Techno-Economic Analysis of Solar Power Plant Project in Binh Thuan, Vietnam

Phuong Truong Le, Van Dung Nguyen, Phuong Long Le

Abstract - ***This paper aims to determine the important parameters of the solar power plant project located in Binh Thuan such as energy production, the number of solar panels, the number of the inverters and economic analysis. In this study, the solar power plant project with 1MW capacity installed and the location has the solar radiation from 1800kWh/m^2 to 1900kWh/m^2 per year is used to analyze. The PVSyst software was used to determine the energy production, the number of inverters, and the number of the solar panels. Furthermore, an economic model was proposed and used to identify the Net Present Value (NPV) with the discount rate 8% and 10%, Internal Rate of Return (IRR), Levelized Cost of Energy (LCOE) and payback years.***

From the results, the energy produced was around 1631MW per year, and NPV with discount rate 8% were beneficial, and LCOE was 21 cents USD per kWh. In addition, with the price to sell of electricity production to EVN was 9.35 cents, the Payback years was within in the range 9- 12 years.

Keywords: ***PV system; economic analysis; Solar Panel; PV sys.***

I. INTRODUCTION

The photovoltaic (PV) electricity has become one of the most popular immense renewable energy sources. It is friendly, clean, environmentally and secures power source. In recent years, the cost of solar energy equipment is significantly reduced. There are many researchers investigating the cost of fossil fuel and environment problems to compare with the efficient cost of the renewable resource such as Solar Photovoltaic, Hydrogen fuel cell, wind energy, wave energy or hybrid energy. In 2017, Babkir Ali has investigated solar chimney power plant have optimized solar radiation by sloped collector design electricity product and the total initial cost of 100 MW is saving 19.63 million USD [1]. The other study focusses on the economics of renewable energy to analysis potential levelized electricity cost in India. Furthermore, the Solar thermal power plant calculates the electricity with low cost was done by S.Beerbaum [2] Anand Singh has proposed a hydrogen fuel cell and solar photovoltaic hybrid using HOME pro software to calculate improve the performance of a hybrid renewable energy system. This methodology is to excess electricity produce 791.7709 kWh/year after supply all AC primary load. In which 5 KW of solar photovoltage energy production is 8909.431 kWh/years and 3 KW a hydrogen fuel cell is 15661.29 kWh/year. The total cost of energy production is $47437.57, 0.2033415$/kWh respectively, and operating cost is 2088.188 $/years [3]. The cost energy production of modular dispatchable solar power tower plant is predicted by Jonathan E. Rea. The methodology combines simulation and analysis potential cost of electricity between natural gas dand alternative dispatchable renewable. The energy production is the full range of 100 KW electric to 1MWelectric in which $300 k for a 100 kW electric STEAL system [4]. The special optimization method is required for the techno-economic assessment of the energy system. There are a few software programs, including HYBRID2, DER-CAM, HOMER, RETScreen, and HOGA etc. used for the assessment of techno-economic performances of the HES [5]. In this study, the PV Syst software is used for simulation the number of the photovoltaic panel, number inverter, and energy production located in Binh Thuan Vietnam. Furthermore, the economic model is developed to determine the NPC, IRR and payback year.

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II. METHODOLOGY

A. PV syst software

PV syst is a PC software package for the study, sizing, simulation and data analysis of complete PV systems [6]. It has been developed at Group of Energy institute of sciences of the Environment University of Geneva. It including quick estimation of production for an early study of your installation, detailed study, sizing and hourly simulation, results in a complete printable report. The PVSyst software using the one diode model to modeling the commercial PV module. It is written as [7].

$$I = N_P I_{PH} - N_P I_S \left\{ \exp\left[\frac{q}{kT_{PV}A}\left(\frac{V}{N_S} + \frac{IR_S}{N_P} \right) \right] - 1 \right\} - \frac{1}{R_{SH}}\left(\frac{N_P V}{N_S} + IR_S \right) \quad (1)$$

where N_P and N_S are respectively the numbers of solar cells in parallel and in series, I_{PH} is the photocurrent, I_S is the dark saturation current, q is the charge of an electron, k is the Boltzmann constant, T_{PV} is the cell temperature that is assumed to be uniform in the PV module, A is the ideality factor that depends on PV technology, R_{SH} and R_S are the resistance of shunt and series resistors, and exp(.) is the exponential function. The photocurrent naturally depends on the solar irradiance and cell's working temperature is shown the equal below.

$$I_{PH} = \left[I_{SC}^{STC} + \alpha\left(T_{PV} - T_{PV}^{STC} \right) \right] \frac{G}{G^{STC}} \quad (2)$$

where I_{SC}^{STC} is the short-circuit current of PV module at the standard test condition (STC) of $I_{PV}^{STC} = 25^{\circ}C$, and $G^{STC} = 1\,\text{kW/m}^2$, α is the temperature coefficient of short-circuit current. The dark saturation current varies with the cell temperature and is defined as

$$I_S = I_{RS}\left(\frac{T_{PV}}{T_{PV}^{STC}}\right)^3 \exp\left[\frac{qE_{BG}}{kA}\left(\frac{1}{T_{PV}^{STC}} - \frac{1}{T_{PV}}\right)\right] \quad (3)$$

where I_{RS} is the reverse saturation current of the solar cell, E_{BG} is the band-gap energy of the semiconductor used in the cell.

III. ECONOMIC MODEL

The purpose of this study is developed the mathematical financial analysis model and cost investment for solar energy project in Binh Thuan province, Vietnam. Based on the total investment capital (1,052,095 USD/MWp) including construction cost, equipment cost, consultancy cost on elaboration of feasibility study reports, etc. In addition, the result of the financial analysis will compare each other's and evaluate an aspect of the investment cost of the project. The economic model in this research, including Net present value (NPV) model, Internal Rate of Return (IRR) and Levelized Cost Energy (LCOE). Furthermore, the Sensitivity analysis has been done to estimate the reliable output effective directly to the input of the project. It has considered the difference input effectively financial possibility of the project such as project setup and operating the solar energy system. Differences current value of cash out NPV is used in the capital budget to analyze the profitability of investment project or project. Net present value analysis is sensitivity analysis for an identity of future cash flow from investment or the profit of project according to expression:

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 \quad (4)$$

Where *t* is the cash flow time, *n* is the total time project, *r* is the discount rate, C_t is the Net cash flow at time *t*, C_0 is the initial cost of the project.

The internal rate of return on an investment or project is the annualized effective compounded return rate or rate of return that sets the net present value of all cash flows both positive and negative from the investment equal to zero. Equivalently, it is the discount rate at which the net present value of future cash flows is equal to the initial investment, and it is also the discount rate at which the total present value of costs (negative cash flows) equals the total present value of the benefits (positive cash flows) [8]. IRR is presented the maximum interest rate of project that can be sustained. If it must be loaned with high interest rate, IRR, the project has NPV lower than zero. It is unsuccessful.

$$\sum_{i=0}^{n} \frac{B_i}{(1+IRR)^i} = \sum_{i=0}^{n} \frac{C_i}{(1+IRR)^i} \quad (5)$$

Where B_i is the income value benefits per year *i*, C_i is the cost per year *I*, *n* is the time operation of the project.

Levelized Cost of Energy is the total cost for each MWh or kWh including capital cost, operating cost and maintenance (O & M cost), based on by capacity and useful life. This is also referred to as the internal cost of the investor, the LCOE does not account for social losses and environmental impacts. In this study, the LCOE is determined with the cost of energy production of solar plant estimated 25 years, with 5% depression per year within 25 years. It is written as:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}} \quad (6)$$

Where I_t is the investment expenditures in year *t* (including financing), M_t is the operation and maintenance expenditure in year *t*, F_t is the fuel expenditures in year *t*, E_t is the electricity generation in year *t*, *R* is the discount rate, *n* is the life of the system.

IV. TECHNICAL SIMULATION RESULTS

A. Input parameter

In this study the PV syst system is used to simulation and the result, including the number of PV panel, the number of inverter, the energy production. The input parameter for simulation not only solar radiation, but also model of PV module, model of inverter and array global power. The input parameter is shown in Table 1.

TABLE 1. INPUT PARAMETERS

Parameters	***Specification***
PV panel	315W
Inverter	1000kW ac
Power	1MW

In addition, the solar radiation is the main parameter for simulation. In this case, the Meteonom is used to extract the solar radiation in Binh Thuan Vietnam. Meteonorm generates accurate and representative typical years for any place on earth. The database consists of more than 8000 weather stations, five geostationary satellites and a globally calibrated aerosol climatology. On this basis, sophisticated interpolation models, based on more than 30 years of experience, provide results with high accuracy worldwide [9]. The details of solar radiation of Binh Thuan, Vietnam are shown in Table 2.

TABLE 2. SOLAR RADIATION IN BINH THUAN, VIETNAM

	Global/Irrad	**Diffuse**	**Temperature**
	kWh/m^2.mth	kWh/m2.mth	^{0}C
Juanary	163.9	60.4	24.2
February	167.4	56.1	25.1
March	183.9	77.6	27.2
April	172.4	76.9	28.8
May	177.2	80.0	29.1
Jun	170.8	79.3	28.2
July	178.8	73.9	27.9
August	161.4	85.6	27.3
September	149.9	83.6	26.6
October	146.1	77.3	26.8
November	125.4	67.8	25.9
December	135.8	65.2	25.1
Year	**1932.9**	**883.2**	**26.8**

B. Technical results

From the simulation results, the number of photovoltaic modules is 2945 each module is 315W peak and number of inverters is 1 1000kW AC and the energy production is 1631.7 MW/year, more detail is shown in Figure 1 and Table 3.

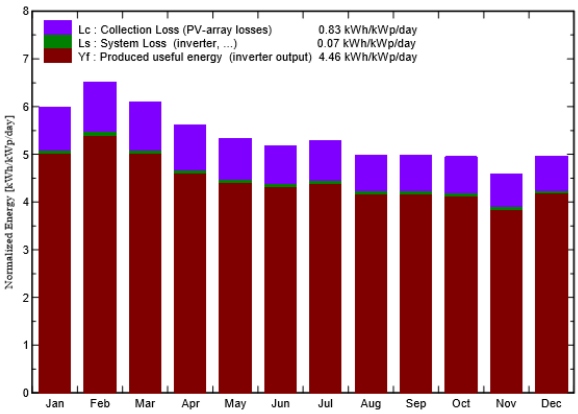


Fig 1. *The normalized energy*

V. FINANCIAL ANALYSIS

In this research to carry out three cases of financial analysis of solar energy in Binh Thuan province, Vietnam. The project financial analysis model has conducted in 25 years.

TABLE 3. THE MAIN RESULTS OF PROJECT IN BINH THUAN

	GlobalHor	T Amb	Global Inc	Global Eff	EArray	E_Grid
	kWh/m^2	^{0}C	kWh/m^2	kWh/m^2	MWh	MWh
Juanary	163.9	24.20	185.8	180.9	158.4	155.9
February	167.4	25.08	182.6	178.1	153.7	151.3
March	183.9	27.24	189.1	183.7	158.2	155.7
April	172.4	28.82	168.6	163.3	140.3	138.1
May	177.2	29.10	165.4	159.7	138.8	136.7
Jun	170.8	28.19	155.7	149.7	131.7	129.7
July	178.8	27.86	164.1	158.0	138.3	136.1
August	161.4	27.27	154.7	149.2	131.5	129.4
September	149.9	26.61	149.7	144.7	127.5	125.5
October	146.1	26.78	153.4	148.5	130.0	128.0
November	125.4	25.91	137.5	133.0	117.6	115.6
December	135.8	25.11	153.7	149.1	131.9	129.8
Year	1932.9	26.86	1960.2	1897.9	1657.7	1631.7

TABLE 4. THE RESULTS OF FINANCIAL ANALYSIS

Analysis	Project 100% equity	Project 70% equity	Project 30% equity
NPV 8%	$160,241,83	$80,344,86	$14,254,17
NPV 10%	-$22,390.88	-$42,890.28	-$62,130.22
IRR(%)	9.52%	8.22%	7.22%
Simple payback period (years)	8.7	10	12.8
Discounted payback period (years) @ 8%	14.66	16.06	20.02
Discounted payback period (years) @ 10%	24	Never	Never
LCOE (Cents/kW)	21		

In the first case, the total investment project has equity ratio 100% the result shows that NPV with 8% discount and IRR 9.52% respectively. The project is feasible because the discount is a chance of the project. In the second case, the total investment project has equity ratio 70% the result shows that 8% NPV and IRR 8.22%. The project can be reached feasible. In the third case, the total investment project has equity ratio 30% the result shows that NPV is positive, but IRR 7.22% is lower than the discount cost of the project. The project can't be reached feasible because it should be invested. Figure 2 shown the flowchart of the cumulative cash flow project during 25 years of the project in Binh Thuan, Vietnam.

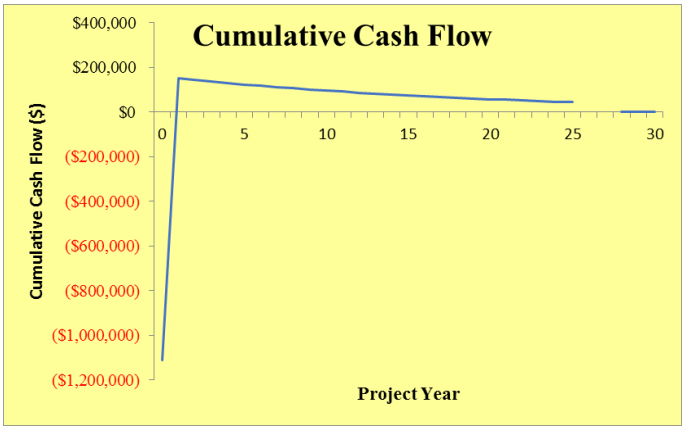


Fig 2. *The Flowchart of cumulative cash flow project*

In the other cases, NPV discount is lower than 10% the result show that it is negative with three cases above. It is not profitable. In this model the policy of taxes follows decision No.11/2017/QĐ TTg of prime minister about encouraging development solar energy project. The time to loan and interest rate performed by world Bank and Viet Nam Bank for the solar energy project.

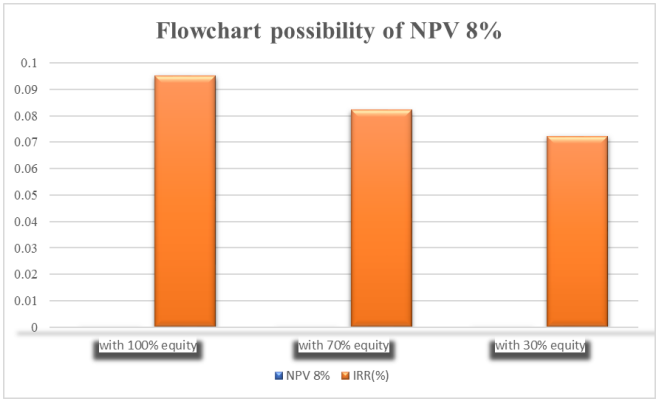


Fig 3. *Flowchart possibility of NPV 8%*

VI. CONCLUSION

The paper addressed a Techno-Economic analysis of the solar power plant project in Binh Thuan, Vietnam. The results of NPV, IRR, LCOE, and the main technical results of 1MW capacity installed were helpful for the renewable system planner. From the result, the energy produced was around 1631MW per year and NPV with discount rate 8%

were beneficial. It was a relatively high impact to project with difference equity ($160, 241, 83; $80, 344, 86; $14, 254, 17). Furthermore, the IRR was within in the range (9.52%, 8.22%, 7.22%), LCOE is 21 cents/MW) and payback years were in the range (8.7; 10; 12.8) was slightly impacted to project. With the conclusions of the paper, the system planner can decide which equity is suitable.

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