Numeric Model Analysis of a Large Scale Solar PV Generations

M. H. Jali, Z.H. Bohari, T.A. Izzuddin, H. Sarkawi, M.F. Sulaima, A. Ibrahim

Abstract - This paper presents a numeric model analysis of a large scale solar photovoltaic (PV) generations projects taking advantage of the Feed-in Tariff (FiT) policies by government. It proposed an optimal plan for low risk and high return investment of one of the most rapidly growth renewable energy technology. In order to achieved that target, several selection criteria has been described such as strategic location, long life time materials, high durability and reliability, less maintenance and affordable raw material price. The objective of this study is to propose an optimal investment plan using structured numeric model analysis based on the case study at the Kuala Lumpur International Airport (KLIA), Malaysia. The PV generation project investment achievement is measured using several parameters such as cash flow, Return of Investment (ROI), payback period, Net Present Value (NPV), Internal Rate of Return (IRR) and cost break-even analysis. Based on the analysis, it can be convinced that solar PV generation FiT project is desired to undertake where it provides good long-term investment.

Keyword – Photovoltaic (PV), Feed-in tariff (FiT), renewable energy, numeric model analysis, investment.

I. INTRODUCTION

Statistic shown that between year 2004 to 2009, the total global grid-connected solar PV capacity has increased to a total of about 21 GW annually [1]. The national renewable energy (RE) policy is introduced to ensure the renewable energy resources utilization could provide reserve to the national electric supply. A feed-in tariff (FiT) is a kind of mechanism designed to encourage the investment in renewable energy sectors. It offers long-term purchasing contracts to anyone who produces renewable energy based on the cost of energy generation commonly due to different technology. For instance wind power has lower per-kWh price than solar PV because solar has higher generation cost, typically based on the cost of generation of each different technology [2]. FiT also enable users to sell excess power to the power grid thus encourage more people to adopt renewable energy sources.

One reason for Malaysia's embrace of progressive renewable energy policies may lie in its role as a destination for solar manufacturing, at a scale particularly impressive for its small size and population of only 28.2 million. Global industry leader First Solar has four plants in Malaysia with a total annual module capacity of 720MW while Sun Power is also constructing manufacturing facilities in the nation. There are several potential impacts of national RE policy towards Malaysia economy. First of all government will save an external cost to mitigate CO_2 emissions that cost RM50 per tonnes. Besides that renewable energy business revenue can generate income tax up to 1.75billion to the government. It also can create more than 52000 jobs to construct, operate and maintain RE power plants [3][4]. This study proposed an optimal strategic plan for low risk and high return investment PV solar power generation to grab the benefit of the Feed-in Tariff (FiT) policies by government. It is based on case study conducted at Kuala Lumpur International Airport (KLIA), Malaysia. Astructured numeric model analysis is thoroughly explained in this study.It also describe briefly the selection criteria and conceptual design to achieve a good long term investment.

II. PROJECT SELECTION CRITERIA

There are a few selection criteriato ensure a low-investment high-return project. These criteria need to be considered thoroughly to establish a well-managed and profitable large scale photovoltaic project. The criteria of this PV power generation project are described as follow [5]:-

i) Long Life Time

Solar panels are usually robust .The current project requires the solar panel to be robust up to 21 years. Our project uses a solar panel which can last up to 25 years. This will decrease the maintenance cost due to the infrequent part replacement.

ii) High Durability and Reliability

Solar panels are very durable and reliable. They are expected to be able to withstand Malaysia's hot and damp climate without sacrificing its output efficiency.

iii) Less Maintenance

Most of the available solar panels are usually require less maintenance. The only maintenance required is cleaning of the panel surface because solar panels are prone to collect dust on its surface, and this can lead to low energy output. However cleaning the panel's surface requires small number of workers and it is importance in order to keep the maintenance cost at the minimum.

iv) Affordable/Minimum Price

When compared to other renewable energy generation method, energy generation using the photovoltaic (PV) system is typically the cheapest.

Revised Version Manuscript Received on October 24, 2015.

M. H. Jali, Department of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

Z.H. Bohari, Department of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

T.A. Izzuddin, Department of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

H. Sarkawi, Department of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

M.F. Sulaima, Department of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

A. Ibrahim, Department of Electrical Engineering, Politeknik Melaka, Plaza Pandan Malim, 75250 MALIM, Melaka, Malaysia.

Solar panels/PV arrays installations are very cheap due to the low priced solar-panels and simplicity of mounting them. The low operation and maintenance cost also contributes to the affordability of this project.

v) Strategic Location

The chosen area for our project is situated at KLIA, Malaysia. This area is a geographically strategic area to install the solar panel array due to its flat and wide plateau and far from hills and mountains. This in turns enable the solar panel to receive sunlight from dusk till dawn.

vi) High ROI/Shortest Payback Period

The low installation, operation and maintenance cost of this project will guarantee the high return-of-investment (ROI) and the short payback period. Based on the calculated projection, this project is expected to give a 12.69% ROI and a payback period of 10.34 years.

III. CONCEPTUAL DESIGN

A. Location

Briefly, the propose location of the Photovoltaic (PV) Solar Energy Generator for up to 1MW and sell the energy to Tenaga Nasional Berhad (TNB) as our client using Feed-in Tariff (FiT) that has been introduced by government. Malaysian Airports Holdings Berhad(MAHB) is one of the Government Link Company(GLC) that provides airport technical services related to management, operation and maintenance of about 21 domestic airports and several international airports such as the Delhi International Airport , SabihaGokcen International Airport and the New Hyderabad International Airport. Our location chosen for this case study is Kuala Lumpur International Airport (KLIA), Malaysia as shown in Fig.1.

Fig.1 : KLIA airport as one of the airport managed by MAHB

The PV/Solar-panels array is planning to be install at the rooftop of the KLIA (2° 44′ 44″ N, 101° 42′ 35″ E), Malaysia. The geographical characteristic of this area ensures the panel’s array to receive unblock sunlight on a clear day. For this project, the plan is to install a number of PV arrays at the rooftop of the main terminal building and the satellite terminal building of KLIA, as depicted in Fig.2.

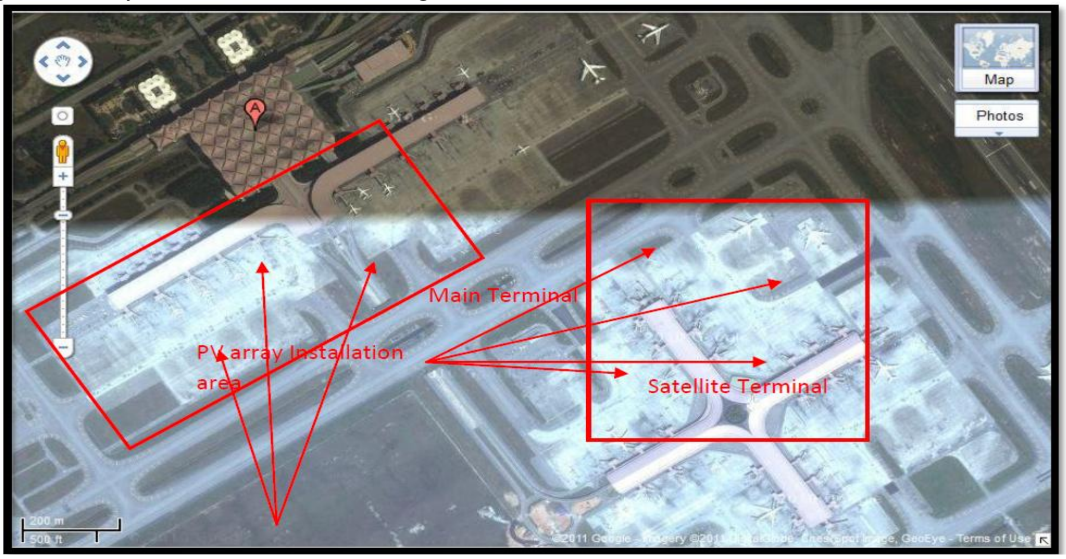

Fig. 2: Satellite view of KLIA and the planned installation area

B. System Designs

This wide rooftop area enables installation of many wide solar PV panels array. These solar PV panels' arrays are then connected to inverters which convert the DC power generated by the PV panels into AC power. This AC power is then fed into the TNB power grid. This type of system is called "On-Grid system" as shown in Fig.3. An on-grid solar PV system essentially uses the existing commercial utility system for power and does not store electrical power. A grid connected solar PV system is shown in Figure below. A solar PV system is installed into the electrical system of a home or facility for use during daylight hours or when grid power is down. It also works the other way, when the solar PV system does not produce enough electricity, it can draw power from the grid. When using the solar PV system, if more electricity is produced than what is needed the excess can be put back on the grid. This is done automatically through a device that monitors the available power and switches between solar and grid power. A second utility meter can be added to keep track of how much electricity has been put back on the grid. Advantages of grid interconnection include having uninterrupted access to standard utility power and avoiding the cost of a battery back-up system.

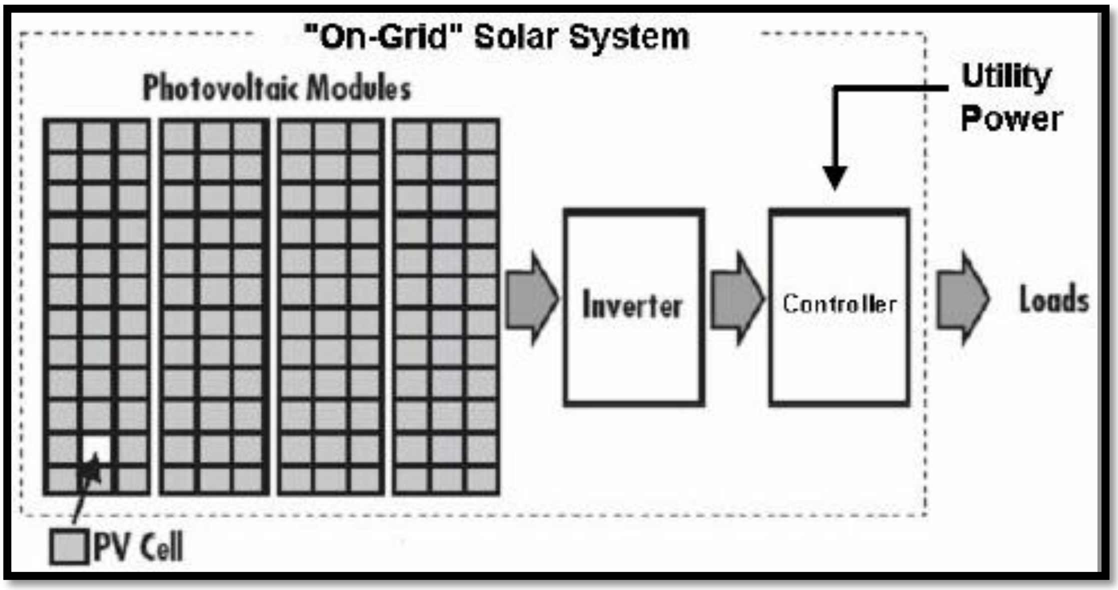

Fig. 3: On-grid power system

In grid-connected application, the DC power from solar cells runs through an inverter and feeds back into the distribution system. Grid-connected systems have demonstrated an advantage in natural disasters by providing emergency power capabilities when utility power was interrupted. Although PV power is generally more expensive than utility-provided power, the use of grid connected systems is increasing. The cost of photovoltaic power (when storage is not required) is two to four times that of conventionally produced power. It is difficult to define this relationship precisely due to wide variations in the cost of producing and distributing conventional electrical power and other variables.

IV. PROJECT ESTIMATION

A. Project Estimation

For the solar PV project, it's expected to use solar PV system with capacity of 1000kW. Generally, the project estimation can be divided into System cost, Other cost, Financial source, Power Generation and expected Total revenues as shown in TABLE 1.

B. Income versus Expenditure Prediction (Cash flow)

By using data from project estimation in TABLE 1, with assumption of loan repayment divided equally over 10 years, the project cash flow is expected as shown in TABLE 2. From the table, it can be seen that the project is expected to generate net profits of approximately RM 30 million by the end of year 2032 (21 years).

TABLE 1: Solar PV project estimation

System capacity (kW)	1,000
System cost (RM)	
PV panel (300W = RM 2,064.60)	6,882,000
Inverter (800W = RM 666.45)	833,062.50
Other cost (RM)	
Labour + Installation materials (bracket, wire, etc.)	250,000
TNB interconnection	54,000
ST license fee (1kW = RM1.50)	1,500
Insurance (2% of system cost)	154,301.25
Operation and maintanence (RM 18,000 x 21 years)	378,000
Total initial investment (RM)	8,174,863.75
Total cost of ownership for 21 years (RM)	8,552,863.75
Financial source (RM)	
Equity (10%)	817,486.38
Bank loan (90%)*	7,357,377.38
Power generation (hour)	
Bright sun light per day	5
Bright sun light (Assume 305 days) per year	1,525
PV panel efficiency for 1-10 years (%)	90
PV panel efficiency for 11-21 years (%)	80
Total hour yield for 21 years	27,145
FiT rates per kWh for 2011 (RM)	1.69
Energy yield for 21 years (kWh)	27,145,000
Total revenues for 21 years (RM)	**45,875,050**

Remarks:
* Loan rates = 10% (annual) and Loan tenure = 10 years

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

TABLE 2 : Income versus expenditure prediction of the project

Description	Year									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Brought forward	-817,486.38	12,563.15	842,612.68	1,672,662.20	2,502,711.73	3,332,761.25	4,162,810.78	4,992,860.30	5,822,909.83	6,652,959.35
Income										
Energy sales (kWh)	1,372,500	1,372,500	1,372,500	1,372,500	1,372,500	1,372,500	1,372,500	1,372,500	1,372,500	1,372,500
1kWh energy price (RM)	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
Total income (RM)	2,319,525	2,319,525	2,319,525	2,319,525	2,319,525	2,319,525	2,319,525	2,319,525	2,319,525	2,319,525
Total Available	1,502,038.63	2,332,088.15	3,162,137.68	3,992,187.20	4,822,236.73	5,652,286.25	6,482,335.78	7,312,385.30	8,142,434.83	8,972,484.35
Expenditure										
Operation and maintenance cost	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Bank loan repayment	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48	1,471,475.48
Total expenditure (RM)	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48	1,489,475.48
Closing Balance (RM)	12,563.15	842,612.68	1,672,662.20	2,502,711.73	3,332,761.25	4,162,810.78	4,992,860.30	5,822,909.83	6,652,959.35	7,483,008.88

Description	Year										
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Brought forward	7,483,008.88	9,526,808.88	11,570,608.88	13,614,408.88	15,658,208.88	17,702,008.88	19,745,808.88	21,789,608.88	23,833,408.88	25,877,208.88	27,921,008.88
Income											
Energy sales (kWh)	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000	1,220,000
1kWh energy price (RM)	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
Total income (RM)	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800	2,061,800
Total Available	9,544,808.88	11,588,608.88	13,632,408.88	15,676,208.88	17,720,008.88	19,763,808.88	21,807,608.88	23,851,408.88	25,895,208.88	27,939,008.88	29,982,808.88
Expenditure											
Operation and maintenance cost	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Bank loan repayment	-	-	-	-	-	-	-	-	-	-	-
Total expenditure (RM)	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Closing Balance (RM)	9,526,808.88	11,570,608.88	13,614,408.88	15,658,208.88	17,702,008.88	19,745,808.88	21,789,608.88	23,833,408.88	25,877,208.88	27,921,008.88	29,964,808.88

C. Payback Period and Return on Investment (ROI)

To determine when the project will return the investment in term of time (Payback period) and average yearly return (ROI), a cash flow and net gain is tabulated with its corresponding year as shown in TABLE 3.As shown in the TABLE 3, the project is expected to return the investment in 10.34 years with the average return of 12.69% yearly.

TABLE 3: Payback Period and ROI of the project

Years	Cash-Flow (RM)	Net Gain (RM)
0	-8,174,863.75	-
1	12,563.15	12,563.15
2	830,049.53	842,612.68
3	830,049.53	1,672,662.20
4	830,049.53	2,502,711.73
5	830,049.53	3,332,761.25
6	830,049.53	4,162,810.78
7	830,049.53	4,992,860.30
8	830,049.53	5,822,909.83
9	830,049.53	6,652,959.35
10	830,049.53	7,483,008.88
11	2,043,800	9,526,808.88
12	2,043,800	11,570,608.88
13	2,043,800	13,614,408.88
14	2,043,800	15,658,208.88
15	2,043,800	17,702,008.88

Years	Cash-Flow (RM)	Net Gain (RM)
16	2,043,800	19,745,808.88
17	2,043,800	21,789,608.88
18	2,043,800	23,833,408.88
19	2,043,800	25,877,208.88
20	2,043,800	27,921,008.88
21	2,043,800	29,964,808.88
Payback period (year) [1]	10.34	
Total gains (RM) [2]	29,964,808.88	
Total profits (RM) [3]	21,789,945.13	
Ave. annual profits (RM) [4]	1,037,616.43	
ROI (%) [5]	12.69	

Remarks:

[1] Payback period = 3 + [(8,174,863.75 - 7,483,008.88) / 2,043,800]
= 10.34 years

[2] Total gains = Total Net Gain
= RM 29,964,088.88

[3] Total profits = Total gains - Original investment
= 29,964,088.88 - 8,174,863.75
= RM 21,789,945.13

[4] Average annual profits = Total profits / Total years
= 21,789,945.13 / 21
= RM 1,037,616.43

[5] Return on invesment (ROI) = (Average annual profits / Initial investment) x 100%
= (1,037,616.43 / 8,174,863.75) x 100%
= 12.69%

D. Net Present Value (NPV)

For the project to be confirmed of generating sufficient profits in future, it is important to consider *time value money* in the cost calculation. This can be done by adding discounted cash-flow factor. The result is Net Present Value (NPV) where it can predict the future value of money into present time. A good project must have a positive NPV. For the solar project, the NPV is shown in TABLE 4. It can be seen that the value of NPV is positive with the interest rate assumption of 10%.

TABLE 4: NPV calculation of the project

Years	Discount Factor (i = 10%)	Cash-Flow (RM)	Present Value (RM)	Net Present Value (RM)
0	1	-8,174,863.75	-8,174,863.75	-
1	0.9091	12,563.15	11,421.05	11,421.05
2	0.8264	830,049.53	685,991.34	697,412.39
3	0.7513	830,049.53	623,628.49	1,321,040.88
4	0.6830	830,049.53	566,934.99	1,887,975.88
5	0.6209	830,049.53	515,395.45	2,403,371.33
6	0.5645	830,049.53	468,541.32	2,871,912.64
7	0.5132	830,049.53	425,946.65	3,297,859.30
8	0.4665	830,049.53	387,224.23	3,685,083.52
9	0.4241	830,049.53	352,022.03	4,037,105.55
10	0.3855	830,049.53	320,020.02	4,357,125.58
11	0.3505	2,043,800	716,339.43	5,073,465.01
12	0.3186	2,043,800	651,217.67	5,724,682.67
13	0.2897	2,043,800	592,016.06	6,316,698.73
14	0.2633	2,043,800	538,196.42	6,854,895.15
15	0.2394	2,043,800	489,269.47	7,344,164.62
16	0.2176	2,043,800	444,790.43	7,788,955.05
17	0.1978	2,043,800	404,354.93	8,193,309.98
18	0.1799	2,043,800	367,595.39	8,560,905.38
19	0.1635	2,043,800	334,177.63	8,895,083.01
20	0.1486	2,043,800	303,797.85	9,198,880.86
21	0.1351	2,043,800	276,179.86	9,475,060.72
Total PV			9,475,060.72	
Total NPV			**1,300,196.97**	

E. Internal Rate of Return (IRR)

Internal Rate of Return (IRR) provides a good estimation to measure and compare the profitability of investment. The higher the IRR, the more desirable it is to undertake the project. For the solar project, the IRR calculation and point in a graph can be seen in TABLE 5 and Fig.4 respectively. The IRR is calculated by interpolating interest rate of 11% and 12% where the NPV changed from positive to negative value.From the table or in the graph, it is shown that the project's IRR is 11.59%.

TABLE 5: NPV of different interest rate

INTEREST RATE (%)	Net Present Value (NPV) (RM)
8	3,396,182.22
10	1,300,196.97
11	444,432.72
12	-307,500.97
13	-970,260.59
15	-2,075,844.13
IRR	**11.59%**

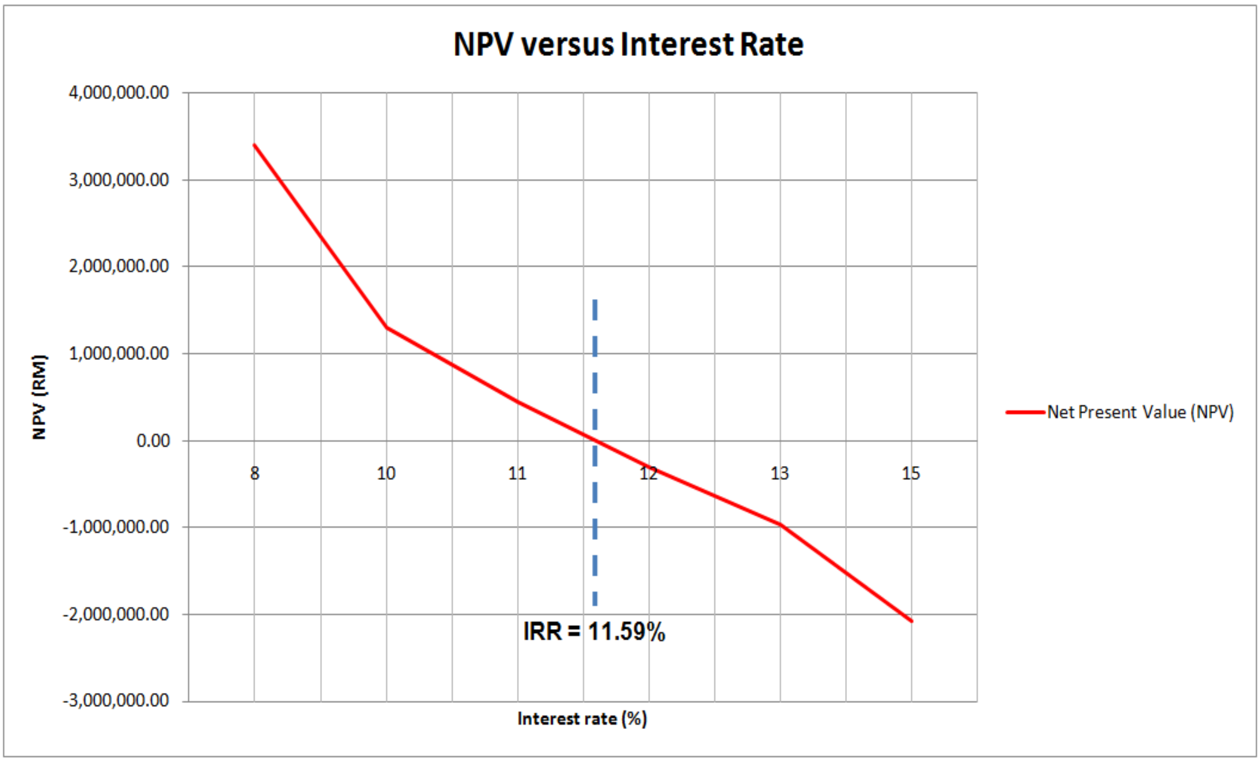

Fig.4: IRR estimation of the project

F. Cost Break-Even Analysis

The cost break-even analysis can show the minimum units need to be sold in order to start profits. The break-even point can be calculated by dividing the fixed costs with contribution per unit. For the solar project, the break-even point can be seen in Fig.5. As can be seen, the break-even point for the solar project is at 14.341MWh of energy sold.

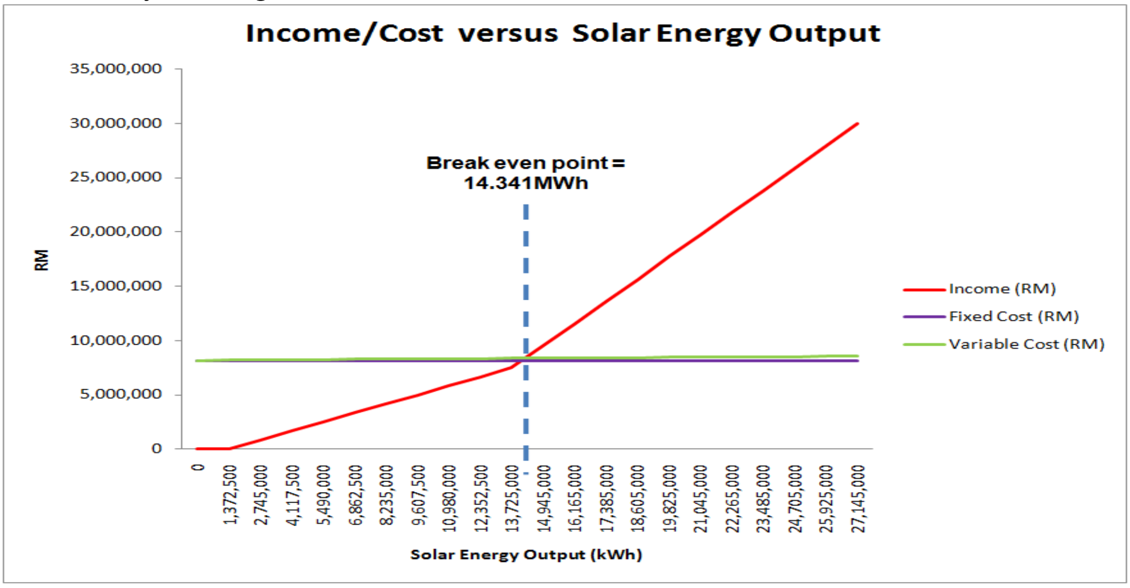

Fig.5: Break-even estimation of the project

V. DISCUSSIONS AND CONCLUSION

In general, the solar PV project numeric models can be summarized as shown in TABLE 6. The project will return the investment during approximately half project life cycle (10.4 years) with the annual return of approximately 12.7%, which is depicted by the payback period (PBP) and return on investment (ROI), respectively. On the other hand, the IRR is considerably high which resulting a considerable margin of allowance for the depreciation rate of time money value. With consideration of bank loan interest rate at 10% per annum, the project is expected to generate total net profits of approximately RM 30 million by end of 21 years with an initial investment of approximately RM 8.2 million.

TABLE 6: Project numeric models summary

Payback Period (PBP)	10.34 years
Return On Investment (ROI)	12.69%
Internal Rate of Return (IRR)	11.59%
Initial Investment	RM 8,174,863.75
Total Net Profits by End of 2032 (21 years)	RM 29,964,808.88

Overall, by looking at the numeric model analysis, it can be convinced that solar PV rooftop FiT project is desired to undertake where it provides good long-term investment. The payback period is considerably short while the ROI and IRR are reasonably high. Besides that the yearly closing balanced cash flow are always positive even though on the first year of the project. Last but not least, other than generates profits, this project also provides benefits to the society by help reducing the CO_2 emission for greener and healthier living.

ACKNOWLEDGMENT

The authors would like to thanks University Technical Malaysia Melaka (UTEM) and Ministry of Education, Malaysia for the financial supports given through Research Grant (Code No. RAGS/1/2014/TK06/FKE/B00052)

REFERENCES

1. Muneer, W. ; Bhattacharya, K. ; Canizares, C.A. ,"Large-Scale Solar PV Investment Models, Tools, and Analysis: The Ontario Case",IEEETransactions on Power Systems , Vol. 26 , Issue: 4 2011 , Pp. 2547 - 2555, 2011.
2. Radhika Perrot &AselDoranova, "The Dynamics of Renewable Energy Transforming in Developing Countries",Technological Systems of Innovation in Renewable Energy Technology of Developing Countries, Retrieved from http://www.ukerc.ac.uk /support/tiki-download_file.php?fileId=1959&display.
3. M.H.Jali, H.Sarkawi, T.A.Izzuddin, M.F.Sulaima, M.N.M.Nasir,"Solar PV Project Implementation Feasibility Study based on Feed-in Tariff in Malaysia", International Journal of Applied Engineering Research, Vol. 9 (21), pp 9629 - 9638, 2014.
4. Ir.AhmadHadriHaris, "Renewable Energy Bill and SEDA Bill", retried from http://www.mbipv.net.my/dload/presentation-RE%20Bill-16Mar2011.pdf.
5. GPEKS Clean Energy Developments and Services, "Feasibility Analysis for 520kW Solar Photovoltaic Project at Consejo Belize", Retrieved from http://solartechnologies.ru/files/520kwSolar.pdf.