Feasibility Study Of Rooftop Photovoltaic Power System For A Research Institute Towards Green Building In Vietnam

Vu Minh Phap1,*, Nguyen Thuy Nga1

1Institute of Energy Science, Vietnam Academy of Science and Technology, Hanoi, Vietnam

Abstract

Use of renewable power technology in urban area can help the buildings to minimize the carbon footprint, meet the electricity needs and achieve the nearly zero-energy building. In this study, the design results of the rooftop grid-tied PV power system with the capacity of 56.7kW for a research institute building in Vietnam are analyzed. The study results have calculated the electricity generation, performance of the rooftop grid-tied PV power system as well as reduction potential of the amount of CO2 emitted into the environment. The design results of the rooftop grid-tied PV power system for a research institute building will be compared with the actual power generation results of an installed rooftop grid-tied PV power system at a building of General Directorate of Energy - Vietnam Ministry of Industry and Trade in the same city.

Keywords: photovoltaic, inverter, rooftop grid-tied PV power system, loss.

Received on 04 November 2019, accepted on 19 January 2020, published on 30 January 2020

Copyright © 2020 Vu Minh Phap et al., licensed to EAI. This is an open access article distributed under the terms of the Creative Commons Attribution licence (http://creativecommons.org/licenses/by/3.0/), which permits unlimited use, distribution and reproduction in any medium so long as the original work is properly cited.

doi: 10.4108/eai.7-1-2020.162825

1. Introduction

At the present, building sector achieves a large proportion in power consumption all over the world. Construction of building and other related operations in building sector accounted for 36% of global final power usage and about 40% of energy which was related carbon dioxide (CO2) emissions [1]. Therefore, governments in the world issued policies towards greener cities and societies by using energy efficiency strategies, renewable energy sources and strategies to fight climate change to decrease the energy consumption of buildings [2-5]. As a kind of sustainable renewable energy source, solar energy can be selected to reduce the pollution and improve energy saving performance of buildings, cities [6-8]. Currently, solar power technology is developing very fast in the world, with a total installed solar power capacity of 509 GW [9]. In 2018, the ground-mounted PV power plant was a major solar market on this type of PV application with the installed capacity of 72.7GW and it was predicted increasing up to 187.4GW in 2023 [9]. Besides, the installed capacity of the rooftop PV power stations was 29.7GW in 2018 and can achieve the target of 76.5GW in 2023 [9] as illustrated in Figure 1.

Construction of rooftop solar power system in urban area can help the buildings, resident homes in general and the institution buildings in particular to reduce carbon footprint, meet the electricity needs and achieve the nearly zero-energy building (ZEB) characterized by a very high-energy performance during the operation and most of the usage energy is produced from renewable energy sources [typically solar thermal and solar power systems] [10]. However, it is noted that when usage of solar power, a part of CO2 emission also is emitted in the production phase of the photovoltaic modules.
Vu Minh Phap and Nguyen Thuy Nga

Development of green buildings with solar power system is an approach to save energy and plays an important role in cutting greenhouse gas (GHG) emission.

Anasuya Gangopadhyay et al [11] studied a 100kW grid-tied rooftop solar PV plant which has been operational since October 2014 at National Institute of Advanced Studies, India to evaluate the performance of grid tied rooftop solar plant from generation, economic and maintenance perspective. Daphne Ngar-yin Mah et al [12] reviewed the usage trends of rooftop solar power in urban area and collected data by conducting 57 interviews with potential rooftop solar PV adopters from the residential, institutional, and commercial sectors in Hong Kong to estimate the perceived barriers and effectiveness of possible government policies for solar power. Adel A. Elbaset, M. S. Hassan [13] researched a new approach for optimum design and implement of rooftop grid connected PV system installation on an institutional building at Minia University, Egypt in order to carry out taking into account PV modules and inverters specifications. Mohammad I et al [14] investigated reduction ways of the electricity demand for Engineering Faculty at Mu'tah University by using the rooftop PV power system with the capacity of 56.7 kW, this plant could generate the electricity of 97.02 MWh per year to the utility grid. Li et al [15] evaluated and compared the techno-economic performance of rooftop grid-connected solar power systems containing 14 families in five climate zones in China. M. MoldovanI, VisaA. Duta [16] presented a nearly zero energy building with solar tracking systems for PV array and solar-thermal convertors, as well as a novel concept for active solar–thermal facades for a sustainable community of the R&D Institute of Transilvania University in Brasov, Romania.

In the case of Vietnam, the electricity demand of administrative and residential buildings increased at an average 9.3 % per annum and achieved an average share of 9.25 % of the whole national power consumption in the period 2010-2016 while energy consumption of commercial buildings have the highest growth rate of about 16.4 % per annum in the same period [17]. Vietnam National Green Growth Strategy [18] was adopted by the government in 2012 with the target for green construction and sustainable urbanization and it was related to the national climate change and economic policy agendas.

Vietnam has good solar energy potential that could be used to successfully develop the solar power sector. Overall solar energy potential in Vietnam is about 4-5 kWh/m².day in the Southern area, Central area, and partially even Northern area in Vietnam while the average peak irradiation of up to 5.5 kWh/m².day in Central-Southern areas [19]. Solar power has been used in Vietnam since the 1990s but it is mainly used for the remote areas where are far from the national power grid such as mountainous areas, islands, etc.... The small grid-tied solar power plants developed from 2010 and installed for the residential applications. The total installed solar power capacity in Vietnam by 2017 is only about 8MW [20], which is very low in comparison with the potential for solar power in Vietnam because there is no policy of the Government to support the development of solar power.

From April in 2017, the Government of Vietnam announced the policy to support the development of solar power in general and the rooftop PV power system in particular. In which, the surplus electricity produced from the rooftop grid-tied PV power station can be sold to the utility grid with the price of 9.35 centUS/kWh [21]. Therefore, investors are interested in constructing the rooftop PV power station in Vietnam.

Since the 2000s, grid-connected PV power systems have been studied for application of building and resident home in Vietnam. Nguyen Xuan Truong et al [22, 23] designed a grid-connected solar power system with the capacity of 15kW for a building to achieve nearly zero-energy building model, the PV arrays were installed in the area of this building to compensate the energy needed and these authors also researched to improve the power production efficiency of the PV system by using the Solar Tracker system. Baulch et al [24] determined the payback period for the rooftop solar power stations in Ho Chi Minh city. General Directorate of Energy (GDE) - Vietnamese Ministry of Industry and Trade cooperated.
with Spanish Agency for International Development Cooperation (AECID) [25] to install and test the effectiveness of the grid-tied PV power station in Hanoi city with the capacity of 22 kW and the off-grid solar power system in Con Dao island with the capacity of 36 kW. German Federal Ministry for Economic Affairs and Energy and GIZ - German Corporation for International Cooperation [26] studied the development potential for solar power rooftop applications in the commercial and industrial sector of Vietnam and to evaluate business opportunities for German solar companies in Vietnam. This report focused on industrial zones and private factories/commercial operations located in Central and Southern Vietnam with the highest solar energy potential.

The rooftop solar power is a new field in the business market in Vietnam. Therefore, this study result will contribute to evaluate the potential of installation of rooftop solar power and reduction of CO$_2$ for buildings in Vietnam. The simulation results of rooftop grid-tied PV power system with the capacity of 56.7 kW for a research institute building have calculated the solar energy potential in a specialized city, the generation electricity, performance of the rooftop grid-tied PV power system by using PVSYST program as well as reduction amount of CO$_2$ emitted into the environment. The design results of the rooftop grid-tied PV power system for a research institute building will be compared with the actual power generation results of another installed rooftop grid-tied PV power system at the building of General Directorate of Energy - Vietnam Ministry of Industry and Trade in the same city.

2. Rooftop PV power system

The main components and working diagram of the typical grid-tied PV power system in Vietnam are presented in Figure 3. In the favorable weather conditions, the PV modules absorb solar energy and generate the power. The DC/AC inverter is used to convert the direct current (DC) from the PV module to the alternating current (AC) and transmit it into the utility power grid [27, 28]. At any time of the day, a customer's solar power system may produce more or less electricity than their demand for home or business. When the PV system's power production exceeds the customer's demand, the excess energy generation automatically goes through the electric meter into the utility grid. At other times of the day, when the customer's electric demand may be higher than the electricity production of PV power system, the customer buy the additional power to serve the demand from the utility grid. The connection operation between solar system and the utility grid is instantaneous, so the customers never notice any interruption in the flow of power.

Currently, application of grid-tied PV power technology is increasing fastly in Vietnam. The Bi-directional meter can measure the electricity in two directions and it measures how much energy comes from the power company versus the electricity production from the PV power systems. If more electric energy is produced from the PV system than the customer’s demands, the surplus electricity is supplied into the utility’s electric system. By which, the surplus electricity produced from grid-tied PV power station can be sold to the utility grid with the price of 9.35 centUS/kWh [21].

3. Design of PV system at Institute of Geological Science

3.1. Site description

The Institute of Geological Science (IGS) under Vietnam Academy of Science and Technology is responsible for scientific research and training on geological and climate change issues. The electricity from grid-tied PV power system will be supplied for buildings, research work and teaching rooms. After the PV power system is completed, IGS will cooperate with other universities and institutions to train environmental geology, geotechnics, energy, environment classes.
The research building in IGS is located at latitude of 21°01’29”N and longitude of 105°48’18”E. The roof of the research building is a concrete roof system and the area of the roof is suitable for constructing the PV power system as shown in Figure 5.

Figure 5. Plan of roof on research building at IGS

3.2 Performance calculation parameters

In this study, the design of the rooftop grid-tied PV power system with the capacity of 56.7 kW for a research building in IGS was implemented by using specialized software PVSYST [29-34].

In PVSYST program [31, 35-38], the losses, yield factor, performance ratio are determined as below:

**Array Yield (\(Y_a\))**: \[ Y_a = \frac{E_a}{P_0} \] (1)

where, \(P_0\) is power of solar array [kWp]; \(E_a\) is output array yield [kWh]; \(Y_a\) (Array Yield) is the array daily output energy, referred to the nominal power [kWh/kWp/day].

**Reference system Yield (\(Y_r\))**: \[ Y_r = \frac{H_t}{G_0} \] (2)

where, \(Y_r\) (Reference system Yield) is numerically equal to the incident energy in the array plane [kWh/m²/day]. \(H_t\) is the total horizontal irradiance on array [kWh/m²] and \(G_0\) is the global irradiance at standard condition (STC) (W/m²).

**System Yield (\(Y_f\))**: \[ Y_f = \frac{E_{ACout}}{P_{max, STC}} \] (3)

where, \(Y_f\) (System Yield) is the system daily useful energy, referred to the nominal power [kWh/kWp/day]; EACout is the amount of electrical energy generated by the solar power plant; Pmax, STC is the total installed power of solar arrays at standard test condition (STC).

**Performance Ratio (PR)**: \[ PR = \frac{Y_f}{Y_r} \] (4)

where, \(PR\) (Performance Ratio) is the global system efficiency with respect to the nominal installed power and the incident energy; \(Y_f\) is System Yield; \(Y_r\) is Reference system Yield.

**Collection Loss (\(L_c\))**: \[ L_c = Y_r - Y_a \] (5)

where, \(L_c\) (Collection Loss) is the array losses, including thermal, wiring, module quality, mismatch and IAM losses, shading, dirt, MPP, regulation losses, as well as all other inefficiencies; \(Y_r\) is Reference system Yield; \(Y_a\) is Array Yield.

**System Loss (\(L_s\))**: \[ L_s = Y_a - Y_f \] (6)

where, \(L_s\) (System Loss) is inverter loss in grid-tied solar power system; \(Y_a\) is Array Yield; \(Y_f\) is System Yield.

3.3. Design of solar power system

In Vietnam, Hanoi city has the fairly solar energy potential with an average annual solar radiation of 3.85kWh/m².day [39]. The period from January to March and from October to December has the lowest daily average solar radiation value from 2.49kWh/m².day to 3.66kWh/m².day while the daily average solar radiation in the period from April to October has a good value from 3.79 kWh/m².day to 4.67 kWh/m².day.

Table 1. Daily solar radiation value in Hanoi city

| Month | Solar radiation (kWh/m².day) |
|-------|-----------------------------|
| 1     | 2.49                        |
| 2     | 2.86                        |
| 3     | 3.66                        |
| 4     | 4.07                        |
| 5     | 4.59                        |
| 6     | 4.67                        |
| 7     | 4.60                        |
| 8     | 4.56                        |
| 9     | 4.39                        |
| 10    | 3.79                        |
| 11    | 3.39                        |
| 12    | 3.02                        |
| Average year | 3.85                        |

Solar panels are installed on the roof system of the research building in IGS with the slope angle of 18° and the azimuth angle of 0° in order to achieve the best energy conversion efficiency.

Figure 7 presents the diagram of PV system connection at the research building with the connection structure as below:

The 1st inverter of 25kW consists of 4 solar panel strings. Each string consists of 13 mono-crystalline silicon solar panels of 350W that are connected in series. Two
strings are connected to input of a Maximum power point tracking (MPPT) tracker of the grid-tied inverter.

The 2\textsuperscript{nd} inverter of 25kW consists of 4 solar panel strings. Each string consists of 14 mono-crystalline silicon solar panels of 350W that are connected in series. Two strings are connected to input of a Maximum power point tracking (MPPT) tracker of the grid-tied inverter.

The 3\textsuperscript{rd} inverter of 25kW have 4 solar panel strings. In which, 2 strings consist of 13 mono-crystalline silicon solar panels of 350W in series connection and they are connected to inputs of the first MPPT tracker of the grid-tied inverter. 2 strings include 14 mono-crystalline silicon solar panels of 350W in series connection and this string is connected to the input of the second MPPT tracker of the grid-tied inverter.

Table 2 shows the main equipments of the the grid-tied PV power station in IGS.

### Table 2. Main equipments of the the grid-tied PV power station

| No. | Equipments | Quantity | Unit |
|-----|------------|----------|------|
| 1   | Solar panel - SolarWorld 350 W | 162 | module |
|     | - Maximum power: 350W | | |
|     | - Open circuit voltage: 47.3V | | |
|     | - MPP voltage: 37.8V | | |
|     | - Short circuit current: 9.82A | | |
|     | - MPP current: 9.29A | | |
|     | - Module efficiency: 17.54% | | |
| 2   | Grid-tied Inverter - SMA 25 kW | 3 | unit |
|     | - Max input voltage: 1000V | | |
|     | - MPPT voltage range: 390V - 800V | | |
|     | - Min input voltage: 150V | | |
|     | - Max input current input A/inputB: 33A/33A | | |
|     | - Rated power (at 230V, 50Hz): 25kW | | |
|     | - AC voltage range: 180V - 280V | | |
|     | - 3 phases | | |

### 3.4. Study result

PVSYST software is used to calculate the power output, performance as well as the losses of the grid connected PV power station. The types of losses include the Collection loss and the System loss.

Figure 8 presents the loss diagram of the PV power station, it is can be seen that the PV loss due to temperature is the highest value of about 4.8% because Hanoi is in the Northern area of Vietnam. Thus, the temperature difference between four seasons is quite high and not close to the standard working temperature of solar panels of 25\(^\circ\)C, the temperature in summer can reach 45\(^\circ\)C while the temperature in winter can be reduced to 8\(^\circ\)C. On the other hand, the loss of AC wire connecting to the grid power point is the lowest value of 0.3% because the connection distance is only about 22 m. The types of losses will affect the output electricity per kW generated to the power grid and the efficiency of grid connected solar power stations as shown in Figure 10, the generated power by the loss of 13.2 \% caused by solar arrays is about 0.53 kWh/kWp/day while the generated power affected by the system loss of 4.4 \% is about 0.18 kWh/kWp/day, the amount of produced useful electricity at inverter output is only about 3.32 kWh/kWp/day. Hence, the solar power station performance shown in Figure 9 will only reach about 82.4 \%.
It is can be seen that the generated power from the PV power system in Figure 11 corresponding to the solar radiation value. The time period from May to September has the highest power generation while January and February in the remaining months of the year have the lowest power output. On the other hand, the Global on tilted plane with the solar array slope angle of 18° is about 0.2 kWh/kWp/day higher than the case of GlobHor horizontal as shown in Figure 12. Total annual average electricity from the solar power station transmitting to the utility grid is 68625 kWh per year.
Environmental impact
At the present, the investment in construction of grid-connected solar power stations can obtain the economic profit and contribute to environmental protection, combat the phenomenon of climate change by reducing the amount of CO$_2$ emitted into the environment [40]. The annual average reduction of CO$_2$ in IGS building is 59.3 ton per year by using the following formula [41]:

$$t_{CO2e} = E_{Grid} \times EF_{grid} \quad (7)$$

where:
- $E_{Grid}$ - the average annual generation electricity from the solar power station (MWh)
- $EF_{grid}$ (CO$_2$ emission factor of Vietnamese power grid) = 0.8649 tCO$_2$/MWh [41]

4. Comparison of design result with another real work

The results of the design of the grid connected solar power station at the IGS is compared with the actual power generation results of a grid connected solar power station at the General Directorate of Energy building (GDE) [25] as can be seen in table 3 because these projects has the same city location in Vietnam.

![GDE building solar PV system](image_url)
Table 3. Comparative parameters of solar power station

| Location   | Coordinate | Power (kW) | Electricity kWh/year | Electricity kWh/kWp/day | Type of solar panel |
|------------|------------|------------|----------------------|-------------------------|---------------------|
| IGS building | 21°01'29" N, 105°48'1" E | 56.7       | 68625                | 3.31                    | mono-C              |
| GDE building [25] | 21°01'27" N, 105°51'1" E | 11         | 13100                | 3.26                    | poly-C              |

Figure 14. Comparative parameters of solar power stations in Hanoi city

The results of comparing electricity from two solar power stations with the same coordinates in Hanoi and similar solar radiation conditions showed that the electricity of the design results of the solar power station of the IGS building is 0.05 kWh/kWp/day and 0.23 kWh/kWp/day higher than the electricity from PV system of GDE building using polycrystalline solar panels and thin film solar panels, respectively.

Moreover, construction of rooftop grid-tied solar power station at IGS building can help reduce the amount of CO₂ of 59.3 tons per year emitted into the environment, so it will contribute to environmental protection and combat the phenomenon of climate change in the city.

Finally, installation of rooftop PV system in Vietnam can help to save energy for the buildings, reduce greenhouse gas emission in the environment, and contribute to achieve targets of the Vietnam National Green Growth Strategy for green construction and sustainable urbanization.

5. Conclusion

The power output generated to the utility grid and the performance of grid-connected solar power stations are affected by different types of losses. In which, the loss of solar panels due to temperature has the highest value of about 4.8% because Hanoi city in the Northern region has a high temperature difference between seasons. So the performance of solar power station at the IGS building is about 82.4%.

The results of comparing electricity from two solar power stations with the same coordinates in Hanoi city and similar solar radiation conditions showed that the electricity of the design results of the solar power station of the IGS building are 0.05 kWh/kWp/day and 0.23 kWh/kWp/day higher than the electricity from PV system of GDE building using polycrystalline solar panels and thin film solar panels, respectively.

References

[1] International Energy Agency (IEA) and the United Nations Environment Programme. (2018) 2018 Global Status Report Towards a zero emission, efficient and resilient buildings and construction sector.
[2] Jia-Jun Ma, Gang Du, Bai-Chen Xie, Zhen-Yu She, Wei Jiao. (2015) Energy Consumption Analysis on a Typical Office Building: Case study of the Tiejian Tower, Tianjin. Energy Procedia, 75, 2745 – 2750.
[3] Carmen de la Cruz-Lovera et al. (2017) Worldwide Research on Energy Efficiency and Sustainability in Public Buildings. Sustainability, 9, 1294.
[4] Khaled Bataineh and Ayham Alrabee. (2018) Improving the Energy Efficiency of the Residential Buildings in Jordan. Buildings, 8, 85.
[5] Isidoros Ziegou, Apostolos Michopoulos, Vasiliki Voulgari, Theodoros Zachariadis. (2018) Implementation of green roof technology in residential buildings and neighborhoods of Cyprus. Sustainable Cities and Society, 40, 233-243.
[6] Kirk Dimond, Amy Webb. (2017) Sustainable roof selection: Environmental and contextual factors to be considered in choosing a vegetated roof or rooftop solar photovoltaic system. Sustainable Cities and Society, 35, 241-249.
[7] David Parra, Gavin S Walker, Mark Gillott. (2014) Modeling of PV generation, battery and hydrogen storage to investigate the benefits of energy storage for single dwelling. Sustainable Cities and Society, 10, 1-10.
[8] Jouri Kanters & Maria Wall. (2018) Experiences from the urban planning process of a solar neighbourhood in Malmö, Sweden. Urban, Planning and Transport Research, 6(1), 54-80.
[9] SolarPower Europe. (2019) Global Market Outlook For Solar Power/2019 - 2023.
[10] Patxi Hernandez, Xabat Oregi, Sonia Longo, Maurizio Cellura. (2019) Handbook of Energy Efficiency in...
Feasibility Study Of Rooftop Photovoltaic Power System For A Research Institute Towards Green Building In Vietnam

Buildings: A Life Cycle Approach. Butterworth-Heinemann, 207-261.

[11] Anasuya Gangopadhyay, Hippu Salk Kristle Natha. (2017) Institutional rooftop solar: NIAS experience with a 100 kwp solar system, National Institute of Advanced Studies.

[12] Daphne Ngar-yin Mah et al. (2018) Barriers and policy enablers for solar photovoltaics (PV) in cities: Perspectives of potential adopters in Hong Kong. Renewable and Sustainable Energy Reviews, 92, 921–936.

[13] Adel A. Elbaset, M. S. Hassan. (2015) Design and implement of 100 kW rooftop grid connected PV system: Faculty of engineering as a case study. Proceeding of 3rd International Conference on Energy Systems and Technologies, Cairo, Egypt.

[14] Mohammad I. Al-Najideen Saad, S. Alrwashdeh. (2016) Future trends for solar energy use in nearly zero energy buildings. Renewable and Sustainable Energy Reviews, 62, 150–160.

[15] Mohammad I. Al-Najideen Saad, S. Alrwashdeh. (2017) Design of a solar photovoltaic system to cover the electricity demand for the faculty of Engineering - Mu'tah University in Jordan. Resource Efficient Technologies, 3(4), 440–445.

[16] Li, Chong & Zhou, Dequn & Zheng, Yuan. (2018) Techno-economic comparative study of grid-connected PV power systems in five climate zones, China. Energy, 165, 1352-1369.

[17] M. Moldovanl, Visa A. Dutu. (2016) Future trends for solar energy use in nearly zero energy buildings. Advances in Solar Heating and Cooling, 547-569.

[18] Programme for Energy Efficiency in Buildings. (2019) Building Sector Brief: Vietnam.

[19] Jerome Meessen, Claude Croizer, Paul Verle. (2015) Programme for Energy Efficiency in Buildings. (2019) Building Sector Brief: Vietnam.

[20] Mohammed I. Al-Najideen Saad, S. Alrwashdeh. (2016) Future trends for solar energy use in nearly zero energy buildings. Renewable and Sustainable Energy Reviews, 62, 150–160.

[21] Prime Minister of Vietnam. (2017) Decision No: 11 /2017/QD-TTg On the Support mechanisms for the Development of Solar Power Projects in Vietnam.

[22] N. X. Truong, N. L. Tung, N. Q. Hung and B. Delinchant. (2016) Grid-connected PV system design option for nearly zero energy building in reference building in Hanoi. Proceeding of 2016 IEEE International Conference on Sustainable Energy Technologies (ICSET), Hanoi, 326-331.

[23] Xuan Truong Nguyen, Viet Dung Nguyen, Dinh Quang Nguyen, Lang Tung Nguyen, Duc Quang Nguyen. (2017) Performance comparison between tracking and fixed photovoltaic systems: A case study of Hoa Lac Hi-tech Park, Hanoi, Proceeding of 2017 International Seminar on Intelligent Technology and Its Applications (ISITIA), Surabaya, 128-133.

[24] Baulch, Bob and Do, Thuy Duong and Le, Thai-Ha. (2015) Solar Home Systems in Ho Chi Minh City: A promising technology whose time has not yet come.

[25] General Directorate of Energy - Vietnam Ministry of Industry and Trade. (2015) Solar Home Systems in Ho Chi Minh City: A promising technology whose time has not yet come.

[26] German Federal Ministry for Economic Affairs and Energy and GIZ - German Corporation for International Cooperation. (2016) Subsector Analysis: Vietnam Solar PV Rooftop Investment Opportunities in Vietnam. Publisher of Federal Ministry for Economic Affairs and Energy (BMWi), Berlin.

[27] Michael Boxwell. (2019) Solar Electricity Handbook – 2019 Edition: A simple, practical guide to solar energy – designing and installing solar photovoltaic systems. Greenstream Publishing.

[28] Vu Minh Phap, Yamamura, N., Ishida, M. et al. (2019) Study on Novel Topology of Solar–Wind Hybrid Power Plant Using Photovoltaic Cell Emitting System. Journal of Electrical Engineering & Technology, 14, 627-634.

[29] A. Soual-mia and R. Chen-ni. (2016) Modeling and simulation of 15MW grid-connected photovoltaic system using PVsyst software. Proceeding of IEEE International Renewable and Sustainable Energy Conference (IRESEC), Marrakech, 70-705.

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

[31] PVsyst, “PVsyst Photovoltaic Software.” [Online]. Available: http://www.pvsyst.com/en/.

[32] N.M. Kumar, M.R. Kumar, P.R. Rejoice, M. Mathew. (2017) Performance analysis of 100 kWp grid connected Si-poly PV system using PVsyst simulation tool. Energy Procedia, 117, 180-189.

[33] Renu Sharma, Sonali Goel. Performance analysis of a 1.12 kWp roof top grid-connected PV system in Eastern India. Energy Report, 3, 76-84.

[34] P. Yadav, N. Kumar, S.S. Chandel. (2015) Simulation and performance analysis of a 1kWp photovoltaic system using Pvsyst. Proceeding of International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Chennai, 0358-0363.

[35] W.R. Anis, M.A.S. Nour. (1995) Energy losses in photovoltaic systems. Energy Convers. Manag., 36, 11 1107-1113.

[36] I. Lillo-Bravo, P. González-Martínez, M. Larrañeta, J. Guasumb-Codena. (2018) Impact of energy losses due to failures on photovoltaic plant energy balance. Energies, 11(2), 363.

[37] Nallapaneni ManojKumar et al. (2019) Performance, energy loss, and degradation prediction of roof-integrated crystalline solar PV system installed in Northern India. Case Studies in Thermal Engineering, 13, 100409.

[38] Irfan Jamil, Jinquan Zhao, Li Zhang, Rehan Jamil, and Syed Furqan Rafique. (2017) Evaluation of Energy Production and Energy Yield Assessment Based on Feasibility, Design, and Execution of 3x50MW Grid-Connected Solar PV Pilot Project in Nooriabad. International Journal of Photoenergy, 1-18.

[39] Ministry of Industry and Trade of the Socialist Republic of Vietnam. (2015) Maps of Solar Resource Potential and Energy Web. EAI Endorsed Transactions on Renewable Energy, 29(3), 345-355.

[40] Stefan Krauter, Ricardo Rüther. (2004) Considerations for the calculation of greenhouse gas reduction by photovoltaic solar energy. Renewable Energy, 29(3), 345-355.

[41] http://vie.jcmvietnam.vn/