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The Enhancement of Solar Power System Implementation in LAS Building

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ABSTRACT

This paper presents the techno economic analyses on the cost of upgrading the abandoned photovoltaic (PV) system that installed at the building of Legal Affairs Section (LAS), Putrajaya, Malaysia. System Advisor Model (SAM) software has been used to analyze the techno economic analyses of the proposed configuration of the new building integrated photovoltaic (BIPV) system. In this study, 4 study cases have been executed that considering different units of inverter and battery installations in the existing BIPV system. From the study, it was found that by maintaining the existing PV inverter system, but by adding one unit of battery may presents best option for this LAS building, where the operational and maintenance costs can be minimized better. Hence, it is projected that the intention to reach the target of making Putrajaya as a Green City on 2025 could be realized in the near future.

Key words: solar, solar inverter, grid connected building, system advisor model (SAM).

1. INTRODUCTION

The renewable energy is the energy was collected from renewable resources such as wind, sunlight, rain, waves, geothermal and etc. The renewable energy implementation initiative has paved the ways to achieve sustainable development goals, especially in the realization of low carbon economies. In Malaysia, the installation of PV panels in residential, industry and commercials buildings has been imposed since 2001. This is due to the 8th Malaysia Plan (2001-2005) in which Government was introduced Malaysia Building Integrated Photovoltaic Technology Application (MBIPV) plan to encourage the application of renewable energy source in Malaysia. The goal of these initiatives is to reduce the dependence on fossil fuels and contribute towards reducing the impact of climate change [1][2]. As an alternative that has been promoted by the Ministry of Energy, Green Technology and Water (KeTTHA), PV panels have been installed at government buildings in Putrajaya [4]. One of the building was building of Section of Legal Affairs (LAS), as shown in Figure 1. The LAS building now has been built more than 10 years ago and has total gross floor area (GFA) of around 56527.82 m², net floor area (NFA) of 30595.9 m² and air conditioned area (ACA) of 41360.91 m² with capacity of 520 person. The building consists of 11th floor including a ground floor and three basement floors for parking. The building is divided into two sections; North and South Wings.

Figure 1: Building of Legal Affairs Section (LAS), Putrajaya, Malaysia.

Based on the electricity bills that have been charged by Tenaga Nasional Berhad (TNB) Malaysia in 2013, this building has annual electricity consumption at around 3,878,205.607 kWh/year, which is costing of RM 1,415,545.05/year for its electricity bills. While, in year 2014, annual electricity consumption is increasing to be 4,054,963.714 kWh/year and provides bill at RM1,480,061.76/year [5]. The electrical energy consumption has been increasing due to the recruitment of staffs and procurements on electrical equipment in the building. Hence, KeTTHA decided to install PV panels at the LAS building with the aim to reduce electricity consumption and pollution level, as well as to develop Putrajaya as a pioneer in green technology township as a platform for the development of others township and to ensure the Putrajaya Green City 2025 could be realized in the future [1][4]. It is therefore, on 2nd June 2015, the PV panels have been installed at this lAS building by Pekat Solar Sdn Bhd as a PV Service Provider. KeTTHA acts as the owner, while Sustainable Energy Development Authority (SEDA) as an execution agency.

Figure 2 depicts the installed PV panels at the LAS rooftop. 186 PV panels have been installed on the roof top of the building with 48.36kWp capacity to cover up 30% of the lighting system at level 6. This project has been managed and maintained by Pekat Solar Sdn Bhd from 3rd June 2015 until 2nd June 2016 [6]. However, after operating for some years, the performance of the PV panels was degrading. Since the maintenance cost for PV system is quite high and no budget was allocated for the maintenance work, this PV system is mostly abandoned now. The project is discontinued after the warranty period from the installation contractor end.

Figure 2: The installed PV Panels at LAS building

Table 1 shows the renewable energy generation planned outcome from 2011 until 2050 that has been quoted from National Renewable Energy Policy [4]. This is an example of the initiatives that has been executed by Malaysian Government in reducing greenhouse gas emission.

Table 1: Renewable Energy Policy Planned Outcome

Year Ending	Cum. Total RE (MW)	Share of RE Capacity	Annual RE Generation (GWh)	RE Mix	Annual CO_2 Avoidance (Tonnes)
2011	217	1%	1,228	1%	773,325
2015	975	6%	5,374	5%	3,385,406
2020	2,065	10%	11,227	9%	7,073,199
2030	3,484	13%	16,512	10%	10,402,484
2050	11,544	34%	25,579	13%	16,114,871

The National Renewable Energy Policy and Action Plan (2009) has been implemented by the KeTTHA. While, SEDA was formed under the Sustainable Energy Development Board Act 2011 to control and manage the implementation of Feed-In Tariff (FiT) mechanism mandated under the Renewable Energy Act 2011 (Act 725). Malaysia FiT systems oblige the distributions license holder such as TNB or WIRAZONE to purchase the electricity from renewable resources that produced by Feed-In Approval Holders (FiAHs). By guaranteed access to the grid and setting favorable price for renewable energy, the feed-in tariff mechanism would ensure that renewable energy becomes a viable and strong investment at long-term for the companies, industries and also for individuals [3][4].

It is therefore, through this study, the installed BIPV system can be re-improvised the existing PV system at LAS building and hence this system can be operated again to supply some of the lighting loads in the building in more efficient way.

2. SOLAR PV SYSTEM AT LAS BUILDING

The type of PV arrays that has been installed on the LAS's rooftop is polycrystalline solar cell with the total power capacity of 48.36kWp, from 186 panels, as shown in Figure 3. The technical data for this PV panel is given in Table 2.

Figure 3: Existing Solar PV Panels at LAS building

Table 2: Technical data for the solar PV panel

Model Type	Peak Power (Pmax)	Number Of Cells	Dimensions	Maximum Power Voltage (Vmp)	Maximum power Current (Imp)	Maximum System Voltage	Normal Operating Cell Temperature
CSUN 260-60P	260W	60 CELL	1640x990x35	30.3V	8.58A	DC 1000V	-40 to +85°C

Inverter used in this LAS building is as shown in Figure 4, functioning to convert the DC supply from the PV panels to an AC supply to the load. The brand of the existing inverter model that used on site is Delta Solivia 11TR as shown in Figure 4, with technical data as shown in Table 3.

Figure 4: The existing inverter

Table 3: Technical data for inverter

DC Input Side (PV-Generator)			AC output Side (Grid Connection)				
Operating Voltage Range (V)	Max. recommended PV power	Max efficiency	Max Power	Max Current	Max. input Voltage	Nominal Current	Voltage range
400V-900V	13300 WP	96.50%	11000	20A	1000	16A	3x400V

Electrical energy that generated by PV system is used for the lighting purpose at level 6, with floor area of 201.6 m². Total number of lightings is 418, where 158 was light up by the mains meanwhile the remains 260 are supplied by the installed PV system. Type fitting for each light is PLL and energy usage is 36W each. Figure 5 is the area that was supplied by the PV system.

Figure 5: Office area that used energy from PV system

In Figure 6, the drawing of the electrical wiring for the existing PV system on site is shown, where it has 4 inverters, 4 DC junction boxes, a solar log, a kWh meter and a AC junction box. While electrical circuit drawing from the solar array to inverter is shown in Figure 7 and the electrical circuit drawing from the inverter to the load distribution board is shown in Figure 8.

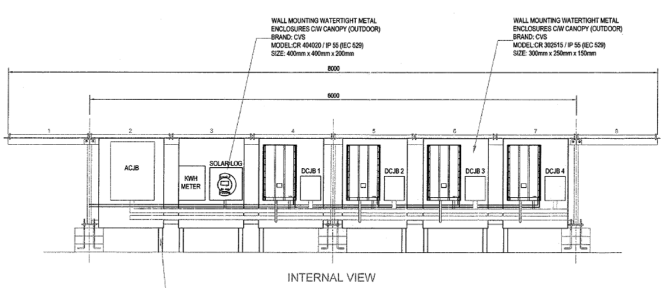

Figure 6: DC and AC junction box, meter, solar log and inverter

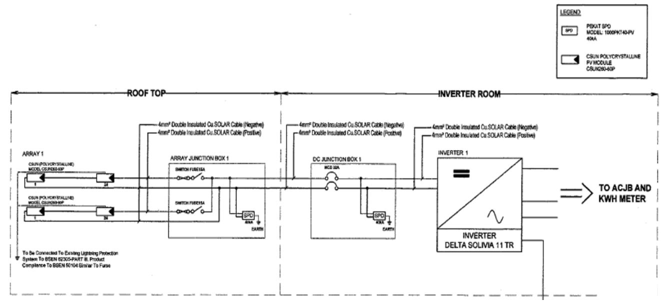

Figure 7: Circuit diagram from solar array to inverter

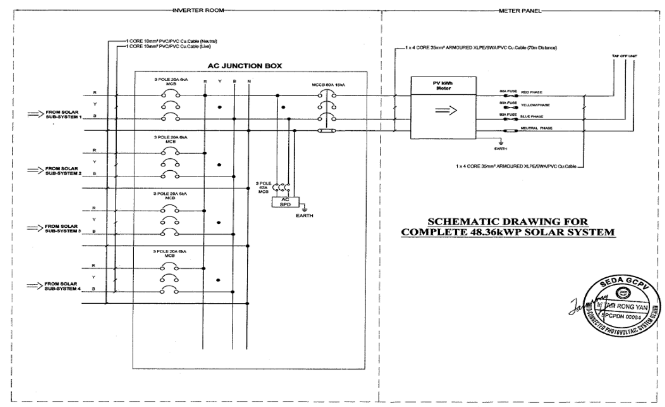

Figure 8: Circuit drawing from inverter to load distribution board

3. SYSTEM ADVISORY MODEL (SAM) SIMULATION

The System Advisor Model (SAM) is a performance and financial model designed software to facilitate decision making in the renewable energy industry. SAM makes the performance predictions and cost of energy estimation for grid-connected power projects based on installation and operating costs, where system design parameters specify by user as inputs to the model. SAM is an electric power generation model that assumes the renewable energy system can be delivers power either to a power grid or to a grid-connected building or facility to meet electric load. It does not to thermal energy systems model that meet a thermal load process. The performance and cost analysis as well as renewable energy projects by using SAM software are derived from computer models developed at NREL, Sandia National Laboratory, University of Wisconsin, and other organizations. SAM requires weather data files that describe the renewable energy resource and weather conditions at the project location. SAM also includes several databases of performance and coefficients for system components such as photovoltaic modules and inverters, wind turbines, parabolic trough receivers and collectors or bio-power combustion systems. The flowchart for the usability of the SAM system's is shown in Figure 9.

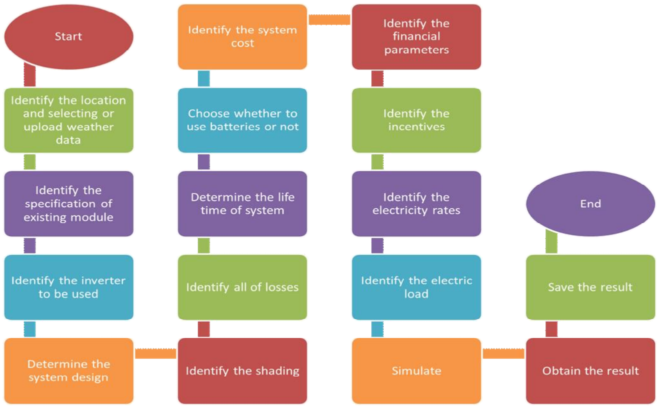

Figure 9: System Advisor Model (SAM) flow chart

3.1 Weather at Selecting Location

Weather data plays an important role in identifying solar irradiance at the specific locations because solar irradiance will affect the electrical energy that will be generated by the PV system. The location of the building should be identified first by using Google Map application as shown in Figure 10.

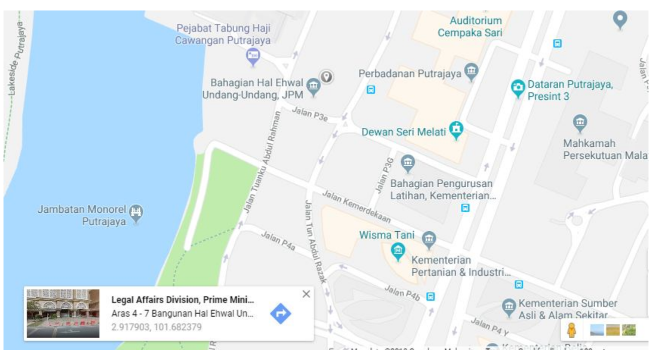

Figure 10: LAS building location by Google Map

The purpose of detecting the selected location is to enable the correct weather data will be uploaded and hence assuring the results of simulation will be accurate. Once the location of the building is identified, the data will be downloading via web http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#TMY as shown in Figure 11. From this website, the desired location can be obtained by using address, latitude and longitude or by using cursor. The location selected from the PGIS website is 2.918.101.682 while the location on the Google Map is 2.917903.101.682379. Once the location is verified correctly, the required data can be downloaded in the "csv" file format.

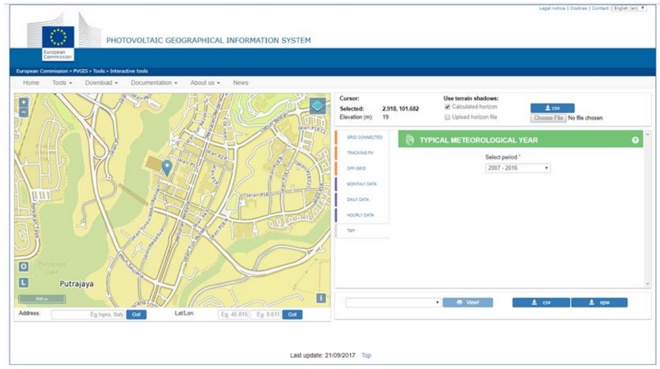

Figure 11: Photovoltaic Geographical Information System website

Once the weather data is obtained, the data will be stored in the operating system's application data folder, which is a hidden folder used by the applications on computer and the relevant data required is as Figure 12. SAM's performance models will use the data from the weather file to represent the ambient weather conditions and renewable resource that affect the PV system's performance.

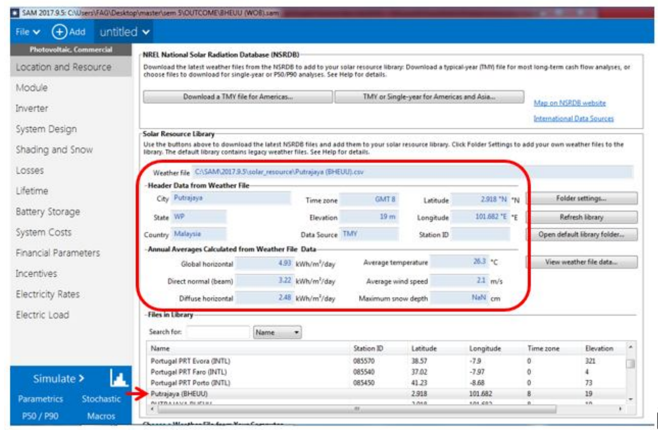

Figure 12: Location and resource data for LAS building

3.2 PV Panel and Inverter Details in SAM

After data for location and resource is obtained, the selection of PV module should be implemented. Before selecting the appropriate type of the desired PV module, the module's performance model should be selected first. Five module performance models existing in the SAM system; Simple Efficiency Module Model, CEC Performance Model with Module Database, CEC Performance Model with User Entered Specifications, Sandia PV Array Performance Model with Module Database and IEC61853 Single Diode Model. In this study, the CEC Performance Model with Module Database (CEC-PMMD) has been selected. The function of CEC-PMMD is to calculate conversion efficiency of module solar energy to electricity from data stored in a library of module parameters for thousands of commercially available modules. After specifying module performance model, PV module CSUN260-60P is selected in this study is the same with the existing of PV module on site. In addition, the NOCT method parameter is also defined as building integrated and two-story building height or higher. However, for study in future, different type of PV panels can be considered. Details on this is available in [7][8].

The requirements of the inverter performance model can be selected either the inverter from the list or insert the inverter parameter from the manufacturer's data sheet using the weighted efficiency or efficiency part of the load part. Therefore, the parameter from the manufacturer's data sheet is used because the detail of the existing inverter is not available in the SAM list. The system design is to determine the variable for the size of the PV system and choose the tracking option. The data needed in system design is the number of modules per string, string in parallel and number of inverters. For system sizing, specify module and inverter are chosen to ensure module per string, string in parallel and number of inverters are the same as on site. The module of each string on site are 2 strings has 24 modules, 6 strings has 23 modules and 8 string in parallel, but the module per string on the SAM system can only set the input data either 23 or 24 only. Therefore, for this option, the module per string selected as 24 modules where 8 strings are connected in parallel, with 4 inverters, as well as tracking and orientation are fixed, just same as on the site.

Shading and snow losses are reduction of incident irradiance caused by shadows or snow on photovoltaic modules in the array. Therefore, shading and snow losses are not considered into account because of the arrangement of PV arrays and observation on site does not involve shading or snow. For other losses such as irradiance losses, DC losses and AC losses shall be considered. The lifetime inputs allow year-to-year decline to be modeled in the system output, for example, for aging of equipment over time. Therefore, the rate of degradation in this system is considered as 0.5% annually. The degradation rate of 0.5% would mean that the annual output of the system's in each year decreases by 0.5% from the previous year's output [9]. Information on installing and operating system costs is also provided in SAM, where is, the costs of system divide into three categories, direct capital costs, indirect capital costs as well as operation and maintenance (O&M) costs. Therefore, in this study, only direct capital costs and O&M costs are counted.

Then, the analysis parameters are executed to determine the period of analysis, inflation rate and discount rate. The analysis period determines the number of years in project cash flow and inflation rate (IR) to calculate the value of costs in years two and later of the project cash flow based on the values of year per dollar that specify on the system costs page, financial parameters page, electricity rates page and incentives page. While, the real discount rate (RDR) is to calculate the present value (value in the first year) of dollar amounts in the project cash flow during the analysis period and to calculate annualized costs and SAM calculates the nominal discount rate (NDR) based on the values of the real discount rate and inflation rate as shown in the following equation:

$$NDR = [(1 + RDR \div 10) \times (1 + IR \div 10) - 1] \times 100 \quad (1)$$

For the electrical power consumption data obtained is based on the data obtained from the Building Consumption Input System (BCIS). The power consumption data for 2014 are referred because the PV system is being completed at BHEUU building in 2015. Therefore, the power consumption data for 2015 and above that specify in BCIS are data that has been minus by the generation of energy by the existing PV system.

3.2 Battery Details in SAM

In this study, the battery considered is lithium iron phosphate batteries. The number of batteries is determined by the time period of use and capacity of inverter. The battery specification used is 300Ah, 48V and bank capacity is 400kWh. Selection of this battery is based on the comparison results during the undertaken study. has been done based on some comparison study as shown in Table 4. As shown in Table 4(a), Lithium-ion provides the required rated power at the LAS building. While in Table 4(a) and 4(b), it shows that this battery provides highest energy density and highest lifetime, compared to others.

Table 4: Comparison on battery [10]

Battery technology	Rated power (MW)	Energy density (Wh/kg)	Discharge duration (h)	Energy efficiency (%)	Lifetime/Cycles	Storage costs (USD/kWh)
Lead-acid battery	< 36	< 50	< 8	75 – 85	3 – 12 years / 500 – 1200	300 – 600
Lithium-ion battery	< 102	< 200	< 6	90 – 94	5 – 15 years / 1000 – 10,000	1200 – 4000
Vanadium based flow battery	< 28	< 30	< 10	70 – 85	5 – 15 years / 12,000 – 18,000	600 – 1500
Sodium-sulfur battery	< 50	< 240	< 8	75 – 86	5 – 10 years / 2500 – 4000	1000 – 3000
Aluminum-ion battery (Estimated)	N/A	< 60	< 6	90 – 94	5 – 15 years / 1000 – 10,000	300 – 600

(a) Comparison of parameter from different battery technology

Battery technology	Advantages	Disadvantages	Energy storage applications
Lead-acid battery	Low capital cost	Limited life cycle, long charging time, high self-discharge rate. Environmental pollution	Hot spare, frequency control and load adjustment
Lithium-ion battery	High energy densities, high efficiency, long life cycle	High production cost, requires special charging circuit	Frequency control, load shifting and power quality
Vanadium based flow battery	High power, long life cycle, fast charge and discharge	High production cost, large area	Load shifting, emergency standby and power quality
Sodium-sulfur battery	High power and energy densities, high efficiency	Production cost and safety concerns	Load adjustment and standby power
Aluminum-ion battery (Estimated)	Low capital cost, fast charge and discharge, high efficiency	Under development, low energy densities	N/A

(b) The advantages and disadvantage technologies of different battery

3.3 Cost Calculations

Cost calculation is the most important element that must be studied before implementing the design on the site, to make assess its effectiveness. In this study, three types of cost will be considered; investment cost, energy cost and return of investment cost.

A. Investment Cost

Investment costs are dependent on selection of the products and suppliers. So, to get the low investment cost, designers have to know how to choose the suppliers and contractors to obtain the desired product at a low price and good quality. Investment costs include calculations on product costs, installations and maintenance. The equation used to calculate the total investment cost is as written below:

$$TIC = \sum[AFN\,(CP + COF + MC)] \qquad (1)$$

where,

TIC = Total investment cost
AFN = Actual fitting needed
CP = Cost of product per each
COF = Cost of fitting per each
MC = Maintenance cost per each

B. Energy Cost

The cost of energy consumption is the energy calculation that used by the entire load within a certain period of time and multiplied by the cost charged by the TNB Malaysia. The equations that used to calculate the cost of energy consumption per day is as follows:

$$TEC = \sum[(ECm - EPm) \times \left(\frac{sen}{kWh}\right)] \qquad (2)$$

where TEC = Total energy cost, ECm = Energy consumption per month (kWh), EPm = Energy produced by PV system per month, Sen/kWh = price per kWh.

C. Return of Investment Cost

Return of investment (ROI) is used to measure the profit or loss generated on an investment relative to the amount of money invested. ROI is usually expressed as a percentage or ratio. It is usually, to compare company profits or to compare different investment efficiencies. The equations are used to calculate ROI in this study is as follows:

$$ROI_{year} = \frac{TIC}{EPm \times \frac{Sen}{kWh}} \qquad (3)$$

where TIC = Total investment cost, EPm = Energy produced by PV system per month, Sen/kWh = price per kWh.

4. SIMULATION RESULTS AND ANALYSIS DISCUSSIONS

In this section, results will be presented based on the four study cases; Case A (4 inverter, no storage), Case B (4 inverter, with storage), Case C (1 inverter, no storage), and Case D (1 inverter, with storage). Figure 13 represents the summary that has been displayed in SAM software for all cases in terms of inverter features at the LAS building. From the SAM simulation results, it was found that the inverter for existing system on site for Case A, C and D is oversized, where the maximum output inverter is 60% of rated power value is 44kWac. While the maximum output inverter for Case C and Case D is 45.05% of rated power value is $56.86kW_{ac}$, and 73.31% of rated power value is $59.86kW_{ac}$, respectively. On the other hand, for Case B, the inverter and PV module are match where no indicator either oversized or undersized was shown.

As shown in Figure 13 as well, the performance ratio (that describes the relationship between the actual and theoretical energy outputs of the installed system) of the study towards Case A, B, C and D was 0.74 (with payback period within 6.7 years), 0.66 (with payback period within 7.7 years), 0.75 (with payback period within 6.3 years) and 0.68 (with payback period within 7.3 years), respectively. Hence, it can be summarized that the shortest payback period can be achieved by implementing Case C where the performance ratio is 75%. Another important detail that should be noted is the capacity factor. Capacity factor is the ratio of an actual electrical energy output over a given period to the maximum possible electrical energy output over that period. The maximum possible energy output of a given installation assumes its continuous operation at full nameplate capacity over the relevant period. From the same figure, it can be observed that Case A and Case C demonstrate same capacity factor which is 3.9%. While Case D presents lower at 3.6%, which is 0.1% greater than Case B.

Case A

Metric	Value
Annual energy (year 1)	17,038 kWh
Capacity factor (year 1)	3.9%
Energy yield (year 1)	341 kWh/kW
Performance ratio (year 1)	0.74
Levelized COE (nominal)	-58.23 ¢/kWh
Levelized COE (real)	-46.06 ¢/kWh
Electricity bill without system (year 1)	$181,374
Electricity bill with system (year 1)	$180,342
Net savings with system (year 1)	$1,032
Net present value	$108,929
Payback period	6.7 years
Discounted payback period	8.5 years
Net capital cost	$163,139
Equity	$163,139
Debt	$0

Case B

Metric	Value
Annual energy (year 1)	15,289 kWh
Capacity factor (year 1)	3.5%
Energy yield (year 1)	306 kWh/kW
Performance ratio (year 1)	0.66
Battery efficiency (incl. converter + ancillary)	86.86%
Levelized COE (nominal)	-40.62 ¢/kWh
Levelized COE (real)	-32.13 ¢/kWh
Electricity bill without system (year 1)	$181,374
Electricity bill with system (year 1)	$180,325
Net savings with system (year 1)	$1,049
Net present value	$71,469
Payback period	7.7 years
Discounted payback period	10.5 years
Net capital cost	$177,551
Equity	$177,551
Debt	$0

Case C

Metric	Value
Annual energy (year 1)	17,255 kWh
Capacity factor (year 1)	3.9%
Energy yield (year 1)	346 kWh/kW
Performance ratio (year 1)	0.75
Levelized COE (nominal)	-63.69 ¢/kWh
Levelized COE (real)	-50.37 ¢/kWh
Electricity bill without system (year 1)	$181,374
Electricity bill with system (year 1)	$180,329
Net savings with system (year 1)	$1,045
Net present value	$119,852
Payback period	6.3 years
Discounted payback period	7.9 years
Net capital cost	$153,376
Equity	$153,376
Debt	$0

Case D

Metric	Value
Annual energy (year 1)	15,712 kWh
Capacity factor (year 1)	3.6%
Energy yield (year 1)	315 kWh/kW
Performance ratio (year 1)	0.68
Battery efficiency (incl. converter + ancillary)	89.11%
Levelized COE (nominal)	-48.21 ¢/kWh
Levelized COE (real)	-38.13 ¢/kWh
Electricity bill without system (year 1)	$181,374
Electricity bill with system (year 1)	$180,296
Net savings with system (year 1)	$1,078
Net present value	$85,530
Payback period	7.3 years
Discounted payback period	9.5 years
Net capital cost	$167,622
Equity	$167,622
Debt	$0

Figure 13: Summary Results Based on the Proposed Inverter and Storage System at LAS Building

Then, in Figure 14, the data on the energy produced by Case A, B, C and D in a year is shown. For Case A, it was recorded that the maximum energy produced is 1800kWh in October and the minimum energy produced is 1100kWh in November. The other 3 cases also show the same pattern where the maximum and minimum energy produced are fall in October and November. Then followed by August, September and July. Among these 4 cases, Case D presents the highest energy produced of about 1850kWh just slightly over than Case A.

Meanwhile, monthly savings from electricity bills for the first year for all the study cases are shown in Figure 15. The highest electricity savings can be achieved during the first-year installation is when Case D is implemented where annual savings can reach up to USD1,078.00. The best savings are mostly obtained during October in line with the data presented in the previous figure.

As summary for the comparison details among the study cases on the energy cost and savings, losses and maintenance costs, Table 3 is presented. In Table 3(a), among the 4 cases, system in Case C presents the shortest payback period (6.3 years), where it also has the lowest net capital cost of USD153,376.00. This is due to the ignorance of the cost on energy storage. Therefore, the annual energy yield, the levelized cost, the net present value and the capacity factor for this system are the highest. This however, in terms of net saving value, Case D is superior than Case C. In Table 3(b), the losses details on the proposed inverter is demonstrated. From the results, it has been found that the best performance ratio (0.75) can be achieved by implementing Case D for this LAS building application. Then followed by Case A. This is relevant as in these systems, battery is neglected in the studied system. Hence, losses only occur in the installed inverter, as applied in Case B and Case D.

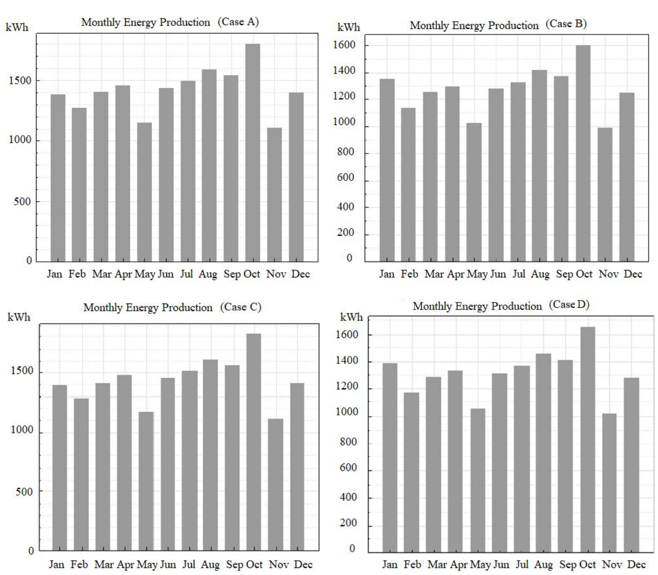

Figure 14: Monthly Energy Production Based on the Proposed Inverter and Storage System at LAS Building

Case A

Month	Without System	With System	Savings
Jan	13,334	13,260	73
Feb	12,205	12,137	68
Mar	13,007	12,932	75
Apr	13,033	12,955	77
May	17,267	17,190	77
Jun	17,001	16,905	96
Jul	16,100	16,000	100
Aug	16,781	16,674	106
Sep	16,770	16,667	103
Oct	17,627	17,507	120
Nov	13,773	13,714	58
Dec	14,470	14,395	74
Annual	181,374	180,342	1,032

Case B

Month	Without System	With System	Savings
Jan	13,334	13,251	83
Feb	12,205	12,135	70
Mar	13,007	12,930	76
Apr	13,033	12,954	78
May	17,267	17,189	77
Jun	17,001	16,906	95
Jul	16,100	16,001	99
Aug	16,781	16,674	106
Sep	16,770	16,668	102
Oct	17,627	17,507	120
Nov	13,773	13,712	60
Dec	14,470	14,393	76
Annual	181,374	180,324	1,049

Case C

Month	Without System	With System	Savings
Jan	13,334	13,260	74
Feb	12,205	12,136	69
Mar	13,007	12,931	75
Apr	13,033	12,954	78
May	17,267	17,189	77
Jun	17,001	16,904	97
Jul	16,100	15,998	101
Aug	16,781	16,673	108
Sep	16,770	16,666	104
Oct	17,627	17,505	121
Nov	13,773	13,713	59
Dec	14,470	14,394	75
Annual	181,374	180,328	1,045

Case D

Month	Without System	With System	Savings
Jan	13,334	13,248	85
Feb	12,205	12,133	72
Mar	13,007	12,928	78
Apr	13,033	12,952	81
May	17,267	17,187	79
Jun	17,001	16,903	98
Jul	16,100	15,998	102
Aug	16,781	16,671	109
Sep	16,770	16,665	105
Oct	17,627	17,503	123
Nov	13,773	13,710	62
Dec	14,470	14,391	78
Annual	181,374	180,295	1,078

Figure 15: Monthly Electrical Savings Based on the Proposed Inverter and Storage System at LAS Building

As shown in the same table, the highest losses came from the DC modules where it contributes 14.5%, and then followed by the DC cable connections for battery which is around 10-13%. In the inverter, the AC inverter night tare loss is the least losses, in which between 0.28-0.43%, compared to the inverter efficiency losses that between 0.53-3.2%, a slightly higher than the tare losses. For the AC inverter power consumption losses however, no losses are found in Case A and Case B, different in Case C and Case D due to 4-unit inverters installed in the system. For Case C and Case D, only 1 inverter is considered therefore, due to its frequent used, power consumption losses are existed. However, between these 2 cases, loss is very small if battery is installed in the system [11] as happened in Case D. It is noted that, battery only installed in Case B and Case D. Among these two, Case D presents higher efficiency compared in Case B.

Table 3: Comparison on energy and cost, losses and maintenance costs

(a) Comparison of energy and cost

	Annual Energy, kWh (1st year)	Energy Yield, kWh/kW (1st year)	Levelized Cost of Energy (cent/kWh)	Capacity Factor, % (1st year)	Net Saving with System, USD (1st year)	Net Present Value, USD	Net Capital Cost, USD	Payback Period
Case A	17,038.00	341	-46.06	3.9	1,032.00	108,929.00	163,139.00	6.7 years
Case B	15,289.00	306	-32.13	3.5	1,049.00	71,469.00	177,551.00	7.7 years
Case C	17,255.00	346	-50.37	3.9	1,045.00	119,852.00	153,376.00	6.3 years
Case D	15,712.00	315	-38.13	3.6	1,078.00	85,530.00	167,622.00	7.3 years

(b) Comparison of losses

	AC Inverter Efficiency Loss, %	AC Inverter Night Tare Loss, %	AC Inverter Power Consumption Loss, %	DC Connected Battery Loss, % (1st year)	DC Module Modeled Loss, %	Battery Efficiency, %	Performance Ratio (1st year)
Case A	3.2	0.43	0	0	14.5	-	0.74
Case B	3.21	0.43	0	12.92	14.5	86.86	0.66
Case C	1.27	0.28	0.87	0	14.5	-	0.75
Case D	0.53	0.36	0.07	10.64	14.5	89.11	0.68

(c) Comparison of maintenance cost

	PV Panel (RM)	Inverter (RM)	Battery (RM)	Cabling and other system (RM)	Total/ Month (RM)	Total/ Year (RM)	Total/ Year (USD)
Case A	100.00	400.00	-	300.00	800.00	9600	2742.86
Case B	100.00	400.00	100.00	300.00	900.00	10800	3085.71
Case C	100.00	100.00		300.00	500.00	6000	1714.29
Case D	100.00	100.00	100.00	300.00	600.00	7200	2057.14

When installing a PV system in a building, the cost maintenance of the system should be investigated as well as financial support on this subject can reduce the possibility of breakdown or can lengthy the life cycle of the system components. Regular maintenance is very crucial to be concerned to ensure that all equipment required for production is always operating at 100% efficiency. It is necessary to avoid any breakdown occurs because the major breakdown cost will be very large when it is compared to the cost of a maintenance cost. From Table 3(c), the detail on the maintenance costs for the PV panels, inverter, battery, and the cablings and other related components is given. From the presented data, since the number of PV panel unit is similar, hence the maintenance cost for this unit is same, fall around RM100/year. Same goes to the inverter system that used 1-unit only. For Case A and Case B, the cost on this becomes 4 times as we used 4-unit of inverter in the systems. Maintenance for battery of course will be considered in Case B and Case D only as in Case A and Case C, no battery is installed. Hence, after considering all costs including cabling system and its components, it can be observed that Case B provides the highest total maintenance cost compared to other due to the inverter's maintenance costs. That is relevant as higher the units installed; maintenance cost also will be higher. As in this study case, for the case of PV system at the LAS building in Malaysia, in the first year, the total maintenance cost per year is about RM6000 to RM9600 (USD1714.29 – USD3085.71) depends on the system configurations.

As summary, based on the study cases, it can be concluded that the higher the number of units installed, the higher will be the total costs. For instance, Case B will require highest costs compared to other 3 cases. Installing optimum number of inverter or battery based on the current situation may avoid oversize of the installed system. However, if considering increment of the load demand and the penetration level of the PV system in the near future, installing more PV units or higher capacity ratings (for battery and inverter) will be more beneficial as higher size in capacity will be just slightly expensive than the lower capacity, save more cost rather than buying 2 units with small capacity. On the hand, to cut all costs, selecting Case D will save the money and give the least costs. However, in terms of system performance and reliability for the LAS building, selecting Case D is preferable as the net saving of this system is better than Case C. In addition, adding 1 battery will increase cost for about USD33.00 only. Although Case D will oversize the system by 26.69%, this percentage is still sensible as this could lead to prolong the inverter lifetime. Besides that, additional installation of PV units in the future also already prepared. To be more efficient, installation of an energy management system or energy monitoring system at building may increase the efficiency and reliability of the power flow management between the solar power plant and the loads [12].

5. CONCLUSION

The enhancement work based on the failure design on the solar photovoltaic application in LAS building, Putrajaya, Malaysia has been executed in this study. To improve the former design, Model Advisor Model (SAM) has been proposed and used, in which the optimal numbers of grid inverter and battery were determined practically. However, the results presented in this study are not considering the comparison performance in terms of different types of PV panels, batteries, and inverters. Hence, these details may be considered in the future. To obtain more reliable results using SAM simulation, detailed costs such as taxes, incentives and others should be considered in the future as well.

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REFERENCES

1. **Towards Putrajaya Green City 2025**, 1st edition, October 2013. Putrajaya Corporation. Retrieved on 30 June 2020: http://2050.nies.go.jp/report/file/lcs_asialocal/Putrajaya_2013.pdf.
2. **Malaysian Building Integrated Photovoltaic Project (MBIPV),** Government of Malaysia United Nations Development Programmed Global Environment Facility, November 2008.
3. **Handbook on The Malaysian Feed-In Tariff for The Promotion of Renewable Energy**, 2nd edition, Kementerian Tenaga Teknologi Hijau dan Air (KeTTHA), March 2011. Retrieved on 30 June 2020: https://www.smsolar.net/files/Malaysia%20FiT-Handbook.pdf
4. **National Renewable Energy Policy and Action Plan**, published by Kementerian Tenaga Teknologi Hijau dan Air (KeTTHA), November 2008. Retrieved on 30 June 2020:https://policy.asiapacificenergy.org/sites/default/files/NREPAP.pdf
5. **Energy Audit Report for Bangunan Bahagian Hal Ehwal Undang-Undang (BHEUU) Jabatan Perdana Menteri**, Gading Kencana Sdn Bhd & Rantau Arau Sdn Bhd, December 2016.
6. **Report for Design, Supply, Deliver, Install, Testing and Commissioning & Maintenance of 12kWp to 48kWp of Solar Photovoltaic System and Ancillary Works for Selected Government Building under the Government Lead by Example (GLBE) – Solar PV Project**, Pekat Solar Sdn Bhd, June 2015.

7. Erdem Elibol, Özge Tüzün Özmen, NedimTutkun, Oğuz Köysal. **Outdoor performance analysis of different PV panel types**, *International Journal of Renewable and Sustainable Energy Reviews*, 67, pp. 651–661, 2017. https://doi.org/10.1016/j.rser.2016.09.051
8. Amornrat Limmanee, Nuttakarn Udomdachanut, Sasiwimon Songtrai, Songpakit Kaewniyompanit, Yukinobu Sato, Masaki Nakaishi, Songkiate Kittisontirak, Kobsak Sriprapha, Yukitaka Sakamoto. **Field performance and degradation rates of different types of photovoltaic modules: A case study in Thailand**, *International Journal of Renewable Energy*, 89, pp. 12-17, 2016. https://doi.org/10.1016/j.renene.2015.11.088
9. Fardila Mohd Zaihidee, Saad Mekhilef, Mehdi Seyed mahmoudian, Ben Horan. **Dust as an unalterable deteriorative factor affecting PV panel's efficiency: Why and how**, *International Journal of Renewable and Sustainable Energy Reviews*, 65, pp. 1267-127, 2016. https://doi.org/10.1016/j.rser.2016.06.068
10. H. Yang, S. Luo, X. Sun, Q. Zhang, C. Zhou. **Research on photovoltaic energy storage system based on LADRC**, *IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific)*, Harbin, China, pp. 1-6, 2017.
11. Swapnil A, et. Al. **Solar PV System for Electric Traction Application with Battery Backup**. *International Journal of Emerging Technologies in Engineering Research (IJETER)*, 7(1), pp. 1-4, 2019.

Elmer R. Magsino. **Energy Monitoring System Incorporating Energy Profiling and Predictive Household Movement for Energy Anomaly Detection.** *International Journal of Emerging Technologies in Engineering Research (IJETER)*, 7(8), pp. 151-156, 2019.https://doi.org/10.30534/ijeter/2019/08782019