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Comparison on Economics and Performance of Large Scale PV Power Plants: a Case Study

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Abstract – *This paper compares the energy generation of two large-scale PV power plants at a rate of 6 MW. Economics and performances are the two main analysis viewpoints for the comparison of the system efficiency and profit of two types PV panel for a service period of twenty-five years. Thin-film and polycrystalline PV power plants have been studied. In the simulation results, three years of actual collected data have been analysed and compared. The PVsyst program has been used to simulate the performance ratio (PR) and the energy production. In addition, the net present value (NPV) has been also used to analyse the economic efficiency. The simulation results have showed that in the case of thin-film PV panels, the energy production in the beginning of the year has been higher than the actual collected data. On the other hand, in the case of polycrystalline PV panels, the energy production has been lower than the actual collected data. By the long term economic efficiency, the results have showed that the efficiency of polycrystalline PV panels has been better than the one of thin-film PV panels. Therefore, the obtained results from this work may be used as a guideline for deciding to invest in the PV power plant in the future.* ***Copyright © 2021 The Authors.***

Keywords: *Thin-Film PV Power Plant, Polycrystalline PV Power Plant, Performance Ratio (PR), Net Present Value*

Nomenclature

a	Repayment cash flow per year
AESs	Alternating Energy Sources
AIM	Array incidence loss
b_o	Coating layer of PV panel
CUF	Cumulative Unity Factor
EVA	Ethylene Vinyl Acetate
E_{AC}	AC energy of PV generated
E_{DC}	DC energy of PV produced per capacity of PV installation
E_{GRID}	AC energy connected to PEA
E_{PV}	Energy of PV generated
E_{Yf}	Energy of PV per capacity of the PV installation
E_{Yr}	Energy of PV generate per reference yield capacity of PV installation
FFANN	Feed Forward Artificial Neural Network
G_{STC}	Irradiance in STC standard condition
GDP	Gross Domestic Product
i	Light angle on PV panel
n	Number of years
NPV	Net Present Value
P_{CR}	Cable power loss
$P_{\max}$	PV module's maximum power
PEA	Provincial electricity authority of Thailand
P_{nom}	Nominal power loss late rate
PCC	Point of Common Coupling
PR	Performance Ratio
R_{array}	Proportion of V_{mp}/I_{mp} at STC
REs	Renewable Energy Sources
SAM	System Advisor Model
S_{irr}	Solar irradiation on surface area of PV panel
SPP	Solar Photovoltaic Plant
SST	Solid State Transformer
T	Inverter time connect to the grid of PEA
TGVI	Total global energy investment
U	Thermal loss factor
U_C	PV constant element
V_{AC}	AC voltage at inverter output
V_{mpp}	Voltage at maximum power point
V_{oc}	Open circuit voltage of PV panel
ϕ	Transformer phase

I. Introduction

The solar energy is known as a source of clean energy. PV technology is used to convert solar energy into electric energy. Subsequently, it has become widely used worldwide. In Thailand, the government has supported the use of solar energy since 1992. Many PV technologies have been used, including monocrystalline silicon PV, polycrystalline PV and thin-film PV. The study has focused on the performance and the economy of two technologies: the polycrystalline and the thin-film PV, in 6 MW PV power plant. The study has predicted the investment cost under contract with Thai government

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in 25 years. Many researches have been published and have been involved in evaluating the PV power plant performance in the past. Many researches have considered related factors such as installed location, environment, and PV technologies. There have been case studies on the system design for stand-alone PV with a power size of less than 1 kW/day. The study result has shown that it could be used for two days on a single charge. This design has been suitable for low-income people and remote area that cannot reach basic electrical systems. Therefore, the use of batteries to store energy could help the system to gain the system reliable [2].

Furthermore, the quality control of solar power using Solid State Transformer (SST) contributes to the stability of the electrical system [3], [4]. The PV systems have been also used to illuminate the roads in order to minimize the costs [5]. The energy storage systems have been used to achieve good performance of the PV power system [6]. The location effect of the PV power plant in a radial distribution system could reduce total power loss by determining the optimal position installation of the PV power plant. The optimum position of the PV power plant has been the length of 67.25% from the substation.

It could decrease the optimal power loss of the grid [7]. Most of the PV power plants have been installed on the ground and on the rooftop, while some other PV power plants have been installed above water [8], [9].

The potential of the PV floating is different from the PV on-ground type [9]. The energy produced depends on the environmental of PV floating power plant. A study of performance analysis of a 25 MW PV power plant in India from 2015 to 2017 has been simulated using the PVsyst program compared to the calculation with Excel. It has been found out that the solar power plant had a similar decrease in performance in the 74-80% range and had a Cumulative Utility Factor (CUF) of 16-24%, respectively [10]. The performance of thin-film PV has been compared with the one of monocrystalline PV panels. It has been found out that performance of thin-film PV has been better than monocrystalline PV panel [11]. The effect of climate and location has presented the performance of the different PV types. The degradation rate of thin-film PV panel has been low with nearly -0.1%, but the one of polycrystalline panel has been in the range of -0.67% to -0.83% [12]. The preliminary analysis has shown that the performance of the thin-film PV panels has been higher than the one of the polycrystalline PV. However, it takes up more installation than the monocrystalline and polycrystalline solar panels. For monotype PV panels using the Ethylene-Vinyl Acetate (EVA) coating on cells when considered in dry climates, it has been found out that the performance has decreased by 2.22% per year. Meanwhile, the PV monotype has reduced the breakdown by 4.57% per year. It has been better to use a solar panel with EVA for better performances in dry conditions [13]. This solar panels technology approach could make power plants more productive with capacity readiness index indicators from less damaged panels, increasing production opportunities. In this study, the proposed method has been used to compare the power generating value from the real-time measurement and the prototype model from System Advisor Model (SAM) analysis. The results have showed that the actual production value has been higher than the prototype model evaluated value. From the study, it has been found out that the most influencing factor has been the sun's radiation intensity. The use of the model is suitable for the initial estimation of the production capacity [14]. In order to analyze the performance of the PV power plants, it is important to know the capacity of the power plant to assess the potential of the power plant. A research has presented the Feed-Forward Artificial Neural Network (FFANN) with rapid forecasting method, which has been used as the principle for the performance prediction of the PV power plant. The big data has been used to analyze, whilst the result of simulations could predict the capacity of the PV power plant [15]. Previous researches have conducted most of the performance studies of the PV power plants in many conditions [24]. They have been studied under different conditions such as location, environmental factors, delegation factor, and PV panel technologies.

The performance studies are based on the simulation production data and the power generation actual production data. Therefore, there is still a lack of articles on investment time, break-even point, and payback period for the large-scale PV power plant. In this article, these topics are detailed. This article has studied and compared two PV power plant technologies: thin-film PV and the polycrystalline PV. The study results have been described in the next section.

II. Fundamental Theory of PV

II.1. Performance of PV Power Plant System

The performance of PV power plant reference follows ICE standard code IEC 61724 [16]. This can be calculated by Equations (1)-(4):

$$E_{DC}=\frac{E_{PV}}{E_{PV(\max)}} \tag{1}$$

$$E_{Yr}=\frac{S_{irr}}{G_{STC}} \tag{2}$$

$$E_{Yf}=\frac{E_{AC}}{E_{PV(\max)}} \tag{3}$$

$$PR=\frac{E_{DC}}{E_{Yr}} \tag{4}$$

where E_{DC} represents the DC energy of PV produced per capacity of a PV installation (kWh/kWp), E_{PV} represents the energy of PV generated (kWh), $E_{PV(\max)}$ represents the maximum capacity of a PV installation (kWp), E_{Yr}

represents the energy of PV generate per reference yield capacity of a PV installation (kWh/kWp), S_{irr} represents the solar irradiation on the surface area of PV panel (kW/m^2), G_{STC} represents the irradiance in STC standard condition (AM 1.5, 1 kWp/m^2 at 25 °C), E_{Yf} represents the energy of PV per capacity of the PV installation (kWh/kWp) and E_{PV} represents an AC energy of PV generated (kWh).

II.2. Loss Effect in PV Power Plant

The energy generation from the PV power plant is divided into two parts: natural effects and the PV system installation. The natural effects are the position of the sun irradiation and the environment. The PV system installed consists of a PV module, an inverter, a transformer, a cable, an installation method, etc. The energy from the PV power plant has been connected to the primary grid and it has been calculated by Equation (5). This energy is the benefit of the power plant:

$$E_{GRID} = V_{AC} I_{AC} T \tag{5}$$

where E_{GRID} represents the AC energy connected to the main grid (kWh), V_{AC} represents the AC voltage at inverter output (V), I_{AC} represents the AC at inverter output (A), and T represents the time of inverter connected to the main grid (hr). The PV power plant has many losses, which affect the generation of energy. They are the PV heat loss factor, the ohmic loss, and the array incidence loss. The loss effects are shown in Equations (6)-(8). The PV heat loss factor is the loss of PV array thermal, as shown in Equation (6):

$$U = U_C + U_V v \tag{6}$$

where U represents the thermal loss factor (W/m^2 k), U_C represents the PV constant element, and v represents the wind speed (m/s). The ohmic loss factor is the loss of cable installation in the PV power plant. The ohmic loss is considered under the standard condition at 1000 W/m^2 and temperature 25 °C. The proportion of the cable power loss is caused by the cable resistance (P_{CR}) with nominal power loss late rate (P_{nom}). The loss is shown in Eqs. (7) and (8):

$$P_{CR} = R_{Cable} I_{SC}^2 \tag{7}$$

$$P_{nom} = R_{array} I_{SC}^2 \tag{8}$$

where I_{sc} represents the short circuit current of PV panel (A), R_{cable} represents the total resistance of cable used (Ω), V_{mp} represents the voltage at maximum power point of PV panel (V), and R_{array} represents the proportion of V_{mp}/I_{mp} at STC (Ω). The array incidence loss (AIM) is the light effect from the sun angle in a day. AIM's effect consists of solar irradiation transferred, and the reflection between two translucent materials followed by the theory of the Fresnel's law. The AIM can be computed by Equation (9):

$$E_{IAM} = 1 - b_o \left(\frac{1}{\cos(i)} - 1 \right) \tag{9}$$

where i represents the light angle on the PV panel, b_o represents the coating layer of the PV panel. In addition to the preceding, there are other losses, such as the PV module efficiency, the PV power plant location, the season, the number of days, the raining, loss from the inverter, etc.

II.3. Annuity Method Theory

The annuity method is the basis of cash flow calculations.

This method commonly uses two forms: static method and dynamic method. The dynamic annuity method can show cash flow more than the static annuity one. The electrical system applies the annuity method for calculation annuity cost by series repayment. The result data of calculation is matched with the average of annuity cash flow:

$$a = NPV \frac{\left[i(1+i)^n \right]}{\left[(1+i)^n - 1 \right]} \tag{10}$$

where a represents the repayment cash flow per year, NPV represents the net present value, i represents the interest, and n represents the number of years.

III. Methodology

Five topics in the methodology have been presented.

There are PV power plant locations, the information of equipment in PV power plant, the single line diagram, the detail of the PV power plant and the economics data of the PV power plant, respectively.

III.1. Location of PV Power Plant

The PV power plant site has been located at Hua Wa subdistrict, Si Maha Phot District, Prachin Buri province, the central part of Thailand. It is located on latitude 13.89N and longitude 101.45E.

The thin-film PV type power plant and the polycrystalline PV type power plant have been used for the cases studied. Both types have the same size of 6 MWp.

III.2. Study on Equipment Installation

The main equipment used in the PV power plant consists of a cable, 125, 130, 310 Wp PV panels, an inverter, and a transformer.

The device has the following detail, as shown in Tables II-IV. These equipment details have been used for the cost estimation of the PV power plant. Table I shows the current rate and the method used in PV power plant capacity. Table II shows the characteristics of 125 Wp thin-film PV panels, and Table III shows the characteristic of the 130 Wp thin-film PV panels used in the PV power plant.

Table IV is the characteristic of 310 Wp polycrystalline PV panels used in the PV power plant.

Fig. 1. PV power plant [17]

TABLE I
CHARACTERISTICS OF XLPE HIGH VOLTAGE CABLE [18]

Surface area (mm^2)	The current rate of 2 conductors: single and multi-core (A)	The current rate of 3 conductors: single and multi-core (A)
No.- 6	54	47
No.- 10	71	63
No.- 35	150	132
No.- 95	271	238
No.- 150	355	312
No.- 300	543	475

TABLE II
CHARACTERISTICS OF THIN-FILM PV PANEL OF 125 Wp (STC) [19]

Thin-film characteristics details	Value
PV module's maximum power ($P_{\max}$)	125 Wp
Open circuit voltage of PV panel (V_{oc})	59.7 V
Short – circuit current of PV panel (I_{sc})	3.37 A
The voltage at maximum power point (V_{mpp})	45.5 V
Current at maximum power point (I_{mpp})	2.75
Power effect compassion with temperature (%/°C)	-0.24
The efficiency of PV panel (%)	8.90
PV panel dimension (L × W × H, mm)	1402×1001×6.7
PV panel weigh (kg)	24

TABLE III
CHARACTERISTICS OF THIN-FILM PV PANEL OF 130 Wp (STC) [19]

Thin-film characteristics details	Value
PV module maximum power ($P_{\max}$)	130 Wp
Open circuit voltage of PV panel (V_{oc})	60.4 V
Short – circuit current of PV panel (I_{sc})	3.41 A
The voltage at maximum power point (V_{mpp})	46.1 V
Current at maximum power point (I_{mpp})	2.82 A
Power effect compassion with temperature (%/°C)	-0.24
The efficiency of PV panel (%)	9.30
PV panel dimension (L × W × H, mm)	1402×1001×6.7
PV panel weight (kg)	24

TABLE IV
CHARACTERISTICS OF POLYCRYSTALLINE PV PANEL OF 310 Wp (STC) [20]

Polycrystalline characteristics details	Value
PV module's maximum power ($P_{\max}$)	310 Wp
Open circuit voltage of PV panel's (V_{oc})	45.50 V
Short – circuit current of PV panel (I_{sc})	8.85 A
The voltage at maximum power point (V_{mpp})	46.1 V
Current at maximum power point (I_{mpp})	8.38 A
Power effect compassion with temperature (%/°C)	-0.41
The efficiency of module PV (%)	15.99
PV panel dimension (L × W × H, mm)	1596×991×45
PV panel weight (kg)	26

Table V shows the characteristic of the inverter size 500 kWp. Table VI shows the characteristic of the transformer size 1,250 kVA.

III.3. Single Line Diagram

The single line diagram shows the position of the equipment installation in the PV power plant. The main equipment consists of a PV panel, an inverter transformer, and other equipment. The PV power plant's energy is connected to PEA at the Point of Common Coupling (PPC). Two PV power plants studied have been located in the same area. The irradiation average has been 17.80 MJ/m^2. The thin-film power plant used has been 24,000 PV panels, 125 Wp and 23,040 PV panels, and 130 Wp.

TABLE V
INVERTER CHARACTERISTICS OF 500 MX [21]

Inverter characteristics detail	Value
DC input	
Rated maximum voltage ($V_{\max}$)	1000
Rate minimum operation input voltage ($V_{\min}$)	460 - 500
MPP range of voltage operation (V)	460 - 850
Total DC input (PCS)	6 - 8
Input current maximum rate (A)	1220
Short circuit current maximum rate (A)	1460
AC output	
Output power	550 kVA @ 50 °C, 500 kVA @ 55 °C
Maximum current (A)	1008
Nominal voltage (V)	315
Nominal frequency/Grid frequency (H_z)	50/45-55, 60/55-65
Total harmonic distortion (THD,%)	<3(at nominal power)
Nominal power factor /adjust table power factor	>0.99/0.8leading – 0.8 lagging
Transformer feed-in/Connection phases	3/3
Maximum efficiency standard /European (%)	99.0 / 98.7

TABLE VI
CHARACTERISTICS OF STEP-UP TRANSFORMER WITH SIZE OF 1,250 kVA [22]

Transformer characteristics detail	Value
Transformer rate power (kVA)	1250 (625/625)
Transformer frequency (Hz)	50
Primary Voltage (V)	22000 V
Secondary Voltage (V)	315/315 V
Maximum short circuit rate (kA)	38.18 kA
Transformer phase (ϕ)	3
Transformer tapping	± 2 × 2.5%
Vector group	Dy11y11
Noise level	≤ 59 dB
No load loss (@1250kVA, 75 °C)	0.95 kW
On load loss (@ 625kVA, 75 °C)	4.75 kW
Transformer step	5

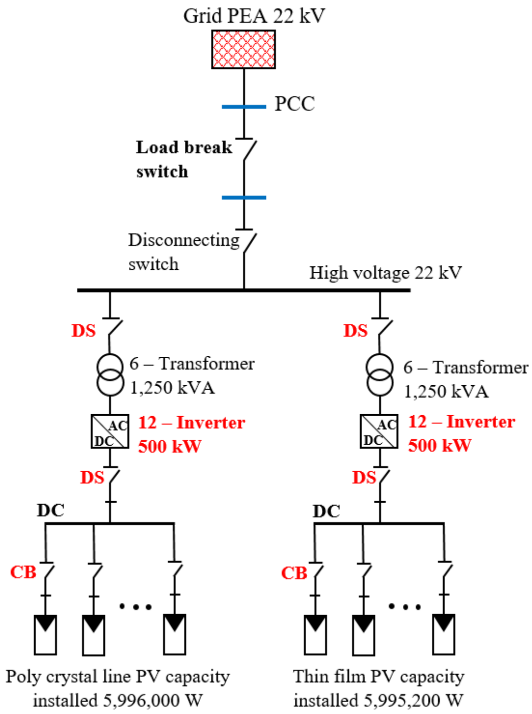

Fig. 2. Single diagram of PV power plant

The total capacity of the power plant has been 5,995,200 Wp. The power plant area has been 66,083 m^2.

The polycrystalline PV power plant used has been 19,341 PV panel, 310 Wp. The total capacity of the power plant has been 5,996,000 Wp. The power plant area has been covered by 34,491 m^2.

III.4. Detail of PV Power Plant

The installation cost is the total cost of the PV power plant. The detail of the installation cost is shown in Table VII. Table VII shows the detail of the installation cost of the PV power plant. The thin-film PV power plant has a total installation cost of 7,610,466 \$, while the polycrystalline PV power plant has a total installation cost of 8,022,077 \$. The total installation cost of a thin-film PV power plant is less than the one of polycrystalline PV power plant, by about 411,610 \$, on 5.131%.

III.5. The Economic Data of PV Power Plant

This study has used the PV power plant data from the first year of the PV power plant operation from 2016 to 2018. The data show the performance and the energy degradation of the PV power plant. The price of energy for sale to PEA is 0.188 \$ per 1 kWh, the period for sale is 25 years.

IV. Results and Discussion

The energy generation from PV power plants is shown in Table VIII from the year 2016 to 2018. The data have been compared with the energy generation, which has been estimated using the PVsyst simulation program [23]. Table VIII compares the actual total energy generation results of the thin-film PV power plant and polycrystalline PV power plant with the PVsyst simulation program simulation result. The energy of the thin-film PV generation in 2016 was 9,718,327 kWh. It is more than the energy from simulation by 2.85%. The energy generation of the ploy crystalline PV power plant was 9,088,734 kWh in 2016. It is lower than the energy from the simulation by 1.57%.

Moreover, the comparison of the energy for each type of PV power plant in 2016 to 2018 is shown in Table VIII. For the thin-film PV power plant, the energy generation has decreased by 1.30% and 3.31% in 2017 and 2018, respectively. In addition, for the power generation of polycrystalline PV power plants, the energy generation has decreased by 2.77% and 4.38% in 2017 and 2018, respectively.

The PV power plant installation cost has been calculated by Equation (5) for finding the NPV of the power plant. It is equal to 8% and the period is 25 years.

Fig. 3 shows the cash flow received comparison of thin-film PV power plant and polycrystalline PV power plant. The first one has the maximum cash flow received of 1,645,947 \$, and the minimum cash flow received of 1,463,064 \$.

The average cash flow received is 1,536,218 \$. The polycrystalline PV power plant has the maximum cash flow received of 1,659,041 \$, and the minimum cash flow received of 1,368,281 \$. The average cash flow received is 1,513,469 \$.

The thin-film PV power plant has an average cash flow higher than the polycrystalline PV power plant by 1.48%.

TABLE VII
INSTALLATION COST OF PV POWER PLANT

Cost detail	PV system price (\$)		Lifetime (Y)
	Thin-film	Polycrystalline	
Land	664,960	412,275	25
Road & wall	575,190	365,063	25
Wire and tube	498,720	398,976	25
PV structure	3,324,800	4,488,480	25
Inverter and connection box	631,712	598,464	10
Transformer and accessories	199,488	199,488	10
Water	398,976	398,976	10
Lightning protection	31,586	24,936	25
CCTV system	93,094	79,795	3
Monitoring system	28,261	28,261	3
Installation cost	930,944	797,952	25
Operation & maintenance	216,112	216,112	1
Spare part	16,624	13,299	1
Total cost	**7,610,466**	**8,022,077**	

TABLE VIII
ENERGY GENERATION FROM PV POWER PLANT

Since	Simulation (kWh)		Real energy (kWh)	
	Thin-film PV	Poly crystalline	Thin-film PV	Poly crystalline
2016	9,441,675	9,163,153	9,718,327	9,088,734
2017	-	-	9,592,114	8,791,575
2018	-	-	9,396,797	8,675,527

TABLE IX
CASH FLOW COMPARISON OF THE THIN-FILM PV POWER PLANT BETWEEN PVSYST SIMULATION WITH INSTALLATION PREDICTION

Year	Efficiency (%)	Thin-Film PV Panel PVsyst cash flow receive ($)	Thin-Film PV Panel Installation cash flow receive ($)	Year	Efficiency (%)	Thin-Film PV Panel PVsyst cash flow receive ($)	Thin-Film PV Panel Installation cash flow receive ($)
0	100%	0	0	13	80%	1,421,415	1,463,064
1	90%	1,599,092	1,645,947	14	80%	1,421,415	1,463,064
2	90%	1,599,092	1,645,947	15	80%	1,421,415	1,463,064
3	90%	1,599,092	1,645,947	16	80%	1,421,415	1,463,064
4	90%	1,599,092	1,645,947	17	80%	1,421,415	1,463,064
5	90%	1,599,092	1,645,947	18	80%	1,421,415	1,463,064
6	90%	1,599,092	1,645,947	19	80%	1,421,415	1,463,064
7	90%	1,599,092	1,645,947	20	80%	1,421,415	1,463,064
8	90%	1,599,092	1,645,947	21	80%	1,421,415	1,463,064
9	90%	1,599,092	1,645,947	22	80%	1,421,415	1,463,064
10	90%	1,599,092	1,645,947	23	80%	1,421,415	1,463,064
11	80%	1,421,415	1,463,064	24	80%	1,421,415	1,463,064
12	80%	1,421,415	1,463,064	25	80%	1,421,415	1,463,064

TABLE X
CASH FLOW COMPARISON OF THE POLYCRYSTALLINE PV POWER PLANT BETWEEN PVSYST SIMULATION WITH INSTALLATION PREDICTION

Year	Efficiency (%)	Polycrystalline PV Panel PVsyst cash flow receive ($)	Polycrystalline PV Panel Installation cash flow receive ($)	Year	Efficiency (%)	Polycrystalline PV Panel PVsyst cash flow receive ($)	Polycrystalline PV Panel Installation cash flow receive ($)
0	100%	0	0	13	89%	1,526,055	1,513,661
1	97%	1,672,625	1,659,041	14	88%	1,513,812	1,501,517
2	96%	1,660,382	1,646,897	15	87%	1,501,569	1,489,374
3	96%	1,648,139	1,634,754	16	86%	1,489,499	1,477,401
4	95%	1,636,069	1,622,781	17	86%	1,477,256	1,465,258
5	94%	1,623,826	1,610,638	18	85%	1,465,013	1,453,114
6	93%	1,611,583	1,598,494	19	84%	1,452,770	1,440,971
7	93%	1,599,340	1,586,351	20	84%	1,440,527	1,428,827
8	92%	1,587,097	1,574,207	21	83%	1,428,284	1,416,684
9	91%	1,574,854	1,562,064	22	82%	1,416,213	1,404,711
10	90%	1,557,611	1,544,960	23	81%	1,403,971	1,392,568
11	90%	1,550,541	1,537,948	24	81%	1,391,728	1,380,424
12	89%	1,538,298	1,525,804	25	80%	1,379,485	1,368,281

TABLE XI
CASH FLOW USING NPV CALCULATION OF THE PV POWER PLANT BETWEEN PVSYST SIMULATION ON 25 YEARS

Year	Thin-film PVsyst NPV ($)	Thin-film Install. NPV ($)	Polycrystalline PVsyst NPV ($)	Polycrystalline Install. NPV ($)	Year	Thin-film PVsyst NPV ($)	Thin-film Install. NPV ($)	Polycrystalline PVsyst NPV ($)	Polycrystalline Install. NPV ($)
0	-7,610,466	-7,610,466	-8,022,077	-8,022,077	13	428,521	443,835	482,890	478,333
1	1,243,595	1,286,979	1,351,702	1,339,124	14	396,774	410,954	442,947	438,761
2	1,151,477	1,191,648	1,241,079	1,229,518	15	367,381	380,510	406,274	402,429
3	1,066,192	1,103,388	1,139,440	1,128,814	16	304,267	316,424	344,520	340,989
4	987,198	1,021,637	1,046,146	1,036,379	17	314,974	326,231	341,748	338,506
5	914,097	945,986	960,348	951,372	18	291,643	302,066	313,370	310,392
6	768,835	798,362	820,705	812,457	19	270,039	279,689	287,319	284,585
7	783,687	811,027	809,052	801,473	20	250,033	258,969	263,407	260,897
8	725,638	750,952	742,509	735,545	21	28,744	37,018	57,849	55,545
9	671,877	695,317	681,374	674,976	22	214,367	222,028	221,360	219,245
10	622,114	643,818	622,921	617,061	23	198,485	205,579	202,875	200,933
11	62,057	79,920	177,329	171,928	24	183,783	190,351	185,918	184,135
12	462,793	479,332	526,372	521,411	25	170,169	176,251	170,358	168,722

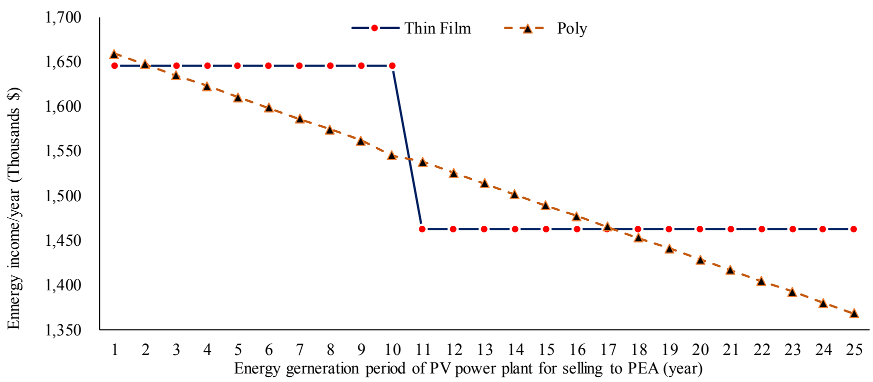

Fig. 3. Cash flow comparisons of thin-film PV and polycrystalline PV

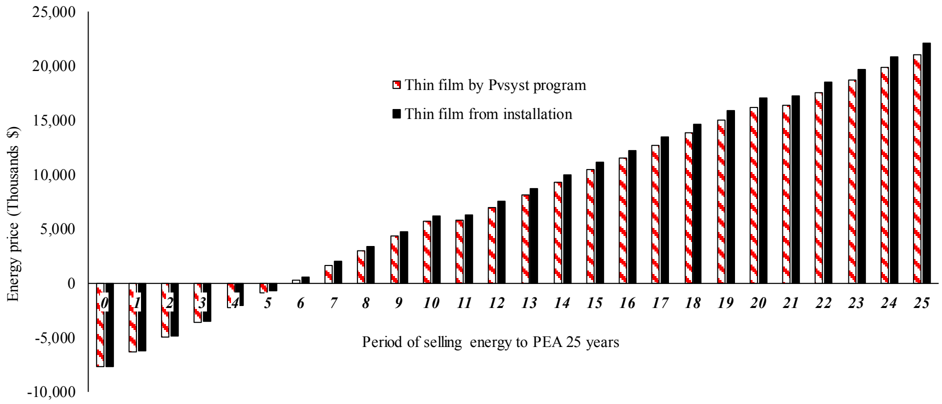

Fig. 4. Cash flow of thin-film PV power plant using NPV calculation by the PVsyst program calculation

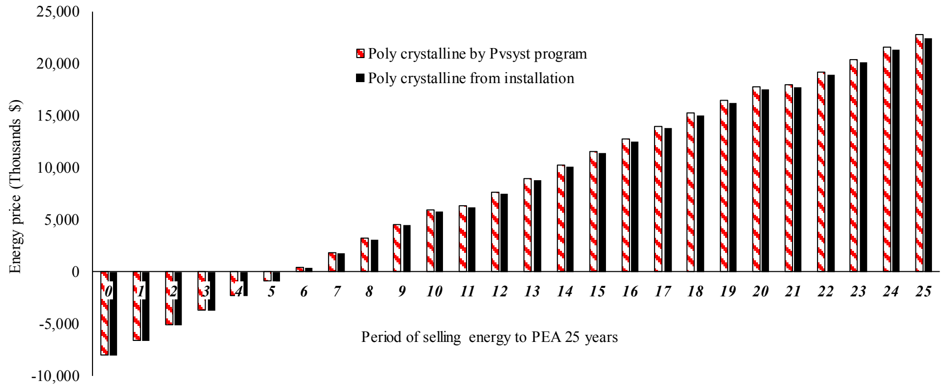

Fig. 5. The cash flow of polycrystalline PV power plant using NPV calculated by the PVsyst program calculation

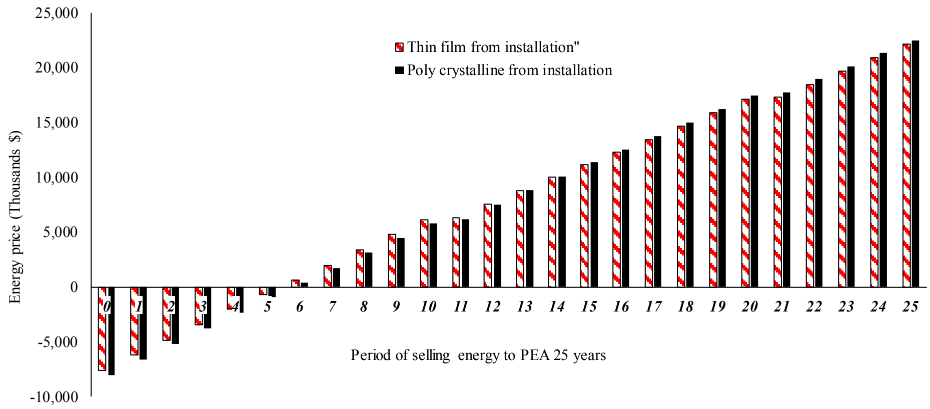

Fig. 6. The cash flow of the thin-film and polycrystalline PV power plant using NPV calculated by real data installation

Fig. 4 shows the comparison between the actual database and the calculation by PVsyst program simulation using the NPV calculation method. The figure shows that the energy from the program simulation is lower than the base of actual data.

The payback period time in Fig. 4 has been started from the sixth year ext.

Fig. 5 shows the same result, but the difference is that the polycrystalline has the cash flow of the NPV. The NPV calculation of the PVsyst program simulation is more than the actual database of the polycrystalline PV installation. The payback period time is shown in Fig. 5, which has started from the sixth year are same that.

Fig. 6 shows the cash flow comparison of thin-film PV power plant and polycrystalline PV power plant using NPV calculation following Equation (10). For cash flow comparison of the thin-film PV and the polycrystalline PV installation, the result shows that the polycrystalline PV cash flow is higher than the thin-film PV power plant. The payback period time is in the sixth years too.

Fig. 7 shows the PV performance of the thin-film PV power plant and the polycrystalline PV power plant. The thin-film PV power plant performance has begun in the first year at a constant rate of 90% through the 10th year. It decreases with a constant rate of 80% after operating the power plant for 11 years.

TABLE XII
PERFORMANCE PERCENTAGE OF THIN-FILM PV AND POLYCRYSTALLINE PV POWER PLANT

Year	Thin-film	Polycrystalline	year	Thin-film	Polycrystalline
0	100%	100%	13	80%	88.50%
1	90%	97%	14	80%	87.79%
2	90%	96.29%	15	80%	87.08%
3	90%	95.58%	16	80%	86.38%
4	90%	94.88%	17	80%	85.67%
5	90%	94.17%	18	80%	84.96%
6	90%	93.46%	19	80%	84.25%
7	90%	92.75%	20	80%	83.54%
8	90%	92.04%	*21*	80%	82.83%
9	90%	91.33%	22	80%	82.13%
10	90%	90.33%	23	80%	81.42%
11	80%	89.92%	24	80%	80.71%
12	80%	89.21%	25	80%	80.00%

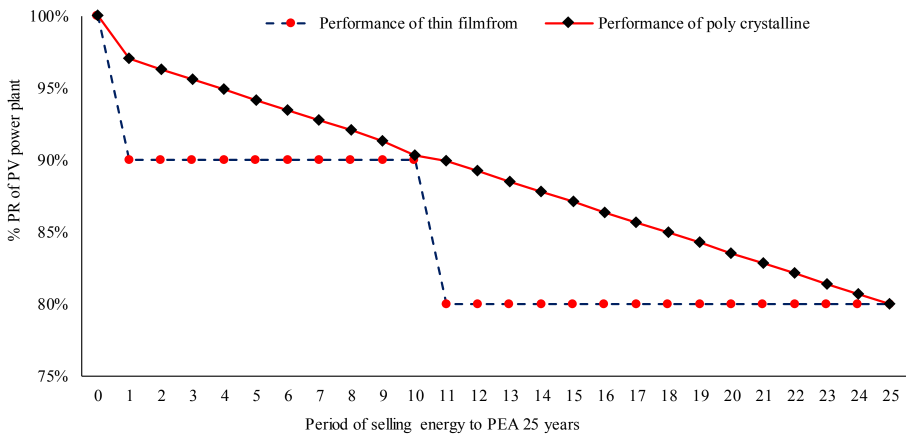

Fig. 7. PV performance of the thin-film PV power plant and the polycrystalline PV power plant

The polycrystalline PV power plant power plants' performance has begun in the first year at 90% from year 1, with linear declines of up to 80% in the 11th year. The thin-film PV power plant's average performance is 85%, and the polycrystalline PV power plant is 89%. The polycrystalline can generate more energy than the thin-film PV power plant 4%.

V. Conclusion

In this paper, two different PV technologies, thin-film and polycrystalline PV, have been chosen for the analysis of performances and economics. The two studied PV power plants have been installed in Prachin Buri province, the central of Thailand. The comparative study of the PV power plant performances has used NPV method in order to determine the performances of the two PV power plants based on PVsyst simulation program and the actual measured data. The thin-film simulation results and the polycrystalline PV panels in 25 years have showed that the thin-film had the energy production of 207,716,850 kWh and the polycrystalline of 211,872,279 kWh. The thin-film PV power plant performances are lower than the polycrystalline PV of 1.962%. The comparative analysis based on real data has shown that the energy production of the thin-film PV power plant had 213,803,194 kWh and the polycrystalline PV has been 210,151,525 kWh. From the results, it is evident that the thin-film PV power plant energy production has been higher than the polycrystalline PV power plant by 1.708%. Therefore, from the study and the comparison of two PV technologies based on the actual data it has been revealed that the thin-film PV technology is suitable for installing a PV power plant in the future.

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