Design of A Grid Connected PV System via PV*SOL Software

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Abstract

In this paper, the authors have dig into the design and simulation of a grid-connected solar power system, which is applied for Hyatt Regency Resort and Spa, located in Danang City, Vietnam. The interesting feature of this paper is the usage of the PV*sol software to improve the effectiveness of the design-and-simulation stage, that partly decides the performance of the implementation stage in reality. In particular, during the design procedure, the values of the optimal sizing of all components of the Photovoltaic system, the power exchange with the grid and the system loss are obviously calculated. Furthermore, the effectiveness of the paper is evaluated by the simulation results.

Keywords: *Grid-connected PV system, Solar panels , System loss, Optimal sizing, PV*Sol.*

1. Introduction

The dramatic growth of the world's population and the global rise of urbanization in accompany with the increasing demand of the energy usage are the urgent issues of each country. As a developing country, Vietnam is also facing the risk of energy shortages in the near future. It can be said that infrastructure energy is a key factor for the process of industrialization - modernization, economic and social growth in Vietnam. However, over the past two decades, our country has witnessed a rapid increasing demand for electricity when the supply problem is always in tense to meet the demand. Beside that, the roar of fuel price and the development of the alternative renewable resource open more opportunities for employing renewable energy in power system. However, Photovoltaic (PV) and wind energy are intermittent sources due to the fact that they depend on the weather. Therefore, it is difficult to match the supply and demand. That makes the system design process become complex in many technical and economic aspects in according to social concerns since it depends not only the components sizing but also the operation strategies.

There are some published papers describing some approaches to optimize the energy management of a grid connected MG in recent literature. For example, in [1], a novel method to estimate the optimal sizing of a PV on-grid system which includes Photovoltaic system, battery energy storage system (BESS). Additionally, the optimal sizing of a PV off-grid system is proposed in [2]. The problem is mentioned as a constrained optimization. In which, the objectives are to minimize the annual cost of the system (ACS) with zero unmet loads as well as to maximize the usage of the PV system with respect to the system operations, reliability and the state of charge (SOC). A Genetic Algorithm (GA) has been proposed for optimal sizing of a PV-diesel-battery system in [3]. The objective is to define the optimum number of PV panels, battery banks and capacity of the DG. In [4], GA is used to determine the optimal sizing of PV grid connected systems.

Another thing to note in this paper is that the sizing and the simulation of the PV system are both executed via the simulation software, for example PVsyst, PV*sol, Home Pro, RET-Screen, INSEL. In [5-7], the PVsyst software is used to design and evaluate the performance of a grid connected PV system.

In this paper, the authors make use of the PV*sol software to design and simulate a grid connected PV system for a resort in Danang city, Vietnam. Section 2 introduces the Configuration of the system and the parameters calculation. The data input and setting are shown in Section 3 and 4. After that, the results simulation is described in Section 5 before concluding this work in Section 6.

2. Configuration and Design Procedure

2.1 Configuration of the studied system

The grid connected PV system that is to be taken into account is described in Fig. 1.

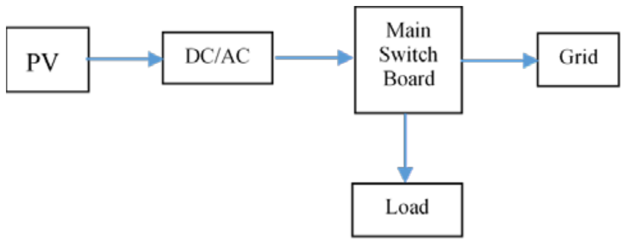

Fig. 1 The studied basic architecture

2.2 Design procedure (Parameters Calculation)

The design procedure is executed by following steps.

- Step 1: Calculating primarily parameters of desired load
- Step 2: Calculating the energy demand from the PV system
- Step 3: Calculating the PV power output
- Step 4: Calculating number of series and parallel modules (or array)

2.2.1 *Step 1*

Assume that we need supply energy for the loads A, B, C, … with respective demand powers P1, P2, P3, … with the daily average operation time being t1, t2, t3, …. Then, the total demand energy supplying for load a day is described by:

$$E_{ng} = P_1.t_1 + P_2.t_2 + P_3.t_3 \ldots \qquad (1)$$

2.2.2 *Step 2*

Calculating the energy demand from the PV systems by the following formula:

$$E_c = \frac{E_{ng}}{\eta_h}. \qquad (2)$$

Where η_h is given efficiency of system while E_{ng} is the designed energy for a whole day. One thing to remark here is that it depends on the location, area and demand loads.

2.2.3 *Step 3*

The PV power output in standard test condition (irradiance Io = 1000 W/m2 and cell temperature T0 = 250C) is estimated as follows:

$$\mathbf{P}_{(\mathbf{Wp})} = \frac{\mathbf{E_c.Io}}{\mathbf{\eta_m I_\beta}}. \quad [W_P] \qquad (3)$$

Where:

- I_β [W_h/m^2] is the radiation intensity on the plane, inclined at an angle β to the horizontal plane,
- η_m is the efficiency of PV system at the temperature (T). It is calculated in following:

$$\eta_m(T) = \eta_m(T_0)[1+P_c(T-T_0)] \quad (4)$$

Where T is the regular working temperature of the panel, while P_c is the temperature coefficient of PV panels.

2.2.4 *Step 4*

Given characteristics of PV cells as follows :

- maximum power point voltage: V_m
- maximum power point: P_m

From this, we can estimate these parameters:

- Number of system's modules : $N = \frac{P_{(WP)}}{P_m}$ (5)

  where $N = N_S . N_P$

  - Number of modules in series: $N_S = \frac{V}{V_m}$ (6)

  Where V is the inverter's voltage.

  - Number of string in parallel: $N_P = \frac{N}{N_S}$ (7)

Remark that for a grid-connected solar power systems without storage system, the power rating of the inverter is at least equal to the installed PV power output.

3. The initial data

3.1 Location Design

- Hyatt Regency DaNang Resort & Spa, Danang City, Viet Nam.
- Geographical location: 16,013 degrees north in latitude; 108,263 degrees east in longitude.
- Construction area: 200000 m2
- Roof area can integrate the panels: 13600 m^2

3.2 Loads

- Peak power: 2457 kW
- Annual electricity consumption: 13192 MWh

3.3 Main Transformer Station Parameters

- Total installed capacity: $S_{Transformers}$= 10000KVA
- Voltage U_h/U_l: 22/0,4 kV

Based on these initial information we can select an appropriate configuration of the PV system in term of ability of supply for the loads. However, it depends also on the rooftop area, which has the maximum power PPVmax (kW). At the first glance, we need to clarify the comparativeness between PPVmax and the Peak power to define the ability generate the relative power for load. For example, PPVmax = 2176 (kW) in comparison with the peak power of 2457 (kW), we can select the installation capacity of the PV system at 2175 (kW).

4. Setup parameters in the software PV*sol.

In order to design a PV system by deploying the PV*Sol, it is necessary to fill in the following sections:

4.1 Geolocation and meteorological data

From the data input of location, we setup a table of parameters as in Table 1. from January to December a year. As we can see that the highest radiation intensity is occurred in May and June.

Table 1: Meteorological data after positioning (Meteonorm 7.1).

Site	Hyatt Regency DaNang Resort&Spa			
Values	GlobH	DiffH	Temp	Wind
Month	kWh/m²	kWh/m²	°C	m/s
January	101,5	57,7	20,2	1,2
February	124	68,3	21,6	1,5
March	158,8	79,3	24,2	1,5
April	173,9	83,0	26,8	1,6
May	196,2	88,6	28,9	1,5
June	191,4	77	29,9	1,3
July	193,7	80	29,7	1,3
August	186,3	74,6	28,7	1,1
September	141,0	81,8	26,6	1,4
October	133,3	70,7	25,3	1,4
November	109,0	65,3	23,3	1,8
December	90,5	55,9	21,3	1,4
Year	1799,6	882,2	25,5	1,4

4.2 Orientation

Photovoltaic battery system in this design is installed on the roof with the mounting bracket system. The panel is mounted directly to the south (azimuth 0^0) and be inclined at an angle of 16^0 to the horizontal plane as showed in Fig. 2.

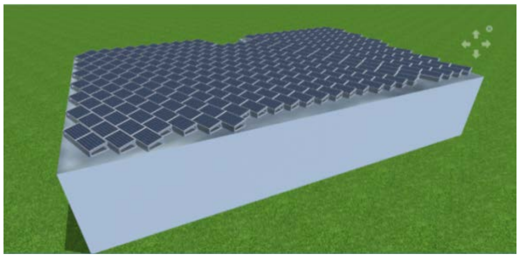

Fig. 2 The simulation of the rooftop PV system

4.3 PV modules

Photovoltaic model must satisfy test standards such as IEC 61215, IEC 61730, IEC 60364-4-41, IEC 61701, IEC 61853-1, IEC 62804, UL1703. And, we choose PV model of “Sun module Plus SW 300 - Mono – Solar World” with the main specifications described clearly in Table 2.

Table 2. Main specifications of SW 300-Mono module

The specifications in Standard test condition STC	1000W/m^2;25^{o}C
Power Rating P_{max}	300Wp
Open Circuit Voltage V_{oc}	40 V
MPP Voltage V_{mpp}	32,6 V
Short-Circuit Current I_{sc}	9,83 A
MPP Current I_{mpp}	9,31 A
Efficiency η_m	18,1 %

4.4 Inverter

The inverter standard: IEC 61683:1999, IEC 61721:2004, IEC 62109-1&2:2011-2012, IEC 62116:2008. We choose inverter model of “Sunny Tripower 17000TL-10 – SMA” with the main specification as in Table 3.

Table 3: Main specifications of Sunny Tripower 17000TL-10

DC Power Rating (DC)	17410 W
Max. Input Voltage	1000V

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MPP Voltage	180V→ 800V
Nom. DC Voltage	600
AC Power Rating (AC)	17000 W
Nom. AC Voltage	400V±10%
Frequency	50Hz
Phases	3
(Large) Efficiency	98,2%

4.5 Cables

The Cable diagram is shown in Fig. 3. In this work, we will choose the AC cable, DC cable and DC String cable.

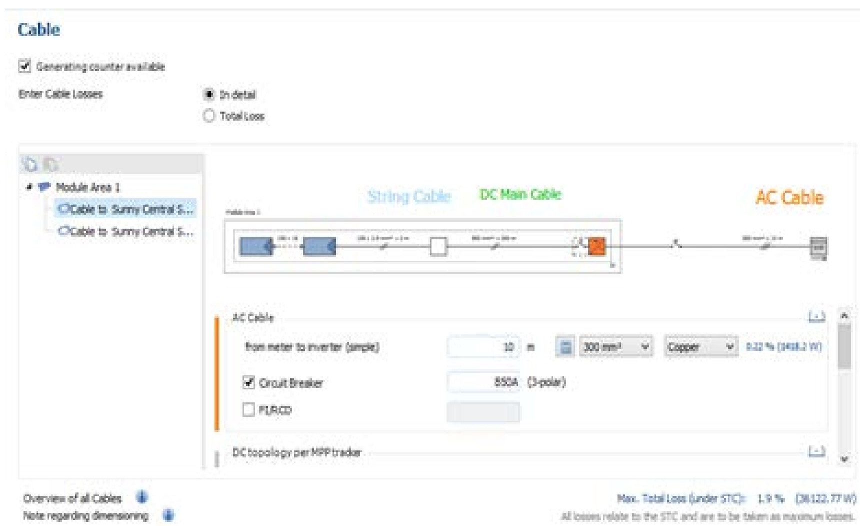

Fig. 3 The Cable diagram

a) AC Cable

This cable transmits the AC output power from the inverter to power meter

- Length: 10 (m)
- Nom voltage: Ulv=230 (VAC)
- Cross-section: 70 mm2

b) DC Main Cable

This cable transmits the DC output power from the MPP tracker to inverter

- Length (go and return): 400 (m)
- MPP voltage: Umpp=689.7 (VDC)
- Cross-section: 500 mm2

c) DC String Cable

This cable connects the PV module in string and transmits DC power to MPP Tracker

- Length (go and return): 200 (m)
- Nom voltage: Ulv=230 (VAC)
- Cross-section: 300 mm2

Finally, after finishing all above steps, PV*sol will declare the summary as in Fig. 4.

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System Type, Climate and Grid	
Type of System	Grid connected PV System with Electr...
Climate Data	Hyatt Regency Da Nang
Resolution of the data	1 h
AC Mains	230 V, 3-phase, cos φ = 1
Maximum Feed-in Power Cl...	No
Consumption	
Total Consumption	12973621 kWh
Load Peak	2,457.0 kW
Resolution of the data	1 min
PV Modules	
Module Area 1	
Module Data	Sunmodule Plus SW 300 mono
Manufacturer	SolarWorld AG
Number of PV Modules	7250
PV Generator Output	2175 kWp
Inclination	16°
Orientation	180°
Installation Type	Mounted - Roof
Inverters	
Module Area 1	
125 x Inverter1	Sunny Tripower 17000TL-10
Manufacturer	SMA Solar Technology AG
Configuration	MPP 1: 2 x 18 | MPP 2: 1 x 22
Cables	
Total Loss	2 % (43500 W)

Fig. 4 The main setting parameter

5. Simulation results

In this section, we make use of the initial information presented in Section 3 and 4 of the given PV system chosen as in Fig. 1. With the purpose to define the capacity of all components in the given PV system, the produced energy, the energy exchange with the main grid as well as the system loss and the CO_2 emission.

5.1 The main simulations results

Running the PV*sol, the main results is provided in Table 4.

Table 4: The main simulation results

Spec. Annual Yield	1.436 kWh/kW$_p$
Performance Ratio (PR)	81,5 %
Produced Energy (AC)	3.123.587 kWh
Energy supplied to the user	12.975.621 kWh
Energy from the grid	9.851.583 kWh
Solar Fraction	24,1 %
CO2 Emission Balance	1.621 tấn

Also, we can synthesize the power exchange with the grid for each month.

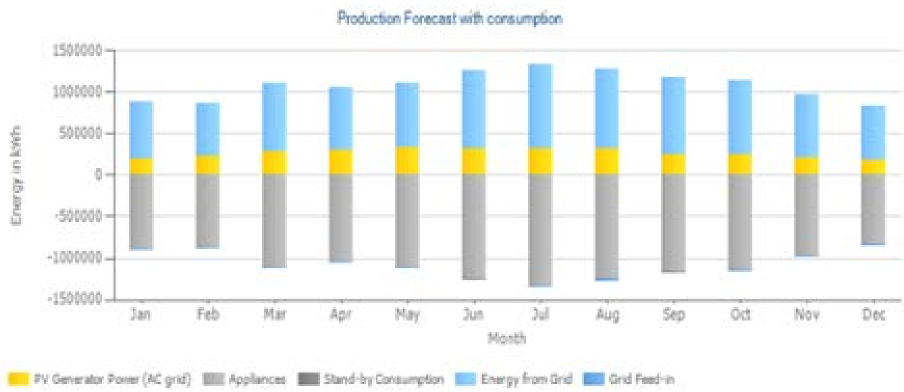

Fig. 5 The power exchange by each month a year

The system production in each month is shown in the Fig. 5 and the Table 5

Table 5: Data of the power exchange by each month a year

Month	***E_Feed(MWh)***	***E_Grid (MWh)***	***Load (MWh)***	***E_PV (MWh)***
Jan	4,84	691,73	884,76	197,86
Feb	4,45	633,09	865,03	236,39
Mar	0,18	817,64	1103,7	286,2
Apr	0,11	754,4	1050,5	296,23
May	0,03	791,35	1106,6	315,29
Jun	0	957,59	1256,4	298,84
Jul	6,14	1031,3	1331,4	306,15
Aug	33,41	971,95	1224,7	306,17
Sep	0	926,34	1171,6	245,25
Oct	0,25	906,87	1150,9	244,25
Nov	4,28	765,97	973,64	211,95
Dec	5,4	662,35	834,44	177,49
Sum	59,09	9910,6	12974	3122,1

As can be seen that the energy from PV system meet the highest values of 315,29 (MWh) in May. And, the maximum energy feeding to the grid goes for August.

5.2 The simulation result in a sunny day

It can be seen from Fig. 6, the load demand is satisfied by the sources. At the beginning of the day, the load demand is supplied by the grid. After that, the consumption is supplied by the PV system production and the main grid. When the PV power is sufficient to meet loads, the excess power from the renewable energy will be sold to grid from 9am to 1pm. From 2pm to 5pm, the PV system and grid will supply for consumption. In the end of the day, the consumption is provided from the main grid.

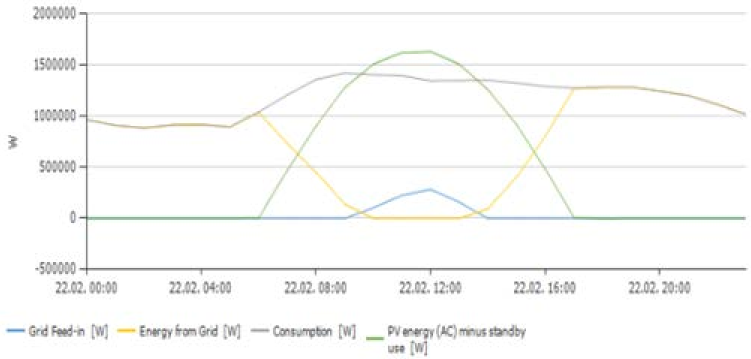

Fig. 6 The active power system on a sunny day

5.3 PV system energy balance

Table 6. The PV system energy balance

Global radiation - horizontal	**1,798.7**	**kWh/m²**	
Deviation from standard spectrum	-18.0	kWh/m	-1.00%
Ground Reflection (Albedo)	6.9	kWh/m	0.39%
Orientation and inclination of the module surface	-10.7	kWh/m	-0.60%
Shading	-35.5	kWh/m	-2.00%
Reflection on the Module Interface	-1.5	kWh/m	-0.09%
Global Radiation at the Module	**1,739.8**	**kWh/m²**	
PV Generator surface	12,155.9	m	
Global PV Radiation	**21,148,573.9**	**kWh**	
Soiling	-283,557.5	kW	-1.34%
STC Conversion (Rated Efficiency of Module 18.1 %)	-17,088,102.2	kW	-81.90%
Rated PV	**3,776,914.2**	**kWh**	
Low-light	-98,972.7	kW	-2.62%
Deviation from the nominal module	-281,880.9	kW	-7.66%
Diodes	-16,980.3	kW	-0.50%
Mismatch (Manufacturer	-101,372.4	kW	-3.00%
Mismatch (Configuration/Shading)	0.0	kW	0.00%
PV Energy (DC) without inverter regulation	**3,277,707.9**	**kWh**	
Regulation on account of the MPP Voltage Range	0	kW	0.00%
Regulation on account of the max. DC Current	0	kW	0.00%
Regulation on account of the max. DC Power	0	kW	0.00%
Regulation on account of the max. AC Power/cos phi	-1,184.8	kW	-0.04%
MPP Matching	-9,656.5	kW	-0.29%
Energy at the Inverter Input	**3,266,866.6**	**kWh**	
Input voltage deviates from rated	-5,601.3	kW	-0.17%
DC/AC Conversion	-73,931.7	kW	-2.27%
Stand-by Consumption	-1,549.5	kW	-0.05%
Total Cable	-63,715.7	kW	-2.00%
PV energy (AC) minus standby use	**3,122,068.5**	**kWh**	
PV Generator Energy (AC grid)	**3,123,587.0**	**kWh**	

Table 6 shows the information of system loss, which presented in the last column according to each term listed in the first column such as horizontal global radiation, global radiation at the module, Global PV radiation, rated PV energy, PV energy (DC) with inverter regulation, Energy at the inverter input, PV energy (AC) minus standby use and PV generator energy (AC grid). In which, each percentage of loss of the system is dedicated for each relative reason, listed in the first column.

6. Conclusions

In this paper, the authors have focused on design a grid-connected solar power system, which is applied in a Hyatt Regency Resort and Spa in Danang City, Vietnam. Another contribution of this work is deploying the PV*Sol software to calculate the optimal sizing parameters of all components of the PV system as well as figure out the value of the power efficiency generated by PV system, the power exchange with the grid and the system loss. From this design and simulation, we can apply and implement in reality.

References

[1] L. N. An, T. Quoc-Tuan, B. Seddik and N. Van-Linh, "Optimal sizing of a grid-connected microgrid," 2015 IEEE International Conference on Industrial Technology (ICIT), Seville, 2015, pp. 2869-2874

[2] Luu-Ngoc, T. Tran-Quoc, S. Bacha “Sizing Optimization of an Isolated Photovoltaic-Diesel-Battery Hybrid System”, IEEE/PES General Meeting, Washington DC, USA, July 2014

[3] H. Suryoatmojo, A. Elbaset, Syafaruddin and T. Hiyama “Genetic algorithm based optimal sizing of PV–wind–diesel–hydrogen–battery systems,” Innovative Computing, Information and Control, vol 6 (2010), pp. 1-09-0844

[4] Hernández, J. C., A. Medina, and F. Jurado. "Optimal allocation and sizing for profitability and voltage enhancement of PV systems on feeders." Renewable Energy 32.10 (2007): 1768-1789

[5] B. Shiva Kumar, K. Sudhakar, “Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India”, Energy Reports 1 (2015), (9)184–192.

[6] Ebenezer Nyarko Kumi, Design and Analysis of a 1MW Grid-Connected Solar PV System in Ghana, “Design and Analysis of a 1MW Grid-Connected Solar PV System in Ghana”, ATPS Working Paper No. 78, African Technology Policy Studies Network, 2013, (6)8-13

[7] Rachit Srivastava and Vinod Kumar Giri, “Design of gridconnected PV system using PVsyst" African Journal of Basic & Applied Sciences 9 (2): 92-96, 2017.John Kellenberg, “Utility-Scale Solar Photovoltaic Power Plants”, International Finance Corporation 2015.