Study Technical Economic Efficiency of Fixing PV Power Plant at Sakon Nakhon Rajabhat University by using Simulation Software

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Abstract. The technical-economic efficiency of fixing PV power plants in the 1 MW model was studied by using the PVSYST program. This model installed at Sakon Nakhon Rajabhat University. The solar panels of mono-crystalline silicon solar panels and poly-crystalline silicon were compared to the capacity of 325 W based on technical and economic efficiency. It was found that mono-crystalline silicon energy produced has entered the grid system, performed more than 1 MWh/year (0.06 %). The main reason is due to the higher losses at poly-crystalline solar panels (0.09%) to the same losses in the inverter (-1.76%), but mono-crystalline silicon has a better performance ratio (average 79.7%). In economics, the mono-crystalline silicon solar cells should be used to generate electricity because the capacity is 1,618 MWh/year and the cost of electricity generation is 0.76 baht / kWh with a payback period of 4 years and 4 months.

1. Introduction
The photovoltaic device has converted renewable energy into electricity [1]. Nowadays, power generation using photovoltaic cells is gaining popularity both at home and abroad, as can be seen from many PV power plant projects and in the Thailand Power Development Plan 2010-2030 (PDP 2010). This research has established a strategy for the development of renewable energy to increase the proportion of renewable energy use to 20% by 2022. At present, Thailand has used solar energy with solar photovoltaic systems more. At the end of 2011, about 100 MW of photovoltaic systems were installed in Thailand, both in PV standalone systems and PV Grid-connected systems. [4]. PV power generation systems are easier to install and maintain than other forms of renewable energy. However, if the installation design of PV power generation systems does not concern enough engineering and geography principles, it will result in a lower than expected amount of electricity generated by the generating system. Therefore, a number of instruments have been invented to help calculate designs for PV power generation systems [5]. The software used to simulate the installation of PV systems must be able to modify the installation power of the PV system and the power of the devices that must be implemented in the system. The software must be able to analyze and control the system to work together properly [6]. Several thermal models have been constructed and simulated to predict the
temperature distribution of the PV panel models under provided environmental conditions. More advanced software typically deals with the thermal models to optimize the performance of the model. In the study by P.W. Ingle et al. [3], but power generation also has a number of relevant factors that need to be studied and assessed appropriately in terms of project feasibility. It is important to study the economic cost-effectiveness of investments [7], studies involving the impact on efficiency, and operation of rooftop PV power generation systems. Research in Malaysia has examined the factors affecting the power generation efficiency of PV cells installed on residential roofs, such as temperature, configuration, and installation height. [8] solar cells with monocrystalline materials and efficiency of around 18% - 20% will be used. [2] An average cell is operating temperature of approximately 37-40 °C, the capacity of mono-crystalline silicon PV modules is approximately 5–6% lower than the standard test condition. The output power is based on the temperature coefficient for maximum energy −0.42% / °C [9]. An example of research studies assessed on the cost-effectiveness of foreign investment that has been studied in the research of Aldo Orioli and the faculty studied economic variables and factors related to the efficiency of electric power generation systems from PV cells installed on a multi-story building [10-11] Currently, the efficiency of solar power plants does not have extensive research at schools in Thailand. This could be a viable option in the near future if schools themselves are considering building self-sustaining PV power plants in line with government policy. The researcher has realized the problem and the significance of this problem to study the technical-economic efficiency study of fixing PV power plant in Sakon Nakhon Rajabhat University by using simulation software.

2. Materials and methods

The aims of research to study the technical-economic efficiency study of fixing PV power plant in Sakon Nakhon Rajabhat University by using simulation software, to show the efficiency and savings use of resources under aim or demand of project analysis contributes and to decisions on effective resource use.

2.1 Technical performance analysis design

In the analysis of technical performance, a feasibility study of PV panel mounting and suitable angular positions must be conducted. The analysis was analyzed with PVSYST by exporting preliminary design data to the simulation software for further performance analysis.

The faculty of agricultural Technology, Sakon Nakhon Rajabhat University area has latitude 17.10, longitude the 104.04, elevation of sea level 177 meters, which is an irregular rectangular area. The area calculated by measuring the distance from the actual location together with the satellite imagery which was divided into 4 sides: a side 37 m, b side 172 m, c side 62 m, and d side 177 m. B side faces south as in Figure 1. From equations (1) and (2), an area is 8,604.56 square meters (5 rai 1 ngan 51.14 square wa).

Figure 1. PV power plant project area survey (google map)
\[ S = \frac{1}{2} (a + b + c + d) \]  
(1)

\[ \text{Area} = \sqrt{(s-a)(s-b)(s-c)(s-d) - \frac{1}{2}abcd\left[1 + \cos(\gamma + \lambda)\right]} \]  
(2)

The Azimuth angle is the direction of the PV panel along with the compass, for example, north is 0 degrees, east is 90 degrees, south is 180 degrees, and west is 270 degrees. To determine the azimuth in PVSYST, the azimuth of PVSYST must be determined differently according to the equation read from the compass.

\[ \text{PVSYST (degrees)} = \text{Azimuth} - 180 \text{ degrees} \]  
(3)

Therefore, the direction of the PV panel was determined at the south angle is the same as 0 degrees of the azimuth of the PVSYST simulation software [12].

### 2.2 Types of PV cells used in the design

#### 2.2.1 Mono Crystalline Silicon PV Cell

Mono crystalline silicon, Schutten Solar, Model STM6-330 / 72 [13]

| Parameters           | Values                                                                 |
|----------------------|------------------------------------------------------------------------|
| Field type           | Fixed tilted plane                                                     |
| Full system, orientation | Tilt / Azimut = 15° / 0°                                                 |
| 1 Sub-array          | PNom = 1057 kWp, modules area = 6217 m²                                |
| Shading fields       | 178 tables, total rough area = 6412 m²                                 |
| Sub-array #1         | PV Array                                                               |
| PV modules           | 178 strings of 18 modules in series, 3204 total                        |
| Pnom = 330 Wp        | Pnom array = 1057 kWp, Area = 6217 m²                                  |
| Inverters (25.0 kWac) | 59 MPPT inputs, total 738 k                                            |

Table 1 shows the results of the preliminary system analysis of the mono-crystalline silicon PV system, namely orientation parameters, compatibility between system and shadings, and system parameters, which have an orientation design by setting plane tilt 15 degrees and setting azimuth angle to face south (0 degrees) before the system design in the PVSYST software.

#### 2.2.2 Poly Crystalline Silicon PV Cells used in Design

The orientation was designed by setting plane tilt 15 degrees and setting azimuth angle to face south (0 degrees) before system design in PVSYST software using the poly-crystalline solar panel, Schutten Solar, Model STP6-330 / 72 [14].

The preliminary system analysis was provided by the poly-crystalline silicon PV system. The basic system was analyzed the orientation parameters, compatibility between system and shadings, and system parameters as shown in Table 2.
Table. 2 Calculation system to run the software (polycrystalline silicon)

| Parameters                        | Values                                      |
|-----------------------------------|---------------------------------------------|
| Field type                        | Fixed tilted plane                          |
| Full system, orientation          | Tilt / Azimut = 15° / 0°                    |
| 1 Sub-array                       | PNom = 1057 kWp, modules area = 6217 m²     |
| Shading fields                    | 178 tables, total rough area = 6412 m²      |
| Sub-array #1                       | PV Array                                   |
| PV modules                        | 178 strings of 18 modules in series, 3204 total |
| Pnom = 330 Wp                      | Pnom array = 1057 kWp, Area = 6217 m²       |
| Inverters (25.0 kWac)              | 59 MPPT inputs, total 738 k                |

2.2.3 Design characteristics for installation in 3D model computer software

![Figure 2. The 3D model of near shading analysis](image)

3. Results and Discussion

3.1 Near shading analysis result of specified area size

The monocristalline silicon and polycrystalline silicon PV panels were specified to be tilted 15 degrees and azimuth 0 degrees (south), it will be shadowed from 7:00 am to 8:00 am and will be shadowed again after 4:00 p.m. to 5:00 p.m. total power is 1,057 kWac are shown in Figure 3.
3.2 Technical results of a 1 MW PV power plant system

3.2.1 Analysis of losses incurred in the system

The losses incurred in a 1 MW PV power plant system was designed by the PVSYST simulation software can generate electricity 1.834 MWh / year. The monocrystalline silicon PV cells can be fed into the grid inverter system at 1,618 MWh / year are used simulations. The main reason loss of PV panels (PV loss) is -11.54% and the loss from the inverter (Inverter Loss) is -1.76% of the average monthly PV power plant’s electricity production. Polycrystalline silicon can produce and feed into a grid inverter system at only 1,617 MWh / year. The main reason loss of PV panels (PV loss) is -11.63% and the loss at inverter (Inverter Loss) is -1.76% of the average monthly PV power plant’s electricity production as shown in Figure 4.

(a) Monocrystalline silicon
3.2.2 The results of the analysis of the power capacity of PV power plants

The average monthly electricity production of PV power plants can be summed up as the monthly average. Both types of PV panels have the same average monthly power generation output of PV power plants, which are able to generate electricity in excess of 4.19 kWh/kWp/day, collection loss 0.92 kWh/kWp/day, and the loss in the system up to 0.15 kWh/kWp/day as shown in Figure 5.

Figure 5. Average monthly electricity production of PV power plants

Monocrystalline silicon PV panels can generate electricity with an average performance ratio (PR) of 79.7%. Polycrystalline PV panels can generate electricity with an average performance ratio of 79.6% as shown in Figure 6.
Results of economic analysis, financial costs, economic costs, and financial returns and break even points

The simulation software was able to analyze the financial costs. It was found the monocrystalline silicon and polycrystalline silicon PV panels can generate PV power with an energy cost equal to 0.76 THB/kWh, generate electricity at 1,618 MWh/year, and 4 years 4 months of the payback range as shown in Figure 7.

Figure 7. Cumulative cashflow (kTHB) of (a) monocrystalline silicon (b) polycrystalline silicon

The annual net profit of simulation software has produced since the first year is higher as 6,401,982 kTHB up to year 19 as 6,847,882 kTHB. In the years 2020-2025, net profit decreased to 3,381,104 kTHB. The result of polycrystalline silicon is 6,456,993 kTHB, up to year 19 is 6,947,725 kTHB. In the years 2020-2025, net profit decreased to 3,486,776 kTHB. The net profit at the end of the service life of the monocrystalline silicon PV panel is 121,111,781.42 THB, which is higher than the polycrystalline PV panel which is 120,994,650.42 THB as shown in Figure 8.
4. Conclusion

The electricity generation and economics of monocrystalline silicon and polycrystalline silicon PV panels were simulated and designed by the PVSYST software in order to predict at Sakon Nakhon Rajabhat University which there compared the same input variables. The energy of monocrystalline silicon produced more efficiency than 1 MWh / year (0.06 %). The collection loss of the polycrystalline silicon PV panel (0.09%) is the highest value. Both types had the same losses at the inverter (-1.76 %), but monocrystalline Silicon had a better performance ratio (79.7 % on average). In economics, it was found that monocrystalline silicon PV cells should be used to generate electricity because the capacity was 1,618 MWh / year, the cost of electricity generation was 0.76 baht / kWh, and the payback period was 4 years and 4 months.

5. Suggestions

In the next research development, the design should be added with a sketch up with PVSYST for more realistic 3D designs.

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