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Stand-Alone Photovoltaic (SAPV) System Assessment using PVSYST Software

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Abstract

The Photovoltaic simulation tool is important in predicting the energy production of the solar system. This paper presents stand-alone photovoltaic (SAPV) system assessment using PVSYST software. The study used simulation software to develop the reliable SAPV system as well as predicting the yearly energy output. The simulation of the SAPV system configuration is presented using the PVSYST tools software. The total amount of electrical energy generated by PV array that supplied to the load and the various types of power losses are determined. The result obtained the optimal size of SAPV system configuration. Besides, the total energy flow through the whole system is calculated. With PVSYST software, the predicting energy supplied to the load for the whole year can be determined.

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Keywords: Stand-alone photovoltaic (SAPV), PVSYST, photovoltaic (PV), battery storage, system losses;

1. Introduction

A SAPV system which converts solar into electricity is an independent system that supplies electricity to the load without being connected to the electric grid. The generated power is directly connected to the load, but a storage device is needed. A complete working of SAPV system comprises two main parts: PV array and the Balance of System (BOS) component. A PV array is produced from a combination of PV modules to boost up electrical power. All components in SAPV except PV modules are called BOS such as battery storage, MPPT charge controller and wiring systems [1].

With the robust growth of solar PV application, sizing SAPV system is very important in order to predict the yearly energy production. System designers and installers require a reliable tool to predict performance for the overall system, including total energy production under real conditions [2]. P. Karki et al. presents comparative analysis of grid-tied PV systems of Kathmandu and Berlin using PVSYST

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software. By using the simulation tool, the total electrical energy in case of Kathmandu found higher than Berlin. Kathmandu can generated more energy caused has greater potential of solar radiation [3]. The economic feasibility for 150 kilowatt-peak Photovoltaic Park was carried out by S.K. Kyprianou et al. by using PVSYST software. The sun in Cyprus is exposed for the majority of the days during the year lead the investment become very attractive [4].

A widely variety of tools exist for the sizing, analysis and optimizing of SAPV system. In this study, the simulations are performed by using PVSYST 6.3.4. PVSYST is dedicated PC software package for a PV system. The process simulation of PVSYST calculates the behavior of the system and all disturbances for each hour of operation of SAPV system. The energy generated depending on meteorological data of site installation. By analysing the energy resources data, energy production, system configuration and the system losses for installing the SAPV system in CERE are discussed.

Nomenclature

PV	photovoltaic
W/m^2	watt per meter square
cm	centimetre
V	voltage
W	watt
A	current
C	Celsius
kWh	kilo-watt-hour
m/s	meter per second
kWh/m^2	kilo-watt-hour per meter square
kWh/d	kilo-watt-hour per day
AH	ampere-hour

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2. Database Collection

To develop reliable the SAPV system, it is important to determine the important data which have affected the performance of the system. The data collection for this study divided into two categories which are the location of site installation and total energy used by requirement loads. Both of the data have great influence in generating economical system.

2.1. Geographical of Site Location

CERE located in Kangar (capital state of Perlis), Malaysia as shown in Figure 1. It lies on 6.43°N latitude and 100.19° E longitude, 4 meters above sea level. Site location selected has great potential of solar radiation [5]. Besides, the potential of ambient temperature and wind resources also the main factor in generating reliable PV system.

Fig. 1. Site location.

2.2. Energy Demand Consumption

In SAPV system, the energy demand must be determined to avoid oversizing the power system which can be led to additional cost [6]. The energy demand consumption is determined based on the daily power used and its operating time. For this study, the lighting system contains 14 LED bulbs with rating power of 18W were applied. Figure 2 shows all bulbs assumed to be used from 8 am to 12 pm and 1 pm to 5 pm every day except for weekends. The peak power of load is determined by 252 W for the hour used. Therefore, the average estimation of daily energy assumed to be 2.016 kWh/day using by load requirement.

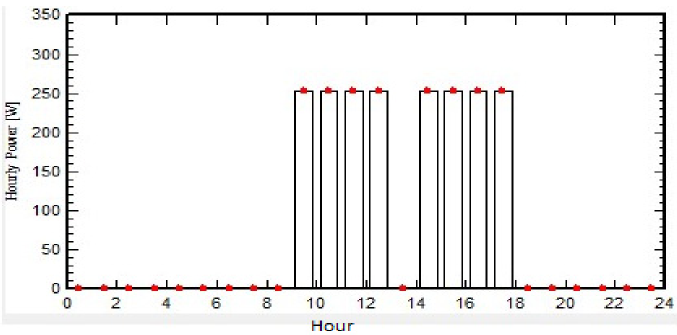

Fig. 2. Energy demand consumption.

3. Parameter Selection and System Configuration

The selection parameter of every component is very important to fulfil the system configuration. All components selected based on the energy requirement of the load demand and the potential of meteorological data of site installation.

3.1. PV Module selection and configuration

Solar energy is presented in the form of radiation. The size of PV arrays is dependent on the solar radiation available. Large number of solar modules is connected to make arrays [3]. The PV array should be sized properly to provide enough energy to the loads and for charging the battery. Table 1 shows the parameters PV module used in the SAPV system. The PV size can either increased or decreased, according to the mount of requirement load.

To receive the maximum amount of solar radiation the PV array needs to be placed at a certain angle. For a fixed PV array, typically the array needs to be oriented to face south in the Northern hemisphere. Optimum PV array output can be achieved using tilt angle approximately equal to the site's latitude. The tilt angle of PV array in this study is 10°.

Table 1. PV Module characteristic

Specification	Parameter
Type of PV module	UniSolar
Nominal power (P_{nom})	64 W
Short-circuit current (I_{sc})	4.80 A
Open-circuit voltage (V_{oc})	23.80 V
Maximum current (I_{mp})	3.88 A
Maximum voltage (V_{mp})	16.5 V

3.2. Battery storage

The design principle for sizing the system's battery was to compensate for daily variations in solar radiation and not to act as seasonal energy storage [7]. PV modules are not an ideal source for battery charging. The output is unreliable and heavily dependent on weather conditions, therefore an optimum charge/discharge cycle can be guaranteed, resulting in a low battery state of charge (SOC) [8]. Low battery SOC leads to shorten the life of the battery. Choosing batteries for PV systems involves many considerations for balancing energy of the PV system. Figure 3 shows the criteria need to be considered in battery selection.

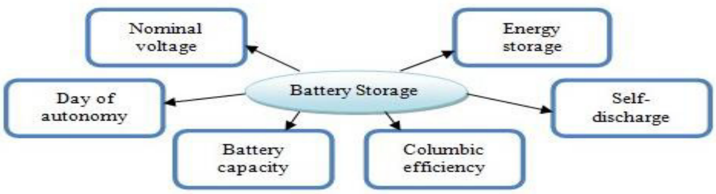

Fig. 3. Battery selection criteria

3.3. Regulator with MPPT converter

A regulator is an essential component of SAPV system. It is used to protect the batteries from overcharge and excessive discharge due to get higher capacity and extend the life cycle. With less than desirable voltage, the battery will not operate recharge, with excessive voltage the battery will overheat, causing terminal damage to the battery cells [9]. The MPPT converter which converts DC mode to AC mode doesn't operate always at their maximum efficiency. The maximum efficiency can be produced is 96% of their output from this MPPT converter.

4. System Performance Evaluation

The performance of this study is totally based on the PVSYST software simulation. The simulation software establishes the overall performance of the SAPV system. This part discussed the output from the simulation tool such as the potential energy resources, system component sizing, and energy production from the SAPV system as well as system losses.

4.1. Energy resources data collection

The global radiation and temperature are the main role to ensure the running of the simulation. The installation solar benefit is strongly depends on the yearly intensity of sunlight. By using PVSYST software, the resources data for the whole year generated from Metronome 6.1. Perlis is blessed with abundant radiation with clear sky. The average daily radiation for the whole day is 4.90 kWh/m^2.day. Perlis, which located in the northern part of Peninsular Malaysia has an average ambient temperature with 27.8 ºC and wind speed about 0.7 m/s. All weather data collected determines the amount of sun energy reached a panel in produced electrical energy.

4.2. SAPV System Configuration

The combination of all components as shown in Figure 4 represented to satisfy the system configuration. From the PVSYST software simulation, the total battery required is 8 units in order to satisfy the energy requirement. The battery proposed is lead-acid battery with 160 AH battery capacity. Then the nominal voltage for each cell is 12 V. The battery has columbic efficiency by 97%. Furthermore, the battery which has 24 V of system voltage expected capable supporting the electrical load for 5 days.

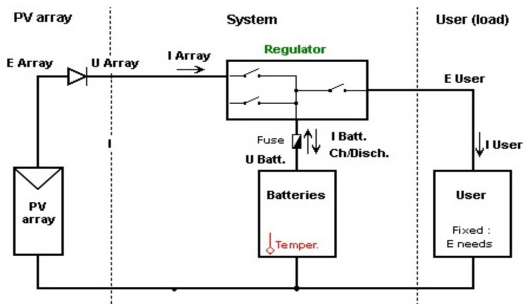

Fig. 4. The SAPV system configuration

There are 10 units of PV module selected in order to satisfy PV array configuration. The PV array must have adequate energy supplies to the load and charging the battery. About 640 W_p of nominal power from PV array expected to be generated. The output of a PV module change depending on the amount of solar radiation, the temperature of the module and the load demand. The Figure 5 explored the incremental level of radiation at constant temperature (ambient temperature = 25 ºC), increased the power output of the PV module. The cell temperature is increase due to the increment of solar irradiance. Besides, the decreasing power output with increasing temperature at constant solar incidence (solar incidence = 1000W/m^2) explored in Figure 6.

In PVSYST software, inverter and MPPT charge controller are part of the regulator configurations. The selection nominal voltage for this regulator is 24 V. The selection made depending on system voltage on battery storage. From the simulation, the maximum voltage from the PV array limited to 52 V. The regulator can regulate until 640 W of the maximum output power from the battery.

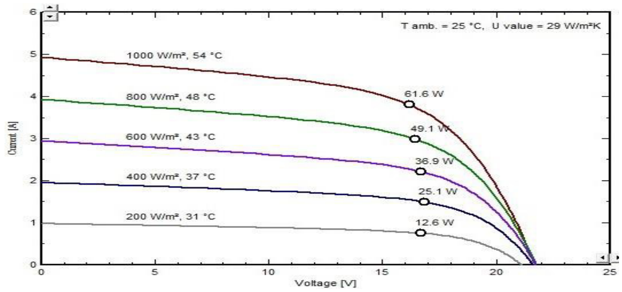

Fig.5. IV (current-voltage) versus irradiance.

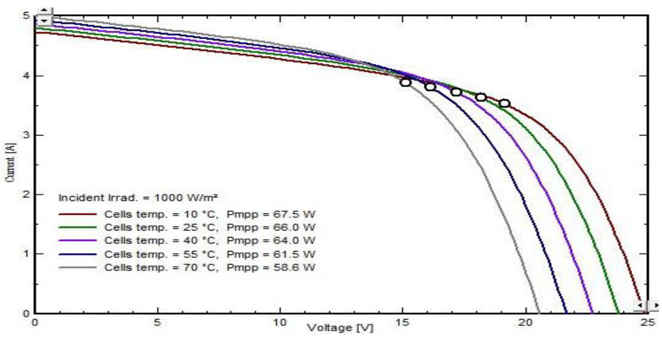

Fig.6. IV (current-voltage) versus cell temperature

4.3. Analysis of Energy Production

From Table 2, the average available solar energy (E_{sun}) injected into the PV array for the whole year is 867.62 kWh. But only 841.31 kWh of effective energy from the PV array (E_{array}) can be produced. The decrement energy occurs due to some losses such as module quality loss and ohmic wiring loss. However the energy produced by PV array is sufficient to meet the load requirement for the entire year. The total energy needed supplies to the user (E_{load}) is 735.84 kWh for the whole year.

Table 2. The energy production of the SAPV system.

Month	E_{sun} (kWh)	E_{array} (kWh)	E_{load} (kWh)
January	73.85	76.60	62.50
February	73.84	64.57	56.45
March	79.87	72.07	62.50
April	74.76	68.24	60.48
May	72.56	68.93	62.50
June	66.30	68.84	60.48
July	68.48	70.68	62.50
August	70.13	71.00	62.50
September	72.25	70.37	60.48
October	76.95	72.48	62.50
November	68.42	67.92	60.48
December	70.21	69.59	62.50
Average	867.62	841.31	735.84

4.4. System Losses

SAPV system failed to generate 100% the energy delivered from the sun because of some losses. Figure 7 explored the overall system loss diagram for site installation. The figure defined the details losses occur in the SAPV system. A collector plane received about 1653 kWh/m^2 of global incident radiation. But the effectiveness plane receives the irradiances only at 1601 kWh/m^2. The biggest losses happen in PV array production energy. Energy produced from the PV array affected by several factors such as ambient temperature, solar incidence, manufacture mismatch and ohmic wiring. The output energy of PV array proved strongly affected on the potential of solar radiation and ambient temperature. The actual energy supplied to the load can identify after through the losses of regulator and battery storage.

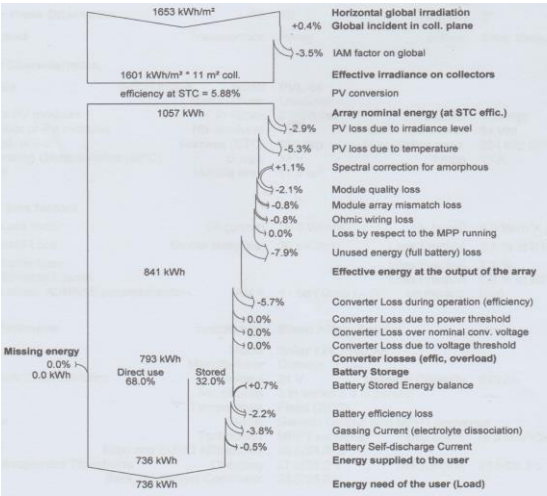

Fig.7. The overall system losses

5. Conclusion

In conclude, this paper represents the simulation tools known as PVSYST software due to evaluate the SAPV system. This software enables the designer of PV solar to design the system configuration as well as predicting the energy production generated. The output generated based on the simulation of the sizing system. The sizing system is strongly depending on geographical site location. This study focused on SAPV system which applied to the lighting system for room in CERE building. To fulfill the load demand, 10 units of PV modules with each rating power 64 W were selected. Where 8 units of 160 AH batteries used as a system.

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