Ann. For. Res. 66(1): 1158-1170, 2023
ISSN: 18448135, 20652445

ANNALS OF FOREST RESEARCH
www.e-afr.org

USE PVSYST AND HELIOSCOPE SIMULATION TOOLS TO EVALUATION OF ON-GRID PV SYSTEM PERFORMANCE UNDER BAGHDAD CITY CLIMATE

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Abstract The HIT (Heterojunction with Intrinsic Thin-layer) technology for the manufacture of solar panels is one of the techniques that depends on the crystal structure of different crystalline materials in their crystalline structure, this technology provided good specifications for its adoption in the manufacturing of solar panels. This research presents a performance evaluation of the solar photovoltaic system connected to the grid with a capacity of 15 kWp as real data and compare it with the hypothetical data of two simulation tools (PV-syst, HelioScope) to find out the extent of the deviation of the HIT solar system from the hypothetical values. The results were that the performance ratio (PR) for the real system and PV-syst program (for year no: 10) is about 74%,79%respectively. performance ratio of PVsyst and HelioScope simulation tools (for year no: 1) is about 83.22%,84% , The difference between the energy output values of the actual system and PV-syst tool(for year no: 10) is1164 KWh and The difference between PV-syst and HelioScope software systems (for year no: 1) is 1190 KWh. There are some evaluate results, in most important expected photovoltaic losses that effect on the module performance were estimated by PV-syst and HelioScope software tools due to irradiance level and temperature losses ware 0.45 % ,7.42 % and 0.2% , 6.2 % , respectively. The performance and productivity results of the photovoltaic system indicate the quality of performance of HIT technology in the climatic conditions of the city of Baghdad.

Keywords: Performance PV solar system, HIT technology, Grid-connected, PVsyst , Helioscope.

Introduction

The topic of ever-increasing energy consumption is one of the most important issues being studied by researchers worldwide. Fossil fuels are becoming scarce and expensive. Oil and uranium are scarce resources that will be depleted in a few decades. Coal, a major energy source, will run out in a few hundred years. It is crucial to keep the environment safe during the energy production process [1].Photovoltaic (PV) systemscan be viewed as the most significant because they are static, silent, immovable, vibrationless, and free of moving parts; furthermore, they have low operating and maintenance expenses, despite their high production prices, which are still decreasing [2].A single photovoltaic cell has an approximate capacity to provide 1 to 2 W of power. PV cells can be linked to create higher power modules for increased power output. A set of modules can be joined together to form an array depending on the power plant capacity or electricity generation [3]. When the energy of the photovoltaic system is insufficient to operate the devices, it will draw energy from the electrical grid, However, when it contains an excess energy production, it will export it to the electrical grid. This connection does not need batteries to transfer energy between the PV system and the electrical grid. When PV solar systems are insufficient to run all loads, government sectors turn to grid-connected systems, which directly supply the utility grid, while also drawing power for their buildings from the utility grid. This is the case (the government sector case) with the solar photovoltaic system studied here[4].More research as conducted worldwide about the performance analysis and parameters of on-grid PV solar systems. Naseer. K.Kasim,et al.[5][6][7],conducted a study on the evaluation of performance through dust depositing and treatment by tracking the panel, and discovered that when the tracker panel bends down to gather solar radiation at sunset, dust deposits down due to gravity. AlaaN.Abed et al[8],have improved Some electrical parameters (solar radiation, array efficiency, current, performance ratio,electrical power) of PV solar systems on-grid using planer concentrators (optical reflectors).The second generation technology (CIGS), an abbreviation for Copper Indium Gallium Selenide, was used. The performance ratio ranged from 86.6%to95%, and efficiency ranged from13.1% to14%. Sandhya Thotakura[9],et al,they evaluated the performance of a megawatt scale rooftop PV solar system for an educational institution in dry and humid climates in India. Validation is performed by comparing the simulated results to the actual results. There are 23 inverters and solar panels in this system. The average mean bias error (MBE) was 5.33 %(PVGIS), 12.33% (PV Watts), and 30.64 % (PV Syst), with the average normalized mean bias error (NMBE) being2.954%(PVGIS),7.88%(PVWatts), and 22.75%(PV Syst). performance ratio of the solar PV plant is around 88%. PVSyst had higher energy yields and PR in the comparison simulation analysis. There was difference between simulated and observed energy performance. VS Chandrika [10], et al, they made an evaluation of the system efficiency for PV connected-grid 250 kWp under different ventilation conditions in southern India. The three systems (BIPV) building integrated photovoltaic without ventilation, (BIPV_V) building integrated photovoltaic ventilated, (FSPV) free-standing pv. PVsyst software was used to simulate these systems. Electrical efficiency for BIPV/BIPV_V and FSPV system is 14.75%, 15.25% and 15.45% respectively.The highest performance ratio was 0.82% while the lowest performance rate was 0.70%.This research will help architects and the general public design roofs using GPVsystems that are more aesthetically pleasing while also providing noise reduction and thermal insulation in equatorial temperature zones. Sonali Goel and Renu Sharma[11], published a paper about analysis and simulated performance of PV system a grid-connected 11.2 kWp in bhubaneswar- india by using pvsyst and helioScope software. The system is made up of 40 polycrystalline silicon modules that are slanted at a 21° angle towards the south. The annual average ambient temperature and solar irradiation is 26.16 °C and 1783.9 kWh/m2. The performance ratio for measured, pvSyst and helioScope is 81%, 78.07% and 75.20%, respectively. The major purpose of this study is to assess the performance of a 15kWp HIT technology grid-tied PV system and compare it with the results of two simulation tool (PVsyst and Helioscope) in Baghdad, Iraq.

performance analysis

PV Solar systems can vary in performance depending on their design methods and locations [12]. and can assessment PV system performance by the following equations:

The Energy Produced

This parameter indicates the amount of alternating current energy that exits from the photovoltaic system during operation, and the energy production can be calculated on an hourly, daily, and monthly basis, as in equations 1to3[13]:

$$\mathrm{EAC,h.} = \sum_{t=1}^{60} \mathrm{EAC,t} \qquad \text{(Eq.1)}$$

$$\mathrm{EAC,d.} = \sum_{h=1}^{24} \mathrm{EAC,h} \qquad \text{(Eq.2)}$$

$$\mathrm{EAC,m} = \sum_{d=1}^{N} \mathrm{EAC,d.} \qquad \text{(Eq.3)}$$

Where:EAC,t,EAC,h,EAC,d,EAC,m it expresses the alternating current energy calculated in minutes; hour; daily; monthly and N Indicates the number of days of the month.

Performance Ratio

It is a very important factor that shows the total losses of the solar photovoltaic system. The performance ratio indicates how close the photovoltaic system to the ideal performance (100%)during the actual working time.[14]. The performance ratio is defined as the ratio the final Yield (YF) to the reference Yield (YR) of the PV solar system [15], and Equation 4 gives it.

$$\mathrm{PR} = \frac{\mathrm{YF}}{\mathrm{YR}}\% \qquad \text{(Eq.4)}$$

Where Final yield (YF) represents AC energy (after converted from DC energy by inverter) and be either (daily (YF,d)) or (monthly (YF,m)) by rated (nominal) power for installed PV array [16].It is expressed as:

$$\mathrm{Y_F} = \frac{\mathrm{EAC}}{\mathrm{PPV;rated}} \qquad \text{(Eq.5)}$$

And reference yield (YR) refer to ratio Ht (In collimated) solar irradiation in unit(W/m2) to Hr (Reference -solar irradiation) in unit (W/m2) during standard test conditions(STC) (1kW/m2) [17] as follows:

$$\mathrm{Y_R} = \frac{\mathrm{Ht}}{\mathrm{Hr}} \qquad \text{(Eq.6)}$$

The Capacity Factor

Is the number of times the module is working at confirmed nominal electrical power. The capacity factor is precisely the AC energy produced by a PV system to the nominal PV system installed[15]. Capacity factor it is given by the following equation:

$$\mathrm{CF} = \frac{\mathrm{EAC}}{\mathrm{Ppv,rated}} \qquad \text{(Eq.7)}$$

EAC represents the AC energy.(the energy after converted from DC energy by inverter).

Degradation Rate

Degradation, which is brought on by operating circumstances, is the progressive degradation of a component's or a system's characteristics that may impact its capacity to function within the parameters of acceptable criteria [18]. Calculating the Degradation Rate (DR) is as follows:

$$DR = \frac{\text{initial PR} - \text{final PR}}{\text{initial PR}} \quad \text{(Eq.8)}$$

Simulation of PV Solar System

The main part of the simulation software, which provides us with a complete study of the project, is the project design and simulation process. This design includes the selection of climate data files; system design; shading; Determining the values of losses and economic evaluation.The simulation takes place on an annual basis and has hourly steps and at the end provides a complete report file on the project.

PVsyst

PVsyst contains a set of tools for studying, sizing, and analyzing PV arrays. Numerous meteorological and PV system component databases, in addition to generic solar energy tools, are supported, including grid-connected, stand-alone, pumping, and DC-grid PV systems. The program is helpful for architects, engineers, and academics. It also has potential as a teaching tool. Swiss physicist Andre Mermoud and electrical engineer Michel Villoz developed PVsyst[19]. When it comes to designing and simulating photovoltaic (PV) systems, this program is universally considered to be the gold standard. The latest release, V7.2, has a trial period of 30 days in DEMO mode. There is an approximate $631 price tag for the unlimited version. Windows software PVsyst V7.2 can access PVGIS and NASA databases for irradiance data import. The four (4) main elements of PVsyst are preliminary design, project design, databases, and tools. Plane orientation, system components, PV array (number of PV modules in series and parallel), inverter model, battery pack, and so on are all inputs into the simulator, which then runs the simulation. A comprehensive report can be generated for each simulation run, detailing not only the run's main outcomes but also all of the simulation's settings[20]. Pvsyst software has 3 limitations as follows:

- The screen cannot be enlarged in the program and this causes boredom in seeing the parameters if the use is in a small screen.
- unavailability to control shadow research with accuracy.
- No single line diagram.

Helio Scope

It is one of the new simulation programs that was introduced by Folsom Laboratory in the United States of America to design photovoltaic systems. It incorporates some attributes of PVSyst and it adds design-specific functionality from AutoCAD, and this allows designers to complete design in one package. HelioScope requires the following inputs: location address, array configuration, PV module and inverter specification. This software allows the user to estimate energy production while accounting for weather and climate losses. Panel mismatches, shading, wiring, component efficiencies for simulation results. This tool displayed yearly output, climate data set, performance ratio plus other system variables. It is a web-based tool, so there is no software to download and you can access it from any computer with an internet connection. You can pay a monthly or annual fee instead of purchasing the program. For the 30-day trial version, you must create a HelioScope account.[21]. HelioScope software has 3 limitations as follows:

- won't to back up financial analysis.
- It is true that feasibility analysis is not supported.
- Not even supported is advanced scientific calculation.

Distinctive Features of Each Model

There are some subtle distinctions between the PVsyst and HelioScope models that set them apart:

- Mismatch losses for each module and circuit effects are calculated independently by helioscope. In contrast, pvsyst uses derates specified by the user to calculate mismatch loss.
- Wiring losses in helioscope are calculated using current and resistance per conductor and hour, while in PVsyst they are calculated using user-defined derates.
- Light-induced deterioration is not particularly corrected by HelioScope (LID). Instead, the gains or losses from LID might be factored into the soiling losses.
- Module-level modifications to the IAM/reflection coefficients are not included in HelioScope. Instead, the value of the coefficient b0 for all modules is 0.05.
- PVsyst allocates 0 degrees for South facing Azimuth while HelioScope assigns 180 degrees.

Materials and Methods

PVsyst and Helioscope, simulation programs include the same actual options in terms of location, nominal power, azimuth angle, tilt angle, latitude, longitude and panel technology. The PV solar system lies in central Baghdad/Alwaziriyah region in the Training and Energy Research office,Iraq-Baghdad (latitude 33.3 ° N, longitude 44.4 ° E). The size of system is 15 kWp The system was related to the feeder that provided contentious electricity to the principal building and the Modules area is 83.57 m2. The current system has a tilt angle of 30° and an azimuth angle of 0°. The mentoring system connected to the sunny portal program that give us daily, monthly and yearly data of power production. The current investigation used 12 modules in string linked together in series to increase the voltage. The number of strings in system is six that are connected in parallel, leading to a higher output current. The total of module for PV solar array is 72 modules. A single solar module (HIT technology) has a power output of 205 W as shown in Figure 1.

Modules Technology of PV

The link between first generation technology (silicon wafer technology), second generation technology (thin film technology) and third generation technology (promising technology) produces novel technologies such as HIT technology (Heterojunction with Intrinsic Thin-layer)is the first module in the world and without competitor where the record of studies in different places showed the ability of panels to produce stable energy for more than 10 years and when compared to traditional homo- junction c-Si solar cells, HIT solar cells have low module degradation comparing with second-generation technologies, low temperature losses coefficient(-0.29 %/°C) and high efficiency reached 25.6% [22].HIT technology is Sandwiched between two layers of amorphous silicon is the efficient monocrystalline silicon part.The thin layer of monocrystalline silicon that serves as the sandwich's "meat" is referred to as "intrinsic thin-layer."Solar panels are usually classified as either crystalline or amorphous technology.The HIT panels are created by combining these into a single module[23].HIT solar cell structure as shown in Figure 2.

Inverter

The inverter transforms the direct current (DC) produced by PV modules into alternating current (AC). An inverter is a device that supplies synchronized frequency power into the utility grid (50 Hz). Maximum Power Point Tracking (MPPT) is a device installed into the inverter that can raise the voltage when it dips during hot days until it reaches the maximum power point . The inverter used in experimental work selected from SMA and has Maximum efficiency is 97%, model SUNNY TRI POWER 15000 TL.

Figure 1 HIT technology 15kWp Solar System Grid-tied.

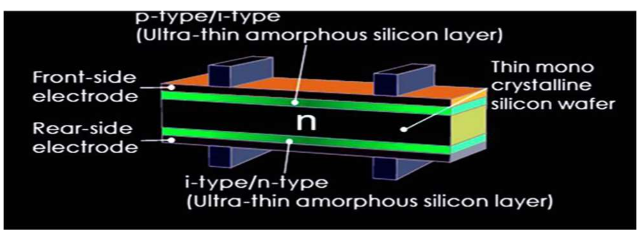

Figure 2 HIT solar cell structure[24].

Table 1 Electrical Specifications for HIT Photovoltaic module

Model	**HIT Power 205 or HIP-205**
Rated Power (Pmax)1	205 W
Maximum Power Voltage (Vpm)	40.7 V
Maximum Power Current (Ipm)	5.05 A
Open Circuit Voltage (Voc)	50.3 V
Short Circuit Current (Isc)	5.54 A
Temperature Coefficient (Pmax)	-0.29% / °C
Temperature Coefficient (Voc)	-0.172 V / °C
Temperature Coefficient (Isc)	0.88 mA / °C
Cell Efficiency	20.2%
Module Efficiency	17.7%
Watts per Ft.2	16.4 W
Maximum System Voltage	600 V
Dimensions L*W*H	1580*812*35 mm
Weight	15Kg

Result and Discussion

To find PV Energy Generation and final yield Figure 3. shows the ranges of energy production versus solar radiation in real system. The lowest value of electrical energy production was in December 1607.2KWh due to the influence of weather factors (little solar radiation intensity, rain, clouds) while the highest value of electrical energy production was in August 2198.28KWh due to the clear sky and high solar radiation intensity. The overall energy production for 12 months of year 2020 was 23346.49KWh, where the monthly average of 1945.5KWh. The total energy generated through 12 month by nominal power 14.76KWp for HIT solar system called energy yield is 1581.7 (kWh/kWp/year) and by dividing it by 365 days, we get a term final yield whose value 4.33 (kWh/kWp/day). The total solar radiation of POA (Plane Of Array) was 2172.3KWh/m2 in year 2020 and changes from 133KWh/m2 in December 2020 to 202.3KWh/m2 in July 2020, the lowest values of solar radiation were during the period of rainy days and cloudy weather, while the highest values were in clear summer days. The average monthly ambient temperature ranges from 16.8°C in January to 44°C in July. While the annual average was 30.3°C. As it is noted, the high temperature in August leads to a reduced in the energy production of the system, however in this month we get the highest value of energy production due to the higher number of sunrise hours that about (15 hs) and the highest intensity of solar radiation. Further, the least value for electric energy production was in December due to a decrease in sunrise hours (about 9 hours) accompanied by less intensity of solar radiation.

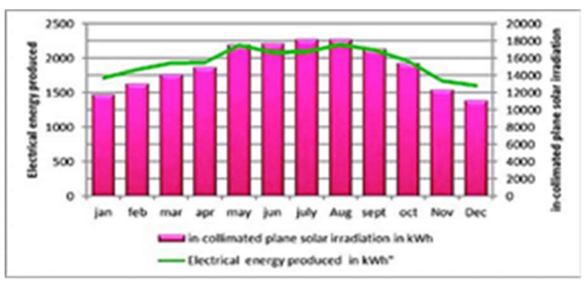

Figure 3 Energy produced and solar insolation in real system.

Figure (4,5). shows the ranges of energy production in (PVsyst, Helioscope) software systems. (PVsyst, Helioscope) software systems have average annual ambient temperature of 24.07 °C,24.4 °C respectively. The annual average energy production of the simulation software (PVsyst, Helioscope) (for year no: 1) is 25810kWh, 27000KWh respectively. The annual average energy production in PVsyst software(for year no: 10) is 24510kWh. The annual energy yield for (PVsyst, Helioscope) systems(for year no: 1) are 1748.6 kWh/kWp/year, 1829.2 kWh/kWp/year respectively, The annual energy yield for PVsyst(for year no: 10) is 1660.5 kWh/kWp/year and by dividing it by 365 days, we get a term final yield for (PVsyst , Helioscope) systems(for year no: 1)is4.7kWh/kWp/day,5kWh/kWp/day respectively.The final yield for PVsyst (for year no: 10) is 4.54 kWh/kWp/day. The simulation results can vary for each software. Guittet and Freeman conducted a PV performance ruse using four software packages including SAM, PVsyst, and Helioscope. The simulation deviations range from several.−7.0% to 5.5%.[25].

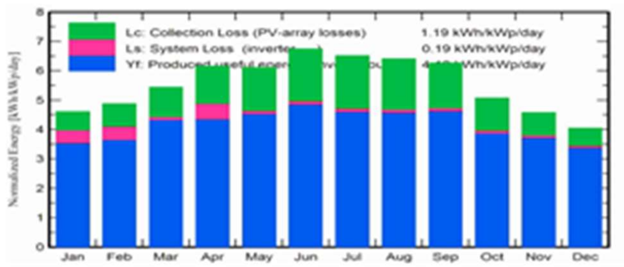

Figure 4 Energy produced in PVsyst software system.

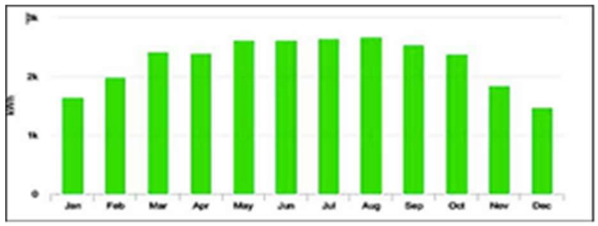

Figure 5 Energy produced in HelioScope software system.

Figure 6. shows the monthly average capacity factor and performance percentage in real system. The yearly average of performance ratio(PR) in test PV solar- system is 74%. The Max performance ratio(PR) with the coldest week(January) of 83% as well as the min performance ratio(PR) with the greatest month(July) of 65%. performance ratio(PR) It is a factor that shows how the performance in the real system approaches the ideal performance during the operation of the photovoltaic system [26] The performance ratio (PR) in test system decreases from May to August below the average, because the ambient temperature rises in these months. The annual capacity factor (CF) average is 18.06 %. CF has a maximum value of 20.02% in August and a minimum value of 14.64 % in December. The capacity factor (CF) is a parameter that indicates the time magnitude in percentage to turn on the PV solar system at full capacity. As a result, the test PV solar system operates at full capacity for nearly 67.16 days or 1611.84 hours per year. The capacity factor has a direct effect on the cost of power output for the PV solar system. As a result, the performance ratio (PR) and capacity factor (CF) are critical parameters for assessment grid-connected PV systems.In Mauritania, the capacity factor varies from 11.7 % to 20.5 % across the country[27]. the CF of the PV system in Malaysia was 10.47%. Our system has an annual average capacity factor of 14.64% to 20.02%, which implies it has the best capacity factor of all the systems above in terms of prevailing ambient temperature.

Figure 7.Performance ratio in PVsyst software system (for year no: 1,10). The annual rate of performance ratio (PR) of the system in (PVsyst, HelioScope) simulation tools(for year no: 1),which is equal to 83.22% ,84%,respectevily. The annual rate of performance ratio (PR) of PVsyst (for year no: 10) is 79%. The annual average capacity factor of (PVsyst, Helioscope) simulation tools (for year no: 1) 20% ,22 % was found that the difference small (only 1.94%,3.94%) in spite of the real system (HIT) works at air temperature bigger than (PVsyst, Helioscope) tools and this tools not takes cloud, rain and dust into consideration. There is a way used to improve the performance ratio and capacity factor of the PV solar modules by using optical reflectors and cooling [28].

Figure 6. Performance ratio and capacity factor of real system.

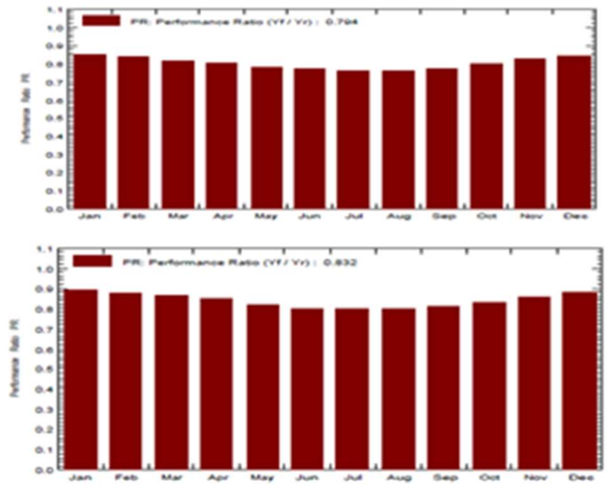

Figure 7 Performance ratio in PVsyst software system (for year no: 1, 10).

Figure 8. Energy injected into grid in 25 years. The rate of photovoltaic (PV) module deterioration is influenced by manufacturing methods, ambient factors, and technology. Transferring the findings of degradation analysis from one nation to another is so difficult. As a result, it is difficult to estimate how quickly PV modules would degrade in the hostile environment of hot, dry Iraq. Additionally, certain breakdown patterns are only visible after years of field work. The Japanese 15KW high efficiency system has a low rate of deterioration that doesn't go over 5%. which has a service life of more than 10 years and this means 0.4 %/year.

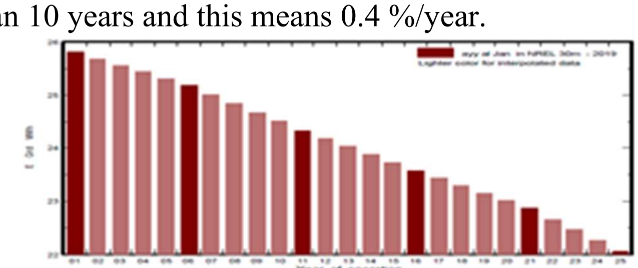

Figure 8 Energy injected into grid in 25 years by PVsyst software.

Table 2. Performance Comparison between real system with two software system.

Table 2. Performance Comparison between real system with two software system.

System	PV energy generation (kWh)	Energy yield (kWh/kWp/year)	Final yield(KWh/KWp/day)	Performance ratio(%)	Capacity factor(%)
Real data	23346.49	1581	4.33	74	18.06
PVsyst	24510	1660.5	4.54	79	19.7
PVsyst	25810	1748.6	4.7	83.22	20
HelioScope	27000	1829.2	5.0	84	22.0

Although the real system operates at high temperatures and is affected by dust, clouds, and rain, the difference is not significant, counter to the simulation tools outputs are at lower temperatures and are not affected by dust, clouds, or rain. This indicates that the practical measurement findings were excellent because they matched to the simulation tools results closely. Variables like as soiling, shading, array mismatch, and wiring losses cause solar PV simulation results to differ from actual performance. After the researchers were able to evaluate the performance of the actual system by finding the convergent values of energy production between the simulation tools and the actual system, they were able to calculate the expected losses for the actual system through simulation tools Figure 9. Sources of System Loss in HelioScope software.

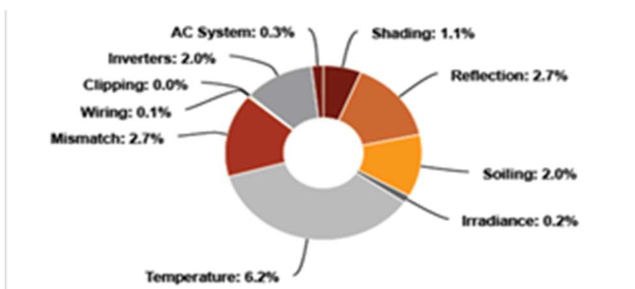

Figure 9 Sources of System Loss in HelioScope software.

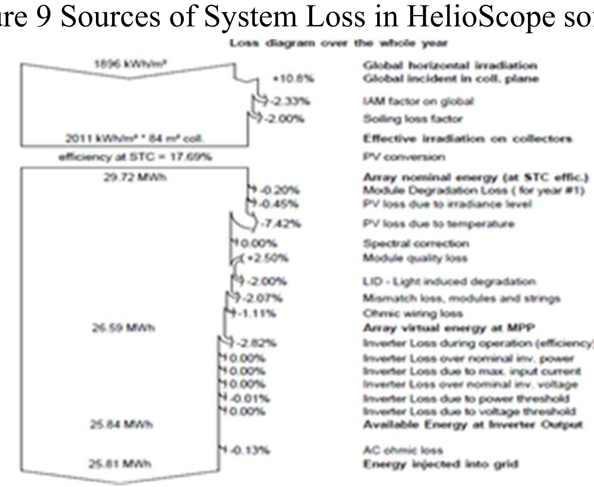

Figure 10 Sources of System Loss in PVsyst software.

Conclusions

In the current study, many facts were confirmed:

- PV Energy Generation of HIT system near from simulation tools(PVsyst and Helioscope) , which is an ideal systems that is not affected by rain, clouds and dust. It works with an annual rate of ambient temperature of 24.07°C and 24.2°C unlike the real HIT system, which has an annual rate of ambient temperature of 30.3°C and is affected by rain, clouds and dust. This means that the real system (HIT System) is not significantly affected under hot weather for the city of Baghdad respect to temperatue coefficient of module that equal to (- 0.29%/ °C).
- Annual average performance ratio and capacity factor are found to be 74% and 18.06 % respectively, which is within the range of studies conducted in other countries. Annual degradation rate is determine based on performance ratio of the system and is found to be 0.4 %/year.
- The difference between the energy output values of the actual system and PV-syst software (for year no: 10) is 1164KWh while the difference values between PV-syst and Helioscpe software systems (for year no: 1) was 1190KWh. This difference was due to the different weather data for each software.
- There are some evaluate results, in most important expected photovoltaic losses that effect on the module performance were estimated by PV-syst and Helioscpe software system due to irradiance level and temperature losses ware 0.45 % ,7.42 % and 0.2%, 6.2%, respectively.
- One of the disadvantages of HelioScope tool has been identified, which is that it does not perform simulations to after the first year of operation.
- The performance ratio (PR) of pvsyst software is lower than (PR) of helioscope. This is because pvsyst calculates the degradation factor which is estimated (0.4%/year) while helioscope not calculated the degradation factor.

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