A solar power plant for Curtin University Malaysia

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Abstract. The Curtin University, Sarawak Malaysia (Curtin Sarawak) is the first and largest offshore campus of Curtin University in Perth, Western Australia, and the first foreign university to be established in East Malaysia in partnership with the Sarawak State Government. Today’s major concern of Curtin is its monthly electrical energy consumption and the electricity bill since its monthly energy consumption exceeds 0.3 Million kWh, and the corresponding electricity bill surpasses RM 95000. Such a situation necessitates Curtin to curtail the heavy energy consumption with immediate effect. Introducing Renewable Energy Source such as PV Solar Systems is a cost-effective and environmental friendly solution to reduce the exponential increase in energy consumption charges of Curtin. Hence, this paper proposes a 90 kW solar power plant for Curtin Sarawak.

1. Introduction

In recent years, copious studies and researches [1-6] highlight on renewable energy sources such as solar, hydro, wind and biomass. The primary objective on these researches is to upsurge the feasibility of renewable energy in substituting the conformist manner of power generation through burning of fossil fuels. The reason behind is not only due to environment pollution, but also the depletion of fossil fuels, its ever-increasing demands, and time-varying prices.

Among innumerable renewable energy technologies, solar power generation [4-6] is widely-accepted due to its lower costs, higher efficiency, and smaller occupation of space. In Asia and Australia, solar power generation [2,5,7,8] is dominant among other types of renewable energies. This is due to the promising availability of sunlight in the region, which can readily be harnessed and converted into electrical power for consumption.

Among all of the renewable energy sources, solar energy acts as an ideal alternative energy source because it can generate electricity directly from the sun. The main advantages of using solar energy are the environmental benefits, higher efficiency, high reliability due to non-rotating conversion principle, and higher life span of solar panels. Besides that, it can be set on or off the grid.

Malaysia is moving towards generating electricity using renewable energy. In order to promote the growth of renewable energy sector in Malaysia, Feed-in Tariff (FiT) mechanism [9,10] has been introduced by Malaysian government in 2011, in accordance with Renewable Energy Act 2011 and Sustainable Energy Development Authority Act 2011. A Feed-in Tariff (FiT) is a policy mechanism designed to promote investment in Renewable Energy technologies by offering long-term power purchasing contracts to renewable energy producers at a fixed premium rate. The FiT is financed by the Malaysian electricity consumers who contribute 1% of their total electricity bill towards a Renewable Energy Fund when they use more than 300 kWh of electricity per month. The approved renewable energy power producers will enter into a Renewable Energy Power Purchase Agreement.
with the Distribution Licensee (Tenaga Nasional Berhad) and will be paid for every kilowatt hour of power exported to the grid for 21 years.

The combination of the fall in the cost of solar panels and attractive tariffs has made investments in solar energy generation lucrative in Malaysia [11-13]. As a result, solar energy in operation grew by an average of 124% per annum since the inception of FiT. Under the 10th Malaysia Plan, Malaysia plans to achieve 985 MW or 5.5% share of renewable energy in the energy mix by 2015. By 2020, the target is for renewable energy to comprise 11% or 2,080 MW of overall electricity generation in the country. However, as to-date, renewable energy has yet to be considered a major source of electricity generation as it contributes less than 1% to the energy mix in Malaysia.

Following Malaysia’s renewable energy plans, Curtin University, Sarawak Malaysia (Curtin Sarawak) [14-16], the first and largest offshore campus of Curtin University in Perth, Western Australia, and the first foreign university to be established in East Malaysia in partnership with the Sarawak State Government has shown keen interest in introducing renewable energy systems. As a support to Curtin's interest, this paper proposes a 90 kW solar power plant.

2. Curtin Sarawak Data

2.1. Sun-path Diagram

Sun-path diagrams map the path of the sun across the sky. They show the position of the sun relative to the site, both by time of day and time of year. The position of the sun in the sky relative to an observer on Earth is defined by its altitude angle \( \alpha \) (solar elevation angle) and its azimuth angle \( \Psi \) [17]. Both the angles with respect to an observer are shown in figure 1.

![Figure 1. Azimuth and Altitude Angles.](image)

For Miri, Sarawak, the relevant information to determine the Sun-path diagram is as shown:
- Latitude: +4.4 (4°24'00"N)
- Longitude: +113.97 (113°58'12"E)
- Time zone: UTC+8 hours
- Country: Malaysia
- Continent: Asia
- Sub-region: South-Eastern Asia

The Sun-path diagram for a twelve month period for Miri has been determined and presented as in figure 2.
2.2. Curtin Energy Consumption

For the twelve month period in year 2013, the monthly kWh, kVAR consumptions and the corresponding energy consumption charges are depicted in table 1. The minimum energy consumption charges are noticed during January and February months, which are semester break months. The maximum energy consumption of 100530 kWh occurs during September month, which is a semester on period, and the corresponding electricity charge is found to be RM 126217.95. It is observed that during the semester break period, practically the campus is with few students; still the energy consumption charges are almost 50% of the semester on period. The daily energy consumption is shown in table 2.

![Sun-path diagram for Miri, Sarawak.](image)

**Table 1. Curtin Energy Consumption and Charges.**

| Month    | kWh   | kVAR  | Charges(RM) |
|----------|-------|-------|-------------|
| January  | 204566| 49003 | 62609.50    |
| February | 200899| 51339 | 61531.00    |
| March    | 359248| 89203 | 109521.00   |
| April    | 307884| 75065 | 94073.45    |
| May      | 338445| 86274 | 103479.45   |
| June     | 318784| 78938 | 93965.20    |
| July     | 307304| 83987 | 97033.55    |
| August   | 33515 | 85370 | 102548.30   |
| September| 413847| 100530| 126217.95   |
| October  | 288578| 71784 | 88353.40    |
| November | 321711| 80731 | 98434.10    |
| December | 267824| 69746 | 81877.90    |
| Total    | 3664699| 921910| 1119645.00  |

**Table 2. Daily Energy Consumption and Charges.**

| Month    | kWh   | kVAR  | Charges(RM) |
|----------|-------|-------|-------------|
| January  | 6818.87| 1633.43| 2086.98     |
| February | 6696.63| 1711.30| 2051.03     |
| March    | 11974.93| 2973.43| 3650.70     |
| April    | 10262.80| 2502.17| 3135.78     |
### 3. Proposed Solar Power Plant

#### 3.1. Proposed Site

Curtin campus map is shown in figure 3. Figure 4 shows the newly built Chancellery building. This is the ideal site chosen for the proposed solar power plant since no tall raised buildings and trees nearby the building; hence no obstacle for the sunlight incidence on the roof-top. Also there won’t be any shading effect reducing the energy capture.

#### Figure 3. Curtin Campus Map.

#### Figure 4. Chancellery Building – Proposed Site.

Figure 5 shows the roof-top area of the Chancellery building. This is the place identified for the proposed 90 kW solar power plant.
3.2. Proposed Solar Panel

The module chosen for this project is Yingli Solar YL255P-29b (255Wp) Polycrystalline with technical information as shown in figure 6. This is due to Yingli Solar (NYSE: YGE) [18] is the world's largest solar panel manufacturer. More than 50 million Yingli solar panels (representing over 13 gigawatts) have been shipped to more than 90 countries. Yingli covers the entire solar panel production process, from polysilicon to ingots and from solar cells to quality solar panels, and its manufacturing capacity has reached to 2.45GW today. This solar power panel has high efficiency, multi-crystalline silicon solar cells with high transmission and textured glass deliver a module efficiency up to 16.2%. This will minimize installation costs and maximize the kWh output of the system per unit area. This kind of solar panel withstands wind loads of up to 2.4 kPa and snow loads of up to 5.4 kPa, confirming mechanical stability. Besides that, it also successfully endures ammonia and salt-mist exposure at the highest severity level, ensuring their performance in adverse conditions. This solar power panel will have 10-year limited product warranty as well as limited power warranty such as 10 years at 91.2% of the minimal rated power output and 25 years at 80.7% of the minimal rated power output.

![Figure 5. Chancellery Building – Roof-top.](image)

![Figure 6. Module – Technical Information.](image)
Figure 7 presents the technical information of the selected module and the physical module dimension is 1650mmx990 mm.

![Figure 7. Proposal One – Roof with 341 Modules.](image)

3.3. Proposed Inverter
The SMA STP20000TL-30 is the ideal inverter for large-scale and commercial and industrial plants [19,20]. It contains cutting edge grid management functions such as Integrated Plant Control. This feature allows the inverter to adjust reactive power at the point of normal coupling and removes the need for a discrete reactive power controller. In addition, it is capable of supporting multistring configurations and provides flexibility in the system design. Some advantages of the SMA STP20000TL-30 inverter include: (i) 98.4% maximum efficiency, (ii) DC input voltage tolerance of 1000V, (iii) Supports SPD type II DC surge arrestor for better safety, and (iv) Supports SMA Sunny Portal and multi-functional relay.

4. Proposal
4.1. Modules on Roof-top
All the solar panels are placed horizontally following the Chancellery building’s roof architecture. Since all are placed horizontally, the tilting angle of the module is 0°. Considering the area of each module and the area of the Chancellery roof, 341 numbers of Yingli Solar YL255P-29b (255Wp) Polycrystalline modules are needed. Plan view of design one is shown in figure 8.

![Figure 8. Monthly Insolation on 21st Day of Every Month.](image)
4.2. Curtin’s Solar Insolation

The solar insolation on the roof-top modules with 0° module tilt angle has been determined on 21st day of every month and shown in figure 9. Besides the daily and monthly insolation on unit area of the solar modules are determined and presented in table 3.

Table 3. Insolation on the Roof-top Modules.

| Month      | Days/Month | Daily Isolation | Monthly Isolation |
|------------|------------|-----------------|-------------------|
| January    | 31         | 7318.51         | 226.87            |
| February   | 28         | 7719.33         | 216.14            |
| March      | 31         | 7870.15         | 243.97            |
| April      | 30         | 7627.63         | 228.83            |
| May        | 31         | 7198.24         | 223.15            |
| June       | 30         | 6947.79         | 208.43            |
| July       | 31         | 7078.34         | 219.43            |
| August     | 31         | 7442.38         | 230.71            |
| September  | 30         | 7669.17         | 233.08            |
| October    | 31         | 7542.05         | 231.01            |
| November   | 30         | 7217.29         | 216.52            |
| December   | 31         | 7082.26         | 219.55            |
| Total      |            |                 | 2697.49           |

Figure 9. Monthly Insolation on the Proposed Roof-top.

4.3. Annual Energy Generated

Considering the net solar insolation of 90%, the total number of solar modules, the efficiencies of the module and the inverter, the annual energy exportable to the grid has been determined and presented in table 4.

Table 4. Insolation on the Roof-top Modules.

| Solar insolation per year (kWh/m²) | 2697.49 | 2697.49 |
| Net insolation per year (90%) (kWh/m²) | 2427.74 | 2427.74 |
Total number of PV module 324 17  
Area of one PV module (m2) 1.634 1.634  
Total Area of the PV array (m2) 529.416 27.778  
Annual solar energy (kWh) 1285284 67438  
Efficiency of solar power panel (%) 15.6 15.6  
Efficiency of the inverter (%) 98.5 97.0  
Annual Solar energy exportable to the grid (kWh) 197497 10205  
Total energy exportable to the grid by all the 341 modules per annum (kWh) 207702  

4.4. Financial Aspects

The capital cost of the proposed 90 kW solar power plant has been estimated and shown in Table 5.

| Item | No. | Price per unit | Total Price |
|------|-----|---------------|-------------|
| Yingli Solar YL255P-29b (255Wp) Poly | 341 | RM 986 | RM 336185 |
| SMA Sunny Tri Power 20 kW Inverter STP20000TL-30 | 4 | RM 22313 | RM 89250 |
| SMA Sunny Boy 4 kW Inverter SB4000TL-21 | 1 | RM 8509 | RM 8509 |
| Total equipment cost | | | RM 433944 |
| Installation cost | | | RM 73256 |
| Total project cost | | | RM 507200 |

The expected generation of the power plant per year is 207702 kWh. The Feed-in Tariff of sustainable energy development authority (SEDA) is RM 0.3504/kWh. The generated revenues and profit are calculated as:

Total revenues generated = 207702 kWh x RM 0.3504/ kWh = RM 72778.78 per year. Considering 12.5% as maintenance and depreciation charges, the net revenue per year = RM 63681. Hence the payback period = 7.96 say 8 years. In terms of Curtin’s annual energy consumption, the proposed 90 kW solar power plant reduces the energy consumption by 207702 kWh or 5.67%.

5. Conclusions

This paper has proposed a solar power project of capacity 90 kW following the renewable energy target of Malaysian Government. The newly constructed Chancellery building has been chosen as the site for consideration since no obstacles are noticed around the building. As Malaysia is a tropical country, the solar insolation thorough out a year is good, and the energy produced by solar panels is found to be attractive even with solar modules of 15% efficiency. The success of a solar power project mainly relies on the site selection, the module & inverter selection and the energy purchase tariff. As far as the proposed project is concerned, the solar energy converted into electrical energy is found to be more than 2300 kWh per kW capacity installed. Moreover, the payback period is highly encouraging as 8 years with an internal rate of return as 12.5%.

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