakarta Special Region. TBBM Rewulu was built in 1972 and started operating in 1973. The land area is 156 667 m^2. TBBM Rewulu is one of Supply & Distribution operating unit of PT Pertamina (Persero) and is under the Directorate of Marketing and Trading, PT Pertamina (Persero). TBBM Rewulu servesa setof process consisting of receiving, stockpiling and distribution of fuel. These three functions are executed with major appliances such as driving pumps driven by electrical energy. Electricity needs are met by PLN with installed power of 555 kVA and supplied through distribution transformers with 1,000 kVAcapacity(PSE,2014).

During operational activity TBBM Rewulu is always interested with savety and minimizes the invironment damage effect. One of agenda which prior by management was energy conservation. According to Regulation of Indonesian Government (Peraturan Pemerintah – PP) No. 70/2009, energy conservation is a systematic planned integrated effort in order to conserve resources and increase efficiency of domestic energy utilization.

One of the energy conservation effort is use of renewable energy sources to meet a part or all of the energy needs of particular working unit. Energy which environmentally friendly is always oriented towards sustainability. One of the potential for renewable energy in Indonesia as a tropical country is sunlight, where the solar radiation can be used for the generation of electrical energy.

"Pertamina Sahabat Bumi" was the spirit of Pertamina, which basedon all energy conservation activity. One of energy consevation activity of TBBM Rewulu that is TBBM Rewulu had planned and apply photovoltaic system which combined with electricity grid to supply energy for lighting in the administrative offices.

2. Methode

2.1. Photovoltaic SystemIntroduction

The Sun is certainly a renewable energy source with great potential. The quantity of solar energy which reaches the terrestrial soil is enormous; about 10 thousand times the energy used globally. Among the different systems using renewable energy sources, photovoltaics is promising due to the intrinsic qualities of the system: it has relativelylow operating costs (the fuel is free of charge) and limited maintenance requirements. Moreover it is reliable, noiseless and quite easy to install. The photovoltaics, in some stand-alone applications, is definitely convenient in comparison with other energy sources, especially in places which are difficult and uneconomic to reach with electric grid lines (ABB,2010).

A photovoltaic (PV) plant transforms directly and instantaneously solar energy into electrical energy without using any fuels. As a matter of fact, the photovoltaic (PV) technology exploits the photoelectric effect, through which some semiconductors suitably "doped" generate electricity when exposed to solar radiation.

The main advantages of photovoltaic (PV) plants can be summarized as follows:

- distributed generation where needed;
- no emission of polluting materials and saving of fossil fuels;
- reliable plants since they do not have moving parts (useful life usually over 20 years);
- reduced operating and maintenance costs;
- system modularity (to increase the plant power it is sufficient to raise the number of panels) according to the real requirements of users (ABB,2010).

Photovoltaicsplant with shows in Figure.1.

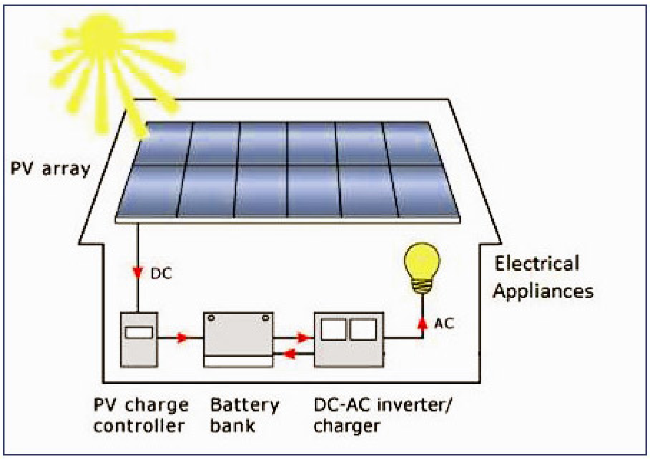

Figure 1. PV system
(Source:www.myace.in)

2.2. Hybrid Photovoltaic

Hybrid photovoltaic systems is a system that combines two power source to serve the utility or load.These two sources are off – grid Photovoltaicsplant and PLN power line. The hybrid design utilizes the PV system as a main source, whilethe PLN power line as back up source. Hybrid power plant was described in Figure 2.

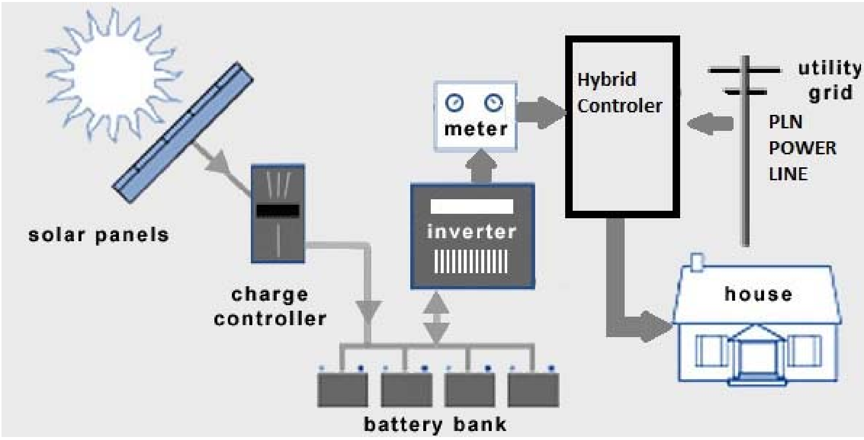

Figure 2. Hybrid PV system

The design of hybrid system is based on two main informations, both load and potential insolation of solar radiation in TBBM Rewulu. The lamp that be used to illuminate the office area TBBM Rewulu was 60 LED lamps with 9 Watt powereach. The LED lampused in TBBM Rewulu is shown in Figure 3with its specifications shown in Table 1.

Figure3. The LED Lamp used in TBBM Rewulu

Table 1. LED Lamp Spesification

(Philips Datasheet,2014)

Merk	Philips

Wattage	9 Watt
Wattage standard bulb	70 watt
Voltage	220-240V
Color rendering index (CRI)	80
Color temperature	6500 K
Power factor	0.7
Lumen	806 lm
Color	*Cool Day Light*

The Office of TBBM Rewulu uses 60 lamps withinitsrooms.It brings the total real power (Pr) of 540 Watt. Apparent Power (Pa) is influenced by power factor (PF). The required apparent power, which is 771.4VA, is derived from the following equations:

$$\mathbf{PF = P_r/P_a} \quad \ldots\ldots 1)$$

where

$P_a = P_r/PF$

$P_a = 540/0.7$

$P_a = 771.4\ VA$

Activity in TBBM Rewulu office lasts for 8 hours every day with light usage percentage average (PL) of 80% of the total of all the lights, so the electrical energy needed to power the lamps during work hours are 4,946.96 VA- hour, which is derived from the following equations:

$$\mathbf{E_l = P_a \times t \times PL} \quad \ldots\ldots 2)$$

$E_l = 771{,}4 \times 8 \times 0{,}8$

$E_l = 4.946{,}96$VA- hour/day

Indonesia is a tropical region that receives sunshine all year round. Solar insolation data is total radiation energy received by the surface of the land per square meter.Indonesia receive an average irradiation 4.0 – 5.9 kWh/m^2/day. Map of potential energy in the world is shown in Figure 4.

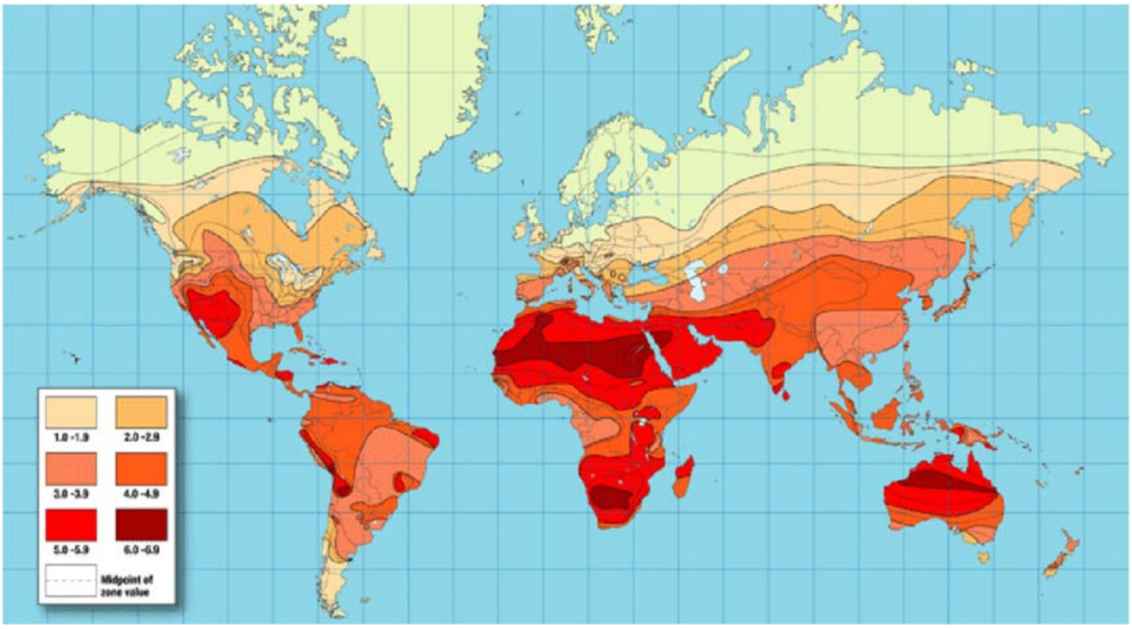

Figure 4. World solar insolation
(source :http://www.matthewb.id.au)

Based on secondary data obtained from NASA web site, Yogyakarta region has the potential solar insolation shown in Table 2.

Tabel 2.Solar insolation in Yogyakarta

Month	Sun Insolation(I) (kWh/m2/day)	*Peak Sun Hour*(PSH) (hour)
January	4.28	4.28
February	4.47	4.47
March	4.59	4.59
April	4.72	4.72
May	4.73	4.73
June	4.55	4.55
July	4.8	4.8
August	5.25	5.25
September	5.54	5.54
October	5.39	5.39
November	4.71	4.71
December	4.57	4.57
Minimum	**4.28**	**4.28**
Maximum	**5.54**	**5.54**
Rate	**4.80**	**4.80**

(Source: https://eosweb.larc.nasa.gov/cgi-bin/sse/subset.cgi?email=skip@larc.nasa.gov)

Table 2 shows that PSH was calculated from insolation devidedby maximum irradiation 1000watt/m^2. It is shown on following equations:

PSH = I (kWh/m^2/day)/1000 (Watt/m^2) ……………………………………….3)

PSH = 4.80(kWh/m^2/day)/1000 (Watt/m^2)

PSH = 4.80x1000 (kWh/m^2/day)/1000 (Watt/m^2)

PSH= 4.8 hour/day

After finishing calculation of the load and analysis energy potential, the next step is determining solar design. The main component is the solar solar panels. Solar panels are used to convert sunlight energy into electric energy. The calculation of the capacity of solar panels in order to meet expected energy demand is shown on following equation:

$\mathbf{P_{wp} = W x\ k_{ec} / (t_{ins}\ x\ k_{if})}$ ……………………………………………….4)

Where $\mathbf{k_{if}}$ = coefficient of efficiency; $\mathbf{t_{ins}}$ = PSH; **W**=Energy demandper day(kWh/day); $\mathbf{P_{wp}}$= Solar panel peak power(Watt) ;

PV system losses is calculated from the sum of the components loss. Total losses in the PV system are shown on Table 3:

Table 3. Photovoltaics system losses

Jenis Rugi-rugi (*Losses*)	**Nilai Rugi-Rugi**	**Efisiensi**
PV temperature loss	10%	90%
PV dirt/shading loss	3%	97%
PV Tolerance	3%	97%
Solar Charge controller	5%	95%
Battery Losses	10%	90%
Inverter	8%	92%
Cable Losses	2%	98%
Efficiency Total(k_{if})		65%

So the calculation of the number of solar panels based on W = 4946.96 VA-hour, t_{ins} = 4.28 jam, and k_{if} = 65% = 0.65 was :

$P_{wp} = W / (t_{ins} \times k_{if})$ ……………………………………………………5)

$P_{wp} = 4946.96 / (4.8 \times 0.65)$

P_{wp} = 1585.56 Watt peak

The number of solar panels that will be used is 12 units with a peak power of 135 Wp each panel, so that the total solar panels that are used for 1620 Wp. The total power of the solar panels is greater than the need for 1585.56 Wp.

3. Results and Discussion

3.1. Desain PLTS

Based on previous calculations of solar panels number, it can also determine other PV system component configuration. PV system component specifications that have been determined are shown in Table 4.

Table 4. PV System Components

Component	**Specification**	**Volume**
Solar Panel	Polycrystaline 135 Wp	12 units
PV Combiner	6 Ampere 30 Volt	12 lines
Solar Charge Controller	MPPT 80A	1 unit
Battery	Deep Cycle 12V 100AH	8 units
Inverter	Power :2000 Watt Wave Form : Pure Sinus Input :24 VDC Output :220 VAC	1 unit
Hybrid Controller	Automatic	1 unit
Metering	Voltage, Current, Power and Energy(kWh)	1 set

These components build a complete hybrid PV system, which is presented inFigure5

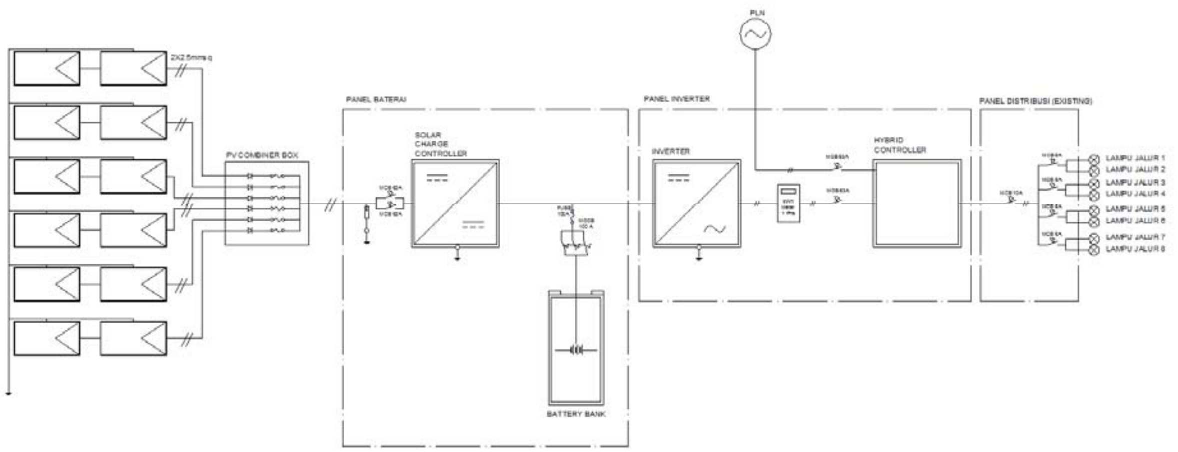

Figure 5. The Hybrid PV System

The Hybrid PV system consist of three main parts, they are solar panels array, solar charge controller and battery panel, inverter and hybrid controller panel. Hybrid controller regulate the power switch between PV system and PLN power line.

3.2. Hybrid PV System Installation

Based on an inventory load, calculation of solar energy potential, and design of hybrid PV system, the next step is the installation process. Installation of solar panels placed on the roof of the office, while the installation battery panels and inverter panel close to PLN distribution panel. The installed PV system in TBBM Rewulu is shown in Figure 6-8.

Figure 6.Solar panel installation

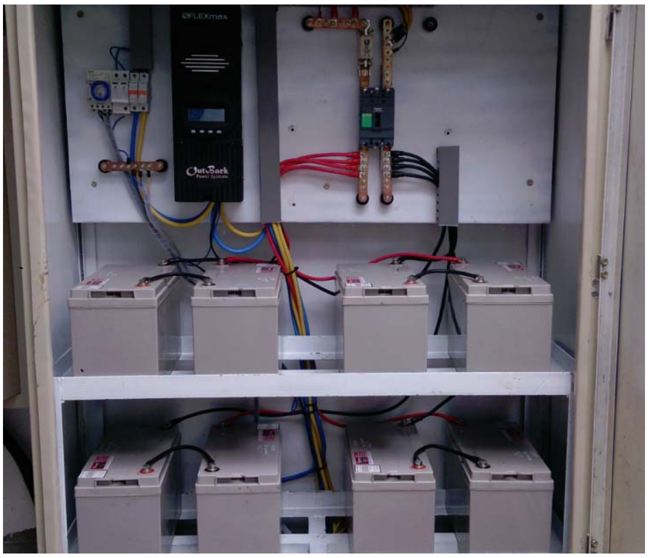

Figure 7. Battery and solar charge controller panel installation

Figure 8. Inverter and hybrid controler panel installation

3.3. Data Acquisition and Analysis

Measurements were taken at two points, in the solar charge controller and inverter output. Measurement of the solar charge controller is performed to determine the production of energy by the solar panels, while the inverter output measurements performed for the net energy output after being reduced by system losses. Measurements were taken for 7 days starting on July, 14th to July, 20th2014. The measurement result is shown in the following Table.

Tabel 7. Solar panel energy production

Date	**Energy (kWh/day)**
July 14th, 2014	4.2
July 15th, 2014	4.1
July 16th, 2014	5.3
July 17th, 2014	8.6
July 18th, 2014	7.4
July 19th, 2014	7.6
July 20th, 2014	7.5
Total	**44.7**
Rate	**6.38**

Tabel 8. Net electric energy consumtion (inverter output)

Date	**Energy (kWh/day)**
July 14th, 2014	5.1
July 15th, 2014	5.2
July 16th, 2014	5.4
July 17th, 2014	5.3
July 18th, 2014	5.2
July 19th, 2014	5.1
July 20th, 2014	5.4
Total	**36.7**
Rate	**5.24**

Based on the above table,the daily energy production is always changing according to the environmental conditions. On sunny days, the maximum energy production, as well as in case of cloudy or rainy then energy production will decrease. Total energy production of solar panels 44.7kWh greater than the energy required 36.7 kWh load. This shows that the real efficiency (PSH) of the hybrid PV system is 82%.This value is higher than the value of the efficiency of the design, which is 65%. Optimistic prediction of yearly energy production (Wan) can be calculated based on the PSH minimumvalue at 4.28 hours/day, the real value of the efficiency (Eff) is 82%, and the solar panel peak power (Pp) 1.62kW.

Wan = PSH x Eff x Pp x 365(day/year) …………………………..………5)

Wan = 4.28 x 0.82 x 1.65 x 365

Wan = 2061.5kWh

Wan = 2.061MWh

Annual total energy which can be produced is 2.061MWh/year. The carbon emission reduction is equivalent to the energy production time conversion factor (Kc) of 0.725 tonCO_2/MWH (Surat ketua harian dewan nasional perubahan iklimNo.B-48/DNPI/05/2011). So the value of carbon emission reduction (Ec) of 1.494 tonCO_2which is obtained from the following equation,

Ec = Wan x Kc ……………………………………………………………..6)

Ec = 2.061 x 0.725

Ec = 1.494 tonCO_2.

4. Conclusion

The installed hybrid solar systems in TBBM Rewulu can work well and produces electrical energy 2.061MWh annually, which reduces 1.494 tons of CO_2. Results of sizing performance in July indicated that the solar system is able to supply the load and has a 82% efficiency.

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