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Comparison of Performance Evaluation of Grid-Connected PV System for 3D Single Family House Using Building Information Modeling (BIM) Technology: A Case Study in Elazig, Turkey

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Abstract- In this study, the engineering design of the proposed single family house project was carried out using the well-known architectural program called the Revit that provides a Building Information Modelling (BIM) tool to analyse the falling solar radiation on the specified location. Based on BIM, regions with abundant solar radiation were chosen for the purpose of installing the PV system and exploiting them in energy production. A simulation of a 6.96 KWh grid-connected rooftop PV system was performed by using PVsyst and PV*SOL software. A 3D single family house that was proposed by the municipality of the Turkish city of Elazig was designed and simulated using PVsyst and PV*SOL software based on BIM. Comparison and evaluation were carried out for the annual energy yield, performance ratio, specific production and energy feed into the grid of the PV system from each software. It has been shown that very similar results are obtained from the simulations of these softwares.

Keywords PV system, solar energy, BIM, PVsyst, PV*SOL, solar radiation.

1. Introduction

Environmental problems and climatic disturbances caused by the use of fossil fuels such as coal, gas and oil as a major source of energy represent the trigger point for the use of clean energy sources [1]. This transformation calls for uniting all efforts to make this goal a reality and involves researchers, skilled workers, educated consumers, as well as the support required from governments and political decision-makers. For this transformation, one of the most important - and abundant - sources of renewable energy is solar energy. Solar energy is an inexhaustible source and is one of the most promising sources of energy to generate electricity and reduce emissions of harmful gases [2]. It is a well-known fact that the solar energy available at a particular location is not the same throughout the year, and it also varies from location to location. It is therefore important to know the climate data before installing solar systems. The economic feasibility of a photovoltaic systems should be analysed before the installation [3]. After the installation the solar system needs to be operated as efficiently as possible under standard operating conditions [4].

As the world turns to renewable energy sources, photovoltaic technologies are developing rapidly despite the high cost and complex technology of the photovoltaic cells industry. However, researchers are continuously working to integrate renewable energy sources into building design by modernizing these systems. Ammar H.A. Dehwah et al. [5] studied the possibility of applying a PV system on the roofs of buildings of al Khubar city in the Kingdom of Saudi Arabia, taking into account two different forms of buildings, namely apartments and villas. They used the techniques of remote sensing and geographic information systems for determining the areas in which the PV system could be applied. They also found that currently 18% and 25% of the respective apartments and villas surfaces of building are compatible with the possibility whereby the PV system is applicable. Owing to cultural and architectural similarities between the Gulf Cooperation Council countries, it is envisioned that the intervention of policymakers can contribute to an increase of up to 35% of future energy production with the use of PV*SOL software for simulation and design of PV system. Morshed et al. [6], studied a stand-alone system for a small house in the city of Dhaka, Bangladesh. They studied a house which has 2 kWh electric load by using PVsyst, HOMER and Solar MAT software. They noted that the PVsyst software yielded significantly positive results although there were small differences in results compared to the results of the practical data. In the case of using Solar MAT, the output result had a great similarity with practical data but it does not give informative graphs and diagrams. In the event of using the HOMER program, they stressed that it is better for the hybrid systems to provide the possibility of sensitivity and analysis. Raphaël Nahon et al. [7] analysed a small portion of the suburban area of Compiegne in France where a type of housing that was envisioned to be compatible with urban improvement had been developed. They calculated the solar radiation falling on the roofs of buildings and windows for a period of one year to achieve a balance between the accuracy of the model used and the calculation time. They could not find a simple base to calculate the loss of the thickness of the wall and the direction of the facade. Chandra Kant Dondariya et al. [8], studied a simulation of grid-connected rooftop solar PV system by using different simulation software (PV*SOL, PVGIS, SolarGIS and SISIFO). The Solar PV system had been simulated to define energy yield, performance ratios and energy consumption. Comparison of the obtained results were very close despite limited differences due to slight variations in the database of climate and model neutralization among simulation software.

There are many software developed for modelling and simulation of PV systems [9]. These software, some of which are free of charge, can make use of meteorological data to analyse the energy production amounts, system losses, economic analysis and performance analyses of PV systems. Most of these software have limited drawing capabilities. Users make modelling by roughly drawing the structure planned to install a PV system. However, BIM technology has become widespread, especially in developed countries. With this technology, information about the building to be built can be accessed as a whole [10]. This methodological approach is based not only on the geometric data of all components of the building, but also on 3D models of data related to timelines, cost estimates, energy supply, lighting, fire protection and installation method for construction. Software such as Revit, Allplan and ArchiCAD, developed for BIM analysis, are also available [11]. These software mostly perform the energy analysis of the PV system to be integrated into the building depending on the amount of radiation falling. Therefore, they have more limited analysis capability than PV system modelling software.

In this study, the 3D model of the family house was first created using Revit software using BIM technology, and the most suitable roof surface facades for the installation were determined depending on the amount of radiation falling on the roof surfaces in different directions. Then, 3D house model was transferred to PVsyst and PV * SOL software, and detailed analysis of PV panels was performed on the most suitable roof surfaces determined by Revit. The most important contributions of the proposed method are:

- ✓ Detailed analyses can be made by transferring the obtained 3D model to PV system software.
- ✓ The advantages of both BIM technology and PV system design and analysis software have been used together.
- ✓ More complex scenarios will be analysed with the proposed methodology.

The performance of a grid-connected PV system was discussed and analysed for a specific geographic location of a single family house that was proposed by the Turkish municipality of Elazig. BIM was integrated with photovoltaic system simulation. We have benefited from integrating the possibilities that were provided by the architecture software (Revit) with the simulation software (PVsyst, PV*SOL) for solar systems. Based on the BIM techniques, the southern and western sides were selected for installation of PV modules. BIM is one of the most important techniques that assists architects and engineers in sustainable design mainly because it provides a clear visualization of required designs. Analysis of the solar radiation of the specific site avoids the random installation of PV modules on roofs, thus making them compatible with modern buildings. The simulations have been performed on a grid-connected 6.96 kWh PV system by using PVsyst and PV*SOL. The compatibility of the grid-connected PV system makes it both an auxiliary and an alternative source of energy. Grid-connected systems work in parallel with the traditional power source; the energy provided by the PV system is also clean, free of harmful emissions and does not experience loss of transmission and distribution. As well as not having requirement for batteries, which makes the system less costly, its maintenance needs are much lower than stand-alone systems. The essence of this study is compression of the performance simulation of solar system, taking into consideration the BIM technology.

In the remainder of this study, a brief description of the importance of solar energy is provided. The methodology (design and simulation) is given in Sec. 2. The case study, geographical location and Building Information Modelling (BIM) are given in the third section. The fourth section contains the detailed description of the PV system and PVsyst and PV*SOL simulations, respectively. In the fifth section, the results and dissections are discussed. Finally, conclusions are presented in the sixth section.

1.1. Importance of Solar Energy

The sun is the main source of energy for the planet Earth. Each living organism on earth depends upon sunlight for its life energies and survival. Solar energy is considered the main source of the vitality of the earth where it gives 99.9% of vital warmth needed for various elements and living organisms. Solar energy is an inexhaustible source and is one of the most promising energy sources for generating electricity – besides it is environmental-friendly [12]. The average solar energy given by solar radiation on Earth exceeds the average energy consumption in the world by around 8000 times. Based on the total amount of solar radiation reaching the Earth, the per capita share of energy based on the total human population, is a very large value of up to 20 MW. Photovoltaic solar technology has been at the forefront of energy technologies with tremendous potential for sustainable growth for more than two decades, with solar power generating about 402 MW at the end of 2017. Solar cells have become reliable devices because they do not contaminate the environment and do not produce noise [13]. Because of global behaviour of low carbon development pathways, solar technology is gaining even greater importance. For all these reasons, the use of solar technology is increasing day by day despite the high cost. Therefore, solar energy is a promising source of renewable energy for a sustainable future and a clean environment.

2. Methodology

2.1. Design

This study used the architectural Revit software in the engineering design of the proposed home in 3D technology. The Building Information Modelling that was provided by the Architectural Revit software has been relied upon in the installation of the proposed PV system. The BIM tool provides the possibility of analysing the solar radiation falling on the site, as well as building information. Analysis of accessed solar energy can be used to determine the best building orientation of a side and to supply the daily incident rate of solar radiation values over the year. Also, it provides an indication of the solar radiation absorbed by rooftops and facades which is the major factor in assessing the performance of solar PV systems in buildings.

For this purpose, a 3D single family house in the city of Elazig, Turkey is modeled with Revit software. The house modelled was prepared completely in accordance with the real architectural project. Later, it was determined which roof directions received optimum irradiance throughout the year with Revit software. The designed 3D model is explained in detail in Section 3, together with the area where the PV modules will be installed. In the context of the scheme of the solar path that determines the height of the sun during the seasons, the angles of the azimuth and tilt were taken into account; these can be used to determine the ideal tilt of the rooftop.

2.2. Simulation

Based on BIM, implementation of simulation studies for photovoltaic systems was carried out by using PVsyst and PV*SOL software. These software have the capability of evaluating the performance of photovoltaic systems. This type of software has a large database of meteorological data for most sites around the world. The 3D family house project obtained with Revit software has been uploaded to both PV * SOL and PVsyst software. The number of PV panels and inverters to be used were determined, taking into account the most suitable roof surface and installed power determined by Revit. In order to create similar conditions, the same type of PV panel and inverter is preferred in both software. The technical specifications of the PV module and inverter used are given in Section 4.

The results are presented in a detailed report, including specific graphs, tables and detailed illustrations. Additionally, it is possible to export data for use in other software.

3. Case Study

The power of photovoltaic system at a given location can be evaluated through software simulation tools. This study was carried out to estimate the feasibility of a grid-connected rooftop solar photovoltaic system for a 3D single family house in the city of Elazig, Turkey. The simulation was done by usıng two software (PVsyst and PV*SOL) taking into consideration the building information module (BIM). Table 1 represents the main data for this study which is required by the design of solar system using the software mentioned above.

Table 1. Main data for the simulation studies

Parameters	Values
Latitude	38.67° N
Longitude	39.22° E
Load	6.96 kWh
Tilt angel	30 °
Azimuth angel	0.0
PV model	TSM-290DD 05A.08[II]
PV model capacity	290 W
Nb. PVs used	24
MPP Current	9.0 A
MPP Voltage	32.2V
Inverter	SE2200H
Nb. Inverter	3* 2.2 kW

3.1. Geographical Location

For the design of any solar system, the geographical location and the amount of solar radiation falling on the surface are the most important factors that control the energy yield. The proposed house for this study was located in the eastern Anatolia region at a latitude of 38.67° N, and longitude of 39.22° E, with an altitude of 1050 m. The chosen location of the study is a single family house with a small space available on the rooftop area (roughly 54 m^2) on the south and west sides. In fact, the deployment of PV systems on the roofs of buildings and the external facade is not without complexity, regardless of low-carbon footprint. The forms and locations of buildings greatly affect the energy produced from the PV systems that are deployed on their rooftop [14]. To enhance the energy produced from the PV system, all factors must be taken fully into account. In order to achieve compatibility between the energy produced and the design of the buildings, a technique of BIM was adopted in the design of the specific site. The Revit architecture software, which provides BIM technology analyzes the falling solar radiation and identifies the most suitable sides for the design of the PV system. The south and west sides of this given location were determined as suitable for installation of the PV system. The results of the analysis through BIM show that the southern and western sides harvest the largest amount of solar radiation as shown in Fig. 1. Throughout the year, the southern and western sides of the house receive solar radiation at an average rate of 250-303 kWh /m^2. Based on the above, solar panels were installed on the south and west sides.

Fig. 1. Analysis of solar radiation falling on the specified house by BIM tool.

3.2. Building Information Modeling (BIM)

Building consumption of energy produced is up to 40% with the growing consensus that photovoltaic systems are one of the best solutions to improve building power. Improving the performance of the PV system located on the roofs of buildings entails many concerns because of the complexities of external construction. In order to simplify the complexities in modeling the building with the integration of solar radiation analysis into the building system, BIM was used. BIM provides automation of solar radiation analysis and a plan to deploy the PV system selectively. PV panels are deployed in areas of abundant solar radiation based on solar radiation analysis as shown Figure 1. BIM provides optimization of PV system design, increases energy production and reduces investment cost of the PV system. Therefore, the best understanding of the advantages and applications of BIM in the design of sustainable construction should be achieved as it is a modern and promising technology. The adoption of BIM technology in the early stages of sustainable building design improves its efficiency and makes it more sustainable.

3.3. Inclination and Orientation

To obtain the highest value from the solar radiation of the specific site, the angles of inclination and azimuth must be determined, ideally. The best orientation depends on the path of the sun for the specific location throughout the year as shown in Fig. 2 and 3 respectively. PV panels are placed to 30^{o} of tilt angle and 0 degree of azimuth angle as these values are very close to the results obtained in Ref. [15]. The tilt angle is compatible with the design inclination of the rooftop.

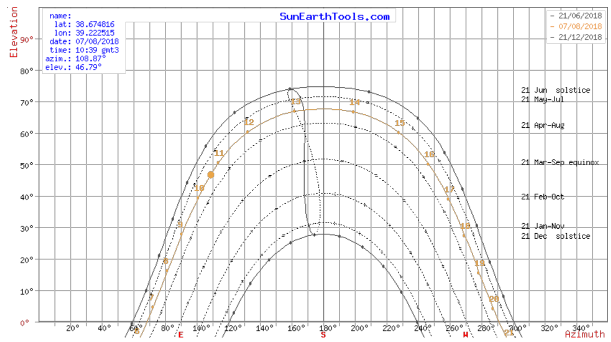

Fig. 2. Sun path of Elazig city.

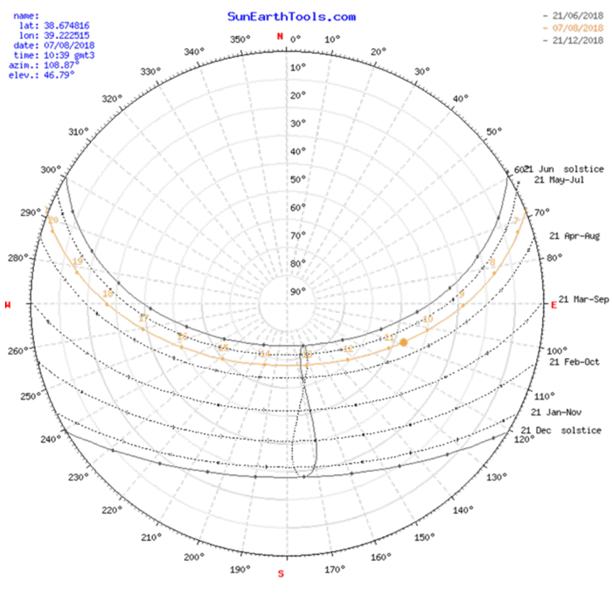

Fig. 3. Movement of the sun during the seasons.

4. Description of PV System

It is a well-known fact that to evaluate or design any PV system, in most cases a lot of obstacles affecting the energy produced need to be considered. Climate conditions and shadow factors are not controllable and have a negative impact on photovoltaic system production. The elements and methods used in the photoelectric system also determine the efficiency of the PV system. Therefore, it is very important to select them according to criteria that increase system efficiency. In actual fact, the space available on the roofs of houses is limited. Adoption of BIM helps to obtain a sustainable design of the PV system through an irradiance analysis of the specific location. The number of PV panels installed on the south side numbered 14 while 10 PV panels were installed on the west side according to the required energy and the efficiency of the PV panels. It is necessary to improve the performance of the photovoltaic system that is subjected to a variety of complex factors. In this study, the PV system was connected to the grid to provide a power source that works in parallel with the grid and does not need batteries for storage. Orientation and tilt angles have an effect on improving the performance of the photoelectric system, so they must be calculated accurately. Therefore, the rooftop tilt of the proposed house is designed to be compatible with the optimal PV panel tilt, which was 30 degrees.

4.1. PVsyst Simulation

PVsyst software is one of the leading tools in the design and simulation of solar energy systems in large-scale commercial projects and small-scale systems, which give accurate assessment and results of the requirements of the systems to be established [16]. PVsyst program is one of the important programs in the applications of design of solar systems that connected to the electrical grid or isolated from it and design of irrigation systems. Another benefit of the software is that it demonstrates the behavior of solar panels according to the intensity of solar radiation, temperatures and shadows. The PVsyst program contains a database of commercial solar panels and inverters. The PVsyst program support ac-load simulators, dc loads, pump systems that used for water and simulates the effect of shadows using a 3D property. The results of the program are in the form of an integrated report containing the calculations of the intensity of solar radiation, the annual production of the design, the number of panels, batteries, interferometers, methods of linking and the amount of losses that occurred. The PVsyst software provided the possibility of importing solar radiation data from the archived solar radiation database of NASA and several other sources. Finally, the program analyzes the economy and the amount of revenue.

In this study, PVsyst was used to simulate the proposed solar system of the abovementioned site. It also provides the possibility of optimizing the angles of tilt and azimuth by simulating different tilt angles and azimuth. Figure 4 shows the view of the location in relation to the position of the sun according to the height and dimensions provided by the architectural Revit software that was used for designing the geometric shape of the house. In Fig. 4, the space allocated for the deployment and installation of the PV system is shown in blue on both the south and west sides.

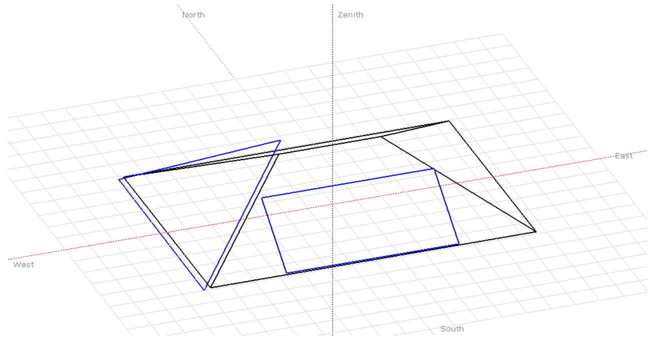

Fig. 4. View of the site for the sun position.

The basic results of the simulations will be presented in the form of tables and diagrams to give a clear idea of the valuation for the proposed solar system. Results include quantity of energy produced, details of incident radiation on the site, the duration of insolation, and economic evaluation. This simulation also explains the effect of temperature and humidity on the performance of PV system. The amount of losses given by PVsyst software is very close to the actual values. All the studies that have used the PVsyst software in simulating solar systems recommend using it due to the abovementioned advantages. The simulation results for this study using the PVsyst software are described below as figures, diagrams and tables. Figure 5 shows system schema, while Table 2 and Fig. 6 represent the outline of the simulation results, and components of the solar system respectively.

Table 2. Main results of simulation

3D single family house
Balances and main results

	GlobHor	DiffHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	
January	61.2	29.84	-1.38	71.2	68.2	473	465	0.938
February	84.7	34.30	0.51	91.4	88.0	599	590	0.927
March	125.7	48.70	6.91	129.0	124.8	814	803	0.894
April	147.1	71.56	11.83	146.4	142.0	911	899	0.882
May	187.7	76.08	16.97	176.3	170.8	1062	1049	0.855
June	215.8	70.54	22.86	202.4	196.5	1174	1160	0.823
July	216.9	76.93	27.43	205.5	199.2	1171	1157	0.809
August	215.8	52.70	27.11	213.5	207.5	1214	1200	0.808
September	158.6	44.60	20.84	161.1	156.1	942	930	0.830
October	114.2	41.63	14.70	122.2	118.0	748	737	0.867
November	70.9	33.27	6.52	78.3	74.9	500	492	0.903
December	53.4	25.57	1.24	63.5	60.5	416	408	0.923
Year	1652.0	605.73	13.04	1660.8	1606.5	10022	9890	0.856

The above table gives the monthly rates of the details of horizontal global irradiation (GlobHor), horizontal diffuse irradiation (DiffHor), ambient temperature (T_Amb), incident global irradiation in the collector plane (GlobInc), effective global (GlobEff) irradiation after all optical losses (shadings, IAM, soiling), array energy for the performance ratio evaluation (EArray), grid energy (E-Grid) and calculated performance ratio (PR) of the specific side respectively.

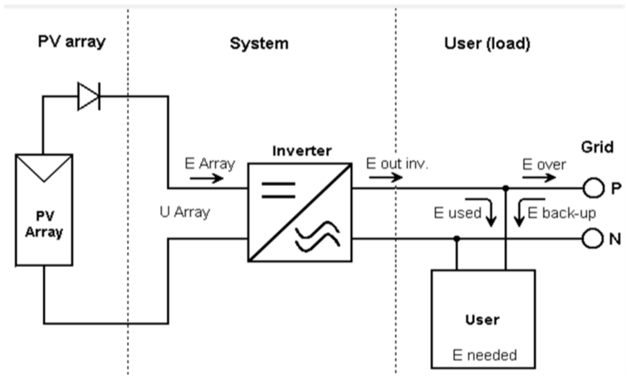

Fig. 5. System schema of the PVsyst simulation.

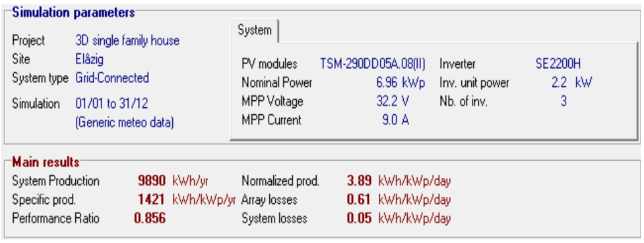

Fig. 6. Results and variant of PVsyst simulation.

The performance ratios, the daily energy injected into the grid, the normalized production and the daily diagram for the input and output of the energy are illustrated in Fig. 7-10 respectively. Finally, Fig. 11 depicts all losses of the solar system.

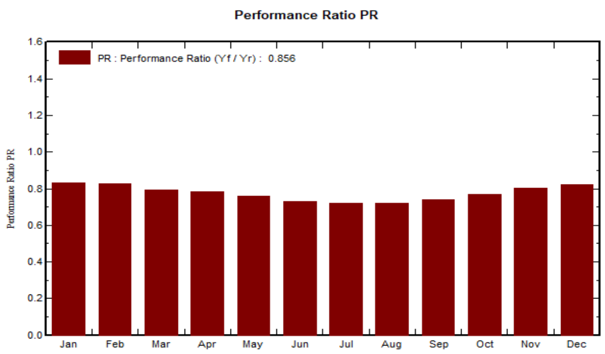

Fig. 7. Monthly performance ratios of PVsyst simulation.

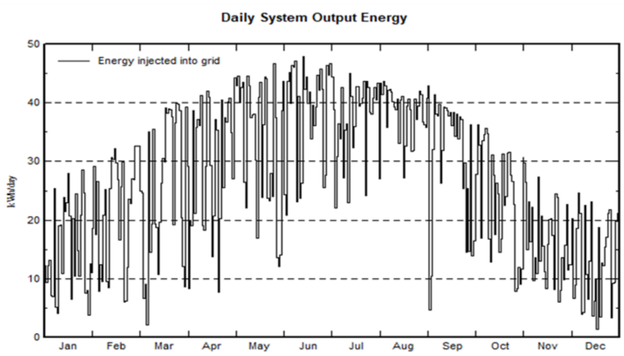

Fig. 8. Daily energy injected into grid.

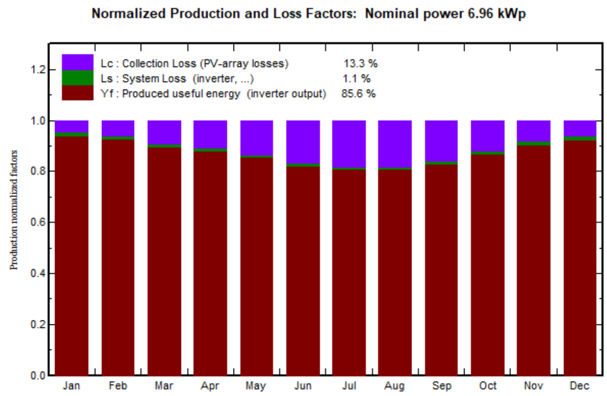

Fig. 9. Normalized production and loss factors.

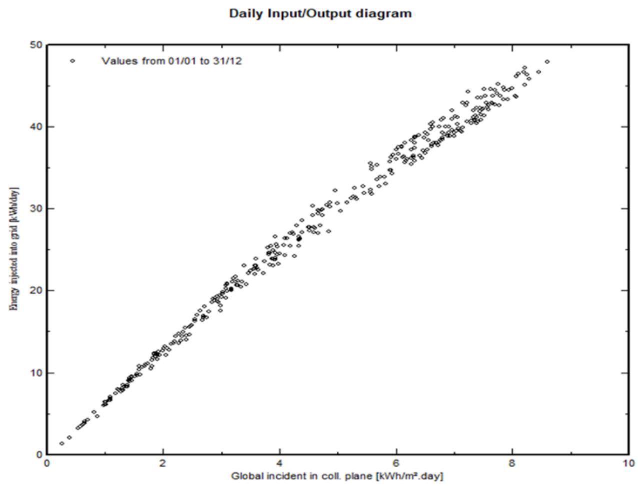

Fig. 10. Daily input and output energy diagram.

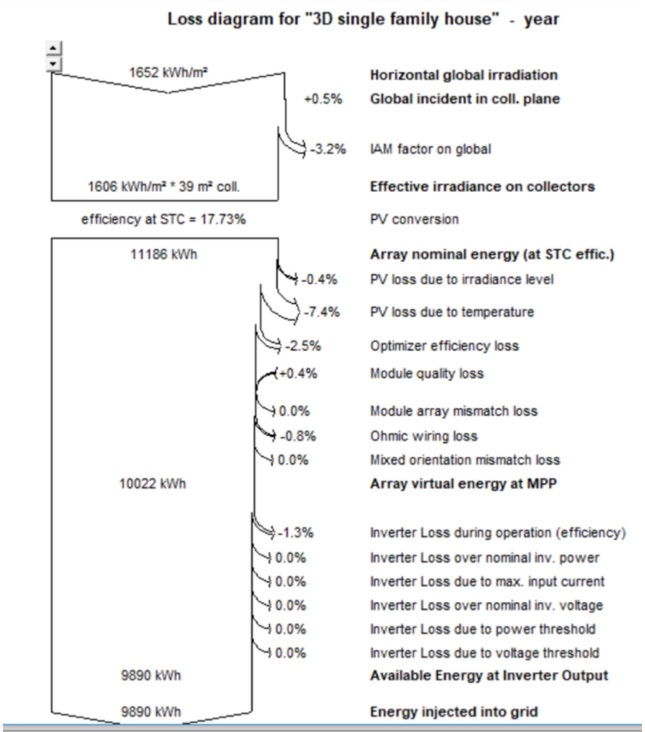

Fig. 11. Details of losses for the solar system.

*4.2. PV*SOL Simulation*

PV*SOL provides excellent support for the evaluation and design of photovoltaic systems. The software provides many possibilities that give an accurate assessment of energy yield and important data. The effect of ambient temperature, humidity and shading factors on the performance of the PV system is calculated in detail by this software. PV*SOL features integrated photography of all photovoltaic systems, whether installed on the surface, ground or even windows. The orientation and tilt of photoelectric panels can be optimally determined in this software. The total area required for the deployment of photovoltaic panels is calculated by taking into account the periodic maintenance, and preventing the effect of shadows. PV*SOL has a large database including climate data, solar radiation details, and also provides a perfect selection of solar system components through the most popular solar energy companies. The most important features of the PV*SOL software are the possibility of importing real and detailed images of 3D models and then studying the mechanism of installation of the PV system. This feature has been applied in this study by importing 3D image of the suggested house. The originally proposed house for this study was designed by Revit architecture program which provides 3D and BIM technologies. The photovoltaic panels were deployed by 14 panels on the southern side and 10 panels on the western side, based on the solar radiation analysis that was provided by the BIM technique as shown in Fig. 12.

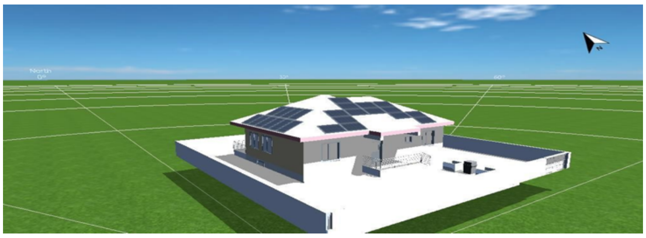

Fig. 12. PV panels are installed on the south and west sides of the proposed house.

Table 2. PV*SOL simulation data for west side

3DS 01-Sketched mounting surface 01	
PV Number	10
PV Generator Output	2.9 kWp
PV Generator Surface	16.3 m2
Global Radiation	1530.9 kWh/m2
PV Generator Energy	3626.4 kWh/year
Spec. Annual Yield	1250.5 kWh/kWp
Performance Ratio (PR)	82.5 %

The figure above shows the 3D image of the proposed house imported from the architectural Revit software. The amount of energy produced, surface area, amount of radiation per side and performance ratio of each side are shown in Tables 2 and 3 respectively.

Table 3. PV*SOL simulation data for south side

3DS 02-Sketched mounting surface 02	
PV Number	14
PV Generator Output	4.06 kWp
PV Generator Surface	22.8 m2
Global Radiation	1784.8 kWh/m2
PV Generator Energy	5945 kWh/year
Spec. Annual Yield	1464.3 kWh/kWp
Performance Ratio (PR)	82.8 %

In addition, PV*SOL provides a detailed economic report of the solar system. PV*SOL software is used for the simulation of 6.96 kWh grid-connected PV system in this study together with PVsyst software. The simulation results include energy yield details, solar radiation, ambient temperature performance ratio and economic feasibility as shown in Fig. 13-17 respectively.

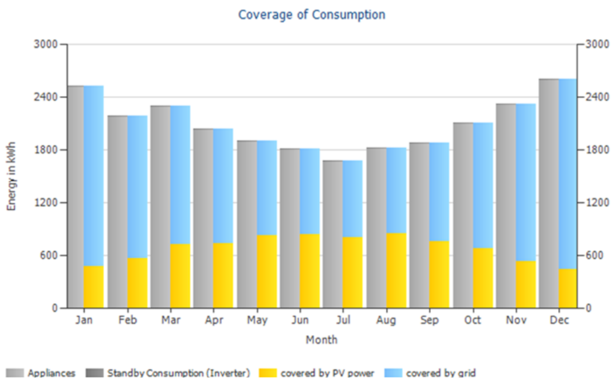

Fig. 13. Coverage of monthly energy consumption.

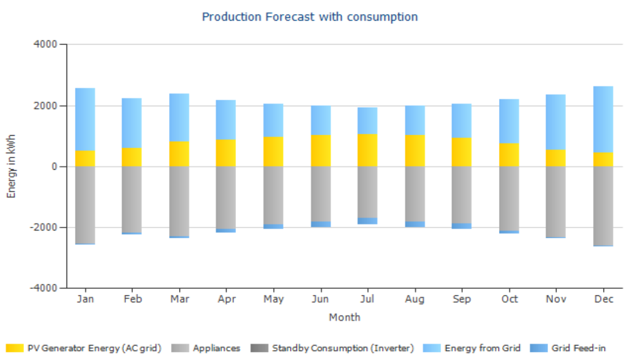

Fig. 14. Monthly rates of energy production with consumption.

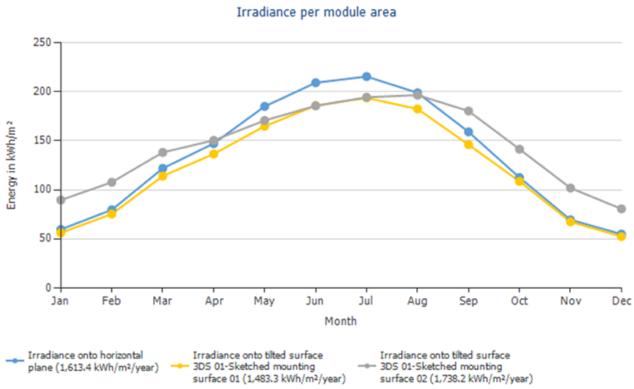

Fig. 15. Monthly rates of incidence irradiance on the PV panels for each side.

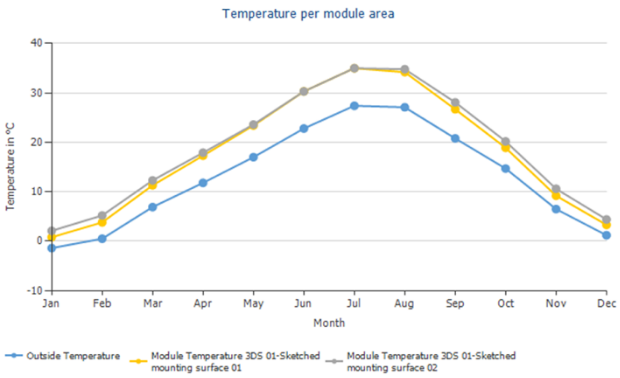

Fig. 16. Temperature of the PV panel with ambient temperature for each side

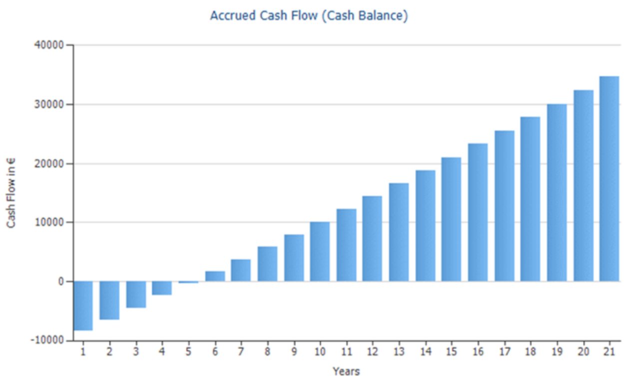

Fig. 17. Economic feasibility

The figure above shows economic feasibility of this study by using PV*SOL software. The proposed project is able to recoup the financial cost outlay during the first five years of its operation.

5. Results and Discussion

5.1. Performance Ratio

The most important parameter of the PV system is the performance ratio. Performance ratio parameters give the full picture of the system performance analysis. Some parameters are necessary such as reference yield (Y_r) and final system yield (Y_f) to calculate the performance of the solar system connected to the grid, as detailed in [17]. Reference yield indicates the amount of energy produced from the photoelectric system when the system operates in standard conditions and is usually installed on the name plate details of the array manufactured at STC. On the other hand, final system yield indicates the amount of energy injected to the grid on annual, monthly or daily basis. It is also known as ratio of AC energy output of the photovoltaic system to the peak power. The PR can be calculated as dividing final system yield by the system reference yield (Y_f / Y_r) and is defined as the final ratio between the actual yield of the energy that is supplied to the conventional grid and energy mentioned in the data sheet (target yield). Performance ratio is very significant in determining the efficiency of the PV systems.

According to simulation results, the monthly performance ratios of PV*SOL and PVsyst simulations are obtained. The annual average PR obtained from PV*SOL is 82.5% whereas the PR value of PVsyst simulation is 85.56%. It is thought that the small difference in the results obtained from PVsyst and PV*SOL is due to the different meteorological databases they use.

5.2. Solar Resource Potential

Solar energy is the most easily obtainable source of energy as well as being a clean form of energy. One of the most important inputs in professional assessment of the performance of photovoltaic systems is solar radiation. The weather data of the site (wind speed, ambient temperature, solar radiation, humidity and pollution) as well as latitude, longitude, orientation and shading factors, are determinants of performance analysis. Humidity and ambient temperature greatly affect the output yield of the photoelectric system. High humidity during the night forms a layer covering the solar panel thus affecting the photovoltaic output energy. Similarly, ambient temperatures that exceed the minimum and maximum limits also influence the photovoltaic power. The peak energy production of solar systems in this locality is in June, July and August, where the irradiation rate was about 217 kWh/m^2. Minimum production is measured in the month of December, where the irradiation rate was about 53.4 KWh/m^2.

5.3. Performance Parameters

The fundamental energy source on earth is solar radiation. The energy yield relies on approaching radiation combined with weather data of the site and the characteristics of the solar panel. The highest energy production was in the months of June, July and August (1100-1200 kWh), while the lowest rates of energy production were in the months of December and January (400-465 kWh). The simulation results of yearly output energy obtained from PVsyst and PV*SOL simulations are similar as shown in Fig. 19. The percentage difference in simulation results for both software do not exceed 3%. Yearly energy feed to grid is 9890 kWh for PV*SOL while this value is 9571.4 kWh for PVsyst.

When we look at the horizontal global irradiance values, the PV*SOL has the bigger value (about 3.3%) than the PVsyst. In addition, the specific energy production value of the installed PV system is 1421 kWh/kWp/year for PV*SOL and 1334 kWh/kWp/year for PVsyst. This means that the PV system simulated with PV * SOL produces 87 kwh / year more energy per kWp installed power than PVsyst. Considering that PV * SOL and PVsyst software use different irradiance and climate data, it can be said that the differences in the results are quite reasonable. This success was achieved by using BIM technology in the design of PV system. It is obvious that drawing the PV system project in each software separately will increase the margin of error in the results to be obtained. The values of the main performance parameters are shown below in Table 4.

Table 4. Summary of Performance parameters for PV*SOL and Pvsyst.

Performance parameter	PV*SOL	PVsyst
GlobHor (km/m^2)	1652	1613.4
Energy feed to grid (kWh/year)	9890	9571.4
Spec. product (kWh/kWp/year)	1421	1334
PR (%)	85.6	82.7
Efficiency of the PV module (%)	17.7	17.7

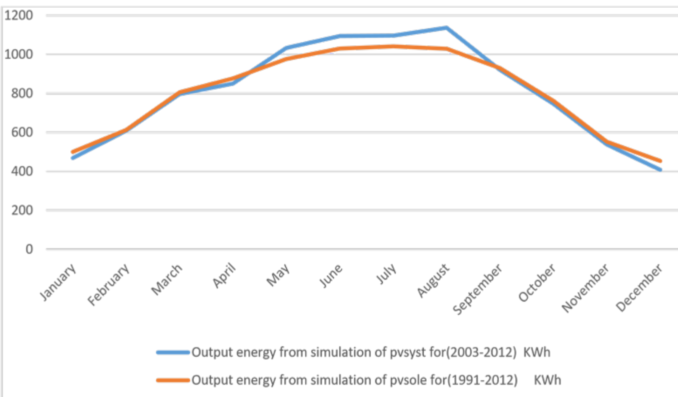

Fig. 19. Monthly output energy from PV*SOL and PVsyst simulations.

6. Conclusion

Sustainable design is rendered more advanced by integrating BIM technology. BIM establishes guidelines and framework that will help architects and designers to use BIM technology in the early stages of building design. BIM-Based on, provides a selective environment for the installation of the PV system in small rooftops areas with optimized design. The photoelectric system was installed on the rooftops of the south and west sides of the proposed house because they have abundant solar radiation based on BIM technology. In this study, simulations were carried out to evaluate the technical performance of a 6.96 KWh PV system connected to the grid on the roof of the house specified. A simulation had been done of mono crystalline solar PV modules to determine the energy yield, consumption of energy, performance ratios and energy feed in the grid. PVsyst & PV*SOL were the software used to simulate this study. The difference in the foreseen value of energy output, performance ratio, and energy yield are due to the slight difference in the database among simulation software. Comparison results for simulations by PVsyst and PV*SOL were very close to each other, as the difference in the performance ratio was not more than 3%. This study provides valuable information for power generation on rooftops under a sustainable design that meets household requirements. This study indicates that the performance of the photovoltaic system for power generation in the Turkish city of Elazig is extremely viable. In addition, this study reinforces the quest for sustainable building by integrating the tool of BIM into the design of photovoltaic systems on the rooftops of homes. The feasibility of this study on a wider scale has much potential in enabling the providing of clean energy and thereby contribute to reducing emissions of harmful gases.

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