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Photovoltaic System Performance in Iraq Using PVsyst: A Review of Literature

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Abstract :

Iraq has strong solar resources, but it also faces a serious need for stable and reliable electricity. Because of that, both grid-connected PV systems and stand-alone (off-grid) systems can be practical solutions in different situations. The paper reviews several studies that used PVsyst in different Iraqi locations and with different system configurations. Most studies aimed to improve system performance by adjusting the tilt angle, identifying where the main losses occur (such as temperature effects, dust/soiling, and shading), or selecting PV technologies that better fit Iraq's climate conditions. Overall, the findings show that PVsyst can provide detailed predictions about system behavior, expected energy production, and areas where the design can be improved. However, the review also highlights some limitations. Many simulations assume fixed tilt angles, the results are not always validated with real field measurements, and the economic analysis is missing or not fully developed in several works. Even with these issues, the review confirms that PVsyst remains a valuable predictive tool for planning solar projects. It supports better system design and can help develop PV solutions that are efficient and cost-effective in Iraq, and in other regions with similar climates.

Keywords - PhotoVoltaic (PV) system, PVsyst software, Energy Production , Performance Ratio, Economic Indicators.

أداء الأنظمة الكهروضوئية في العراق باستخدام برنامج PVsyst: مراجعة للأدبيات

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مستخلص:

يمتلك العراق موارد شمسية قوية، لكنه يواجه أيضًا حاجةً كبيرة إلى كهرباء مستقرة وموثوقة. لذلك، يمكن أن تكون كلٌّ من أنظمة الخلايا الكهروضوئية المرتبطة بالشبكة وأنظمة الخلايا الكهروضوئية المستقلة (خارج الشبكة) حلولًا عملية في ظروف مختلفة. تستعرض الورقة عدة دراسات استخدمت برنامج PVsyst في مواقع عراقية مختلفة ومع تكوينات متنوعة للأنظمة. وقد هدفت معظم الدراسات إلى تحسين أداء النظام من خلال ضبط زاوية الميل، وتحديد مواقع الفواقد الرئيسية (مثل تأثيرات درجة الحرارة، والغبار/الاتساخ، والتظليل)، أو اختيار تقنيات كهروضوئية تتلاءم بصورة أفضل مع الظروف المناخية في العراق. وبوجه عام، تُظهر النتائج أن برنامج PVsyst قادر على تقديم تنبؤات مفصلة حول سلوك النظام، وإنتاج الطاقة المتوقع، والجوانب التي يمكن تحسينها في التصميم. ومع ذلك، تُبرز المراجعة أيضًا بعض القيود؛ إذ إن كثيرًا من المحاكاة تفترض زوايا ميل ثابتة، ولا يجري دائمًا التحقق من النتائج باستخدام قياسات حقلية فعلية، كما أن التحليل الاقتصادي غائب أو غير مكتمل في عدد من الدراسات. وعلى الرغم من هذه الملاحظات، تؤكد المراجعة أن PVsyst ما يزال أداة تنبؤية قيّمة لتخطيط مشاريع الطاقة الشمسية، إذ يدعم تحسين تصميم الأنظمة ويساعد في تطوير حلول كهروضوئية كفوءة وذات جدوى اقتصادية في العراق، وفي مناطق أخرى ذات مناخ مشابه.

1. INTRODUCTION

Iraq holds around 8% of the world's proven oil reserves and almost 17% of the Middle East, making it one of the biggest crude oil producers in OPEC [1]. By the year 2030, the country is expected to become the third largest supplier of oil worldwide [2]. At present, fossil fuels are still dominating, providing more than 80% of the national electricity [3]. Even though Iraq owns huge amounts of traditional energy resources, the power sector still suffers from shortages and frequent blackouts which slow down the economic growth. On the other side, the country is located in a very sunny region, with high solar radiation, more than 3000 hours of sunshine every year, about 11–12 hours per day in summer and 7–8 hours in winter [4]. This shows the country has a great potential for solar photovoltaic development.

Compared with other forms of renewable energies, photovoltaic (PV) technology has expanded very quickly and has been highly studied by researchers and industry [5]. Today PV systems are used in very small applications, such as calculators, and also in very large solar power plants. The exceptionally low PV system prices due to large-scale production in factory settings and innovation in technology [6] are a crucial factor in this worldwide expansion. PV systems are generally divided into three main types which are as water pumping, standalone (off grid) and grid connected GTS. The main focus of this study is the grid-tied PV systems usually contain PV modules, inverter, MPPT and grid-connection accessory. The utility grid can also export excess power made by the system. GTS are usually easy to operate with fewer components than off-grid systems, and they generally provide superior efficiency and lifetime [6]. While the science lately keeps developing, scientists are still trying to ensure that PV systems output the most electricity possible. One of the most productive solutions is the grid-connected PV solutions network supported directly by the power grid. However, this does not make design straightforward, as many important design parameters are in conflict with each other. For instance, more PV modules means more energy production, but it also means higher system cost and high maintenance. Due to this reason, pv energy efficiency improvement and optimal design selection have attracted strong attention from academy and industry [7]. PV performance is commonly estimated by modeling and simulation software, where characteristics of PV modules and inverters are combined with hourly or sub hourly local weather data to calculate energy production and system behavior [8]. Even though there are a lot of tools occasionally PVsyst is the most widely used in the world. It was developed at the University of Geneva, over two decades ago, and offers useful features for research, sizing and simulation, especially for pre-feasibility studies [9–11]. PVsyst has been used to simulate weather-adjusted energy production and losses of a 200 kW rooftop PV system [12] and to studies locate a 1000 kWp grid-connected solar plant [13].While there are many benefits to PV systems, significant limitations remain which include high initial investments and the low solar cell conversion efficiency. An important benefit of grid-connected PV design is the elimination of high energy storage costs, as the grid provides a backup and a sink for excess energy. With appropriate sizing and optimization, it will enhance the overall system utilization along with net cost reduction. PVsyst is useful here because it provides both a technical and economic evaluation, which assists designers in choosing better and more informed decisions [14].

The effectiveness of PVsyst has been proved in many studies worldwide. Researchers have applied it to analyze PV performance in different climates and irradiation levels [15]. The software integrates real meteorological data and considers shading, temperature impacts, and even module degradation. Because of that, PVsyst is considered a reliable tool for estimating real-world PV performance [16].

Finally, this review paper will cover the basic concepts of solar energy systems and their applications. It will mainly focus on three key areas: (1) Photovoltaic systems including standalone and grid-connected configurations, (2) the role and functions of PVsyst software in design and simulation, and (3) an updated literature review to highlight recent progress and research gaps.

2. Photovoltaic systems

The electrical characteristics of semiconductor materials, primarily silicon, are used by photovoltaic (PV) panels to transform incident sunlight into electrical power [17] . Because PV systems don't emit any toxic emissions while in operation, they are environmentally benign. They are also cost-effective to run because they require little maintenance and last an extended time[18] . One or two thin silicon sheets make up a photovoltaic cell, which generates electrical charges when exposed to light. The necessary voltage and current can be generated by packing the cells into a module. Additionally, PV modules can be joined in series or parallel to create arrays of panels with larger capacity[19]. Equation 1 shows that the panel output power (P) is equal to the product of the voltage (V) and the current (I).

$$P=I.V \qquad (1)$$

Equation 2 defines the panel efficiency (η) as the output power divided by the irradiation power (solar radiation intensity G times the panel surface area (A)).

$$\eta = \frac{P}{AG} \qquad (2)$$

The solar panel's average efficiency falls between 12 and 15%. Numerous studies are underway with the goal of raising these levels . Depending on the application, the PV systems are divided into two primary categories: stand-alone (off-grid) and grid-connected (on-grid) as shown in Fig.1 . An inverter and solar panels are used in the first kind, which is an on-grid system. An apparatus called an inverter transforms the direct current (DC) produced by the solar cells into one or three phases of alternating current (AC) that is suitable for various appliances. However, in addition to the elements above, the second off-grid form also incorporates storage units (batteries). The first type is better because it is easier to use and more cost-effective for buildings that are close to the public electrical grid or do not require energy storage for night-time use, as is the case in the current situation [14].

2.1 Stand-alone PV system

Rooftop standalone systems can range in capacity from a few milliwatts to several kilowatts and are not connected to any electrical grid. The primary components of battery-operated rooftop freestanding systems are an inverter, controller, and solar panels [20]. Solar modules are installed on a mounting structure, which generates DC electricity. This power is channeled via the charge controller, which charges the battery. The controller has two tasks to complete: charging the battery and preventing overcharging of the battery. During the night, they stop any reverse current flow from the batteries back into the solar panels. Anytime, day or night, the battery's daytime energy can be utilized. To power AC equipment, the inverter can convert battery energy into AC [21-22].

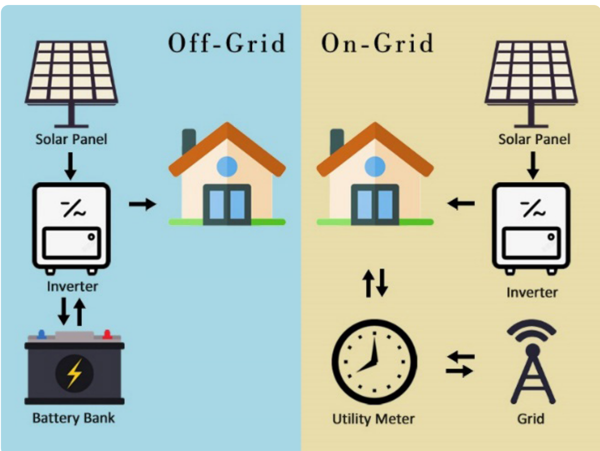

Fig. 1. Types of solar system

2.2 Grid-Connected Photovoltaic Systems

A grid-connected photovoltaic (PV) system interacts easily with the utility grid and uses the power of sunshine to create electricity. These adaptable systems are used in large-scale grid-tied settings as well as homes and businesses. Grid-connected systems effectively use the utility grid as a dependable power supply, negating the need for battery energy storage compared to off-grid systems. PV systems that are connected to the grid run dynamically. When they produce more electricity than they use, an inverter and a distribution board are used to feed the extra energy back into the grid. On the other hand, the system uses grid power to meet its operational needs when energy generation is lower [23]. Grid-tied PV systems offer several advantages to off-grid systems, including net energy metering, lower upfront costs, and higher reliability, just to name a few. A grid-connected photovoltaic (PV) system has the advantage of exporting the surplus electricity to the grid which helps to earn credits for the power supplied w. This arrangement is in place through a plan referred to as net energy metering. This has allowed for decreasing electricity bills for the owners of PV systems, and it also shortens the payback of their initial investments. Finally, net energy metering also enables to fortify the overall resiliency and reliability of the electrical grid by promoting distributed and renewable generation of electricity [24]. A grid-connected PV system consists of the basic components including photovoltaic modules (PV modules), an inverter that converts direct current (DC) to alternating current (AC), and net metering whereby the two-way electricity exchange can be measured [25,26].

3. PVsyst Software

A program simulation named PVsyst. was developed at University of Geneva. This software assists in the calculation of operation and the functioning of PV systems. This software helps with calculating the energy produced provides assistance in system configuration design. The user should know where the selected location is, as well as the PV module panel and inverter configurations. The result is based on a simulation of the size system, which is often determined by where the PV system is located. Results show one or more simulation variables, specified as monthly, daily, or hourly values, depending on the input parameters. The output results can be visualized within tables and graphs, along with the report, and can be used for data [27] analysis. This program facilitates the creation of the system's setup and makes it possible to determine how much energy is produced. The output is based on the size of the system simulation, which is further dependent on the PV system's geographic location. A number of simulation variables that can be shown as monthly, daily, or hourly values may be included in the results. The Loss Diagram anticipates the system design flaws. The procedures below are used to simulate the solar system in PVSyst.

i. Defining the Project: The PVSyst databases already have a variety of sites and metro files, but one can establish one's own projects based on the location of the site and the metro files to be utilized. Basic parameters to be defined are shown in Fig. 2.

ii. Developing a system variant:

The user creates a calculation version of the project made in step 1. The user is responsible for defining the module orientation, system configuration, and loss parameters, as seen in Figure 3.

iii. Executing the simulation: The simulation produces various PV system graphs and reports. The results can be saved for later analysis, exported to another application, or analyzed by the user within the program [28]. Figure 4 show the loss diagram of overall system, figure 5 show the Normalized productions (per installed kWp).

From the steps that was explained, it's clear that PVsyst really give almost all-important information's for PV system design. Starting from defining the project with the site data, then making the system variant and finally run the simulation, the user can get a full picture of how the system will perform. The results in tables, graphs and specially the loss diagram make it easier to see the weak points and think about improvements before the system is built. This shows how much the program is helpful to reduce mistakes, save time and support more confident decisions in PV projects.

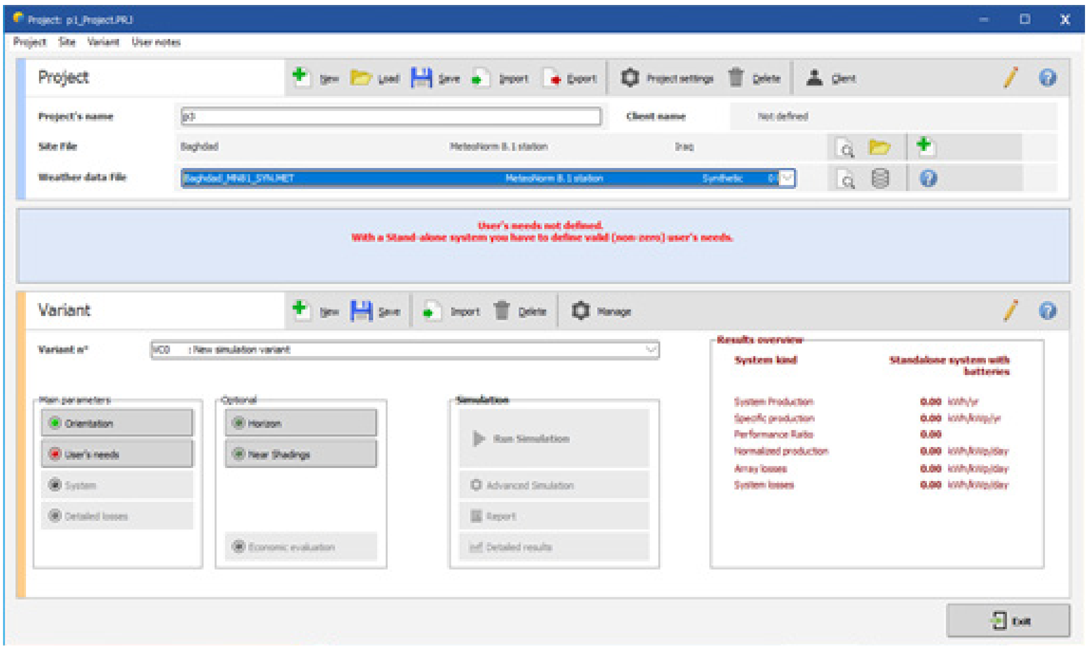

Fig. 2 Basic parameters to be defined

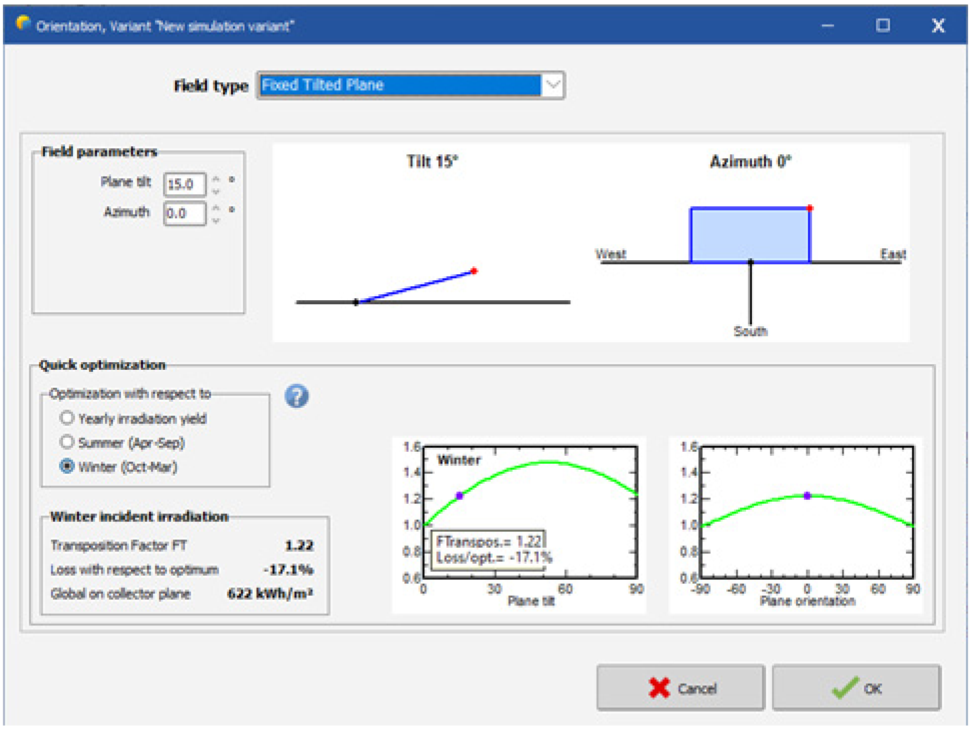

Fig. 3. Orientation dialog

4. Performance Criteria of Photovoltaic System

The performance of photovoltaic system is examined using the IEC 61724 standard. The Dicle University solar power plant's performance was examined using the IEC 61724 standard parameters. These standard states that the system's energy and performance data are tracked over a predetermined time frame (τ). The following definitions and formulas can be used to evaluate the data analysis in terms of days, months, and years. [29]

1. Energy Production (E)

Energy production shows the total electricity that PV system produces in a given time, normally written in kWh per day, month or year. It is the simplest way to see how much energy the system can give to the load or the grid. Many papers prefer to use the yearly output to make comparison between different system sizes, module type and weather condition. But energy production by itself not always showing the efficiency, since it depends too much on the installed capacity and also on the solar irradiation in that location ([30]).

The quantity of AC (alternating current) power generated by the system over a certain time period was used to compute the energy output[31].

$$E_{AC}, D = \sum_{H=1}^{24} E_{AC}, H \quad (3)$$

$$E_{AC}, M = \sum_{D=1}^{N} E_{AC}, D \quad (4)$$

Where

E_AC,H: Alternating current (AC) energy output per hour.

E_AC,D: Alternating current (AC) energy output per day.

E_AC,M: Alternating current (AC) energy output per month

N : Number of days in the month.

2. Reference Yield (Yr)

The reference yield indicates the equivalent hours of full sun that the PV system receives. It is calculated from the total in-plane irradiation divided by the reference irradiance under STC (1 kW/m²). In simple words, it tells how many "sun hours" were available for the modules independent from system losses. This metric is very useful for site-to-site comparison because it reflects only the solar resource and not the technology. Many researchers used Yr to normalize results across different locations [22].

$$Y_R = \frac{H_t(KWh/m^2)}{G(KW/m^2)} \quad (5)$$

Where H_t is total solar radiation received by a specific platform with unit (KWh/m^2) , **G** is reference radiation with unit (KWh/m^2)[29].

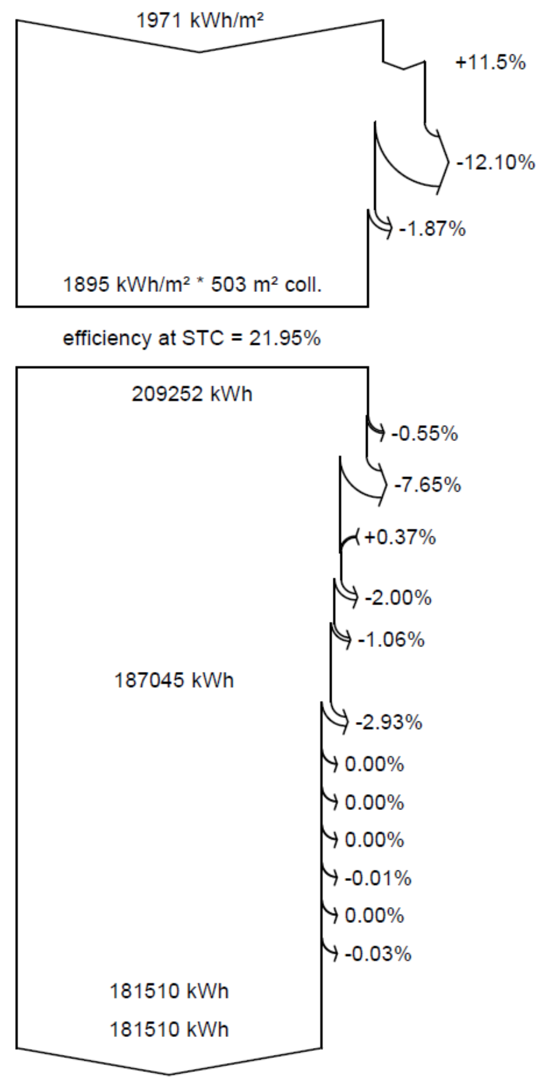

Fig. 4. Types of solar system Loss

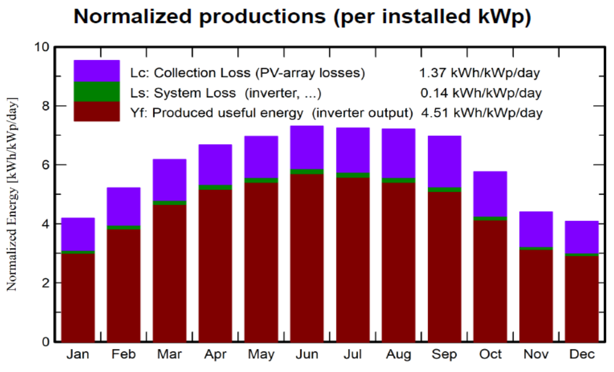

Fig. 5. Normalized productions (per installed kWp)

3. Final Yield (Yf)

Final yield is the ratio between the total AC energy injected to the grid (or delivered to the load) and the installed PV capacity in kWp. This indicator shows the real useful output of the system after including all types of losses such as temperature, inverter, mismatch, and wiring. For example, if a 10 kWp system produces 15,000 kWh per year, then the final yield is 1500 kWh/kWp/year. This makes Yf a key performance metric that helps to evaluate how effective the system operates in practice [32].

The final yield, can be written as follows, is the ratio of energy delivered to the system over a specific time period (day, month, or year) to the installed power.

$$Y_F = \frac{E_{Use,PV}}{P_0} \qquad (6)$$

Where P_0 is the installed power, $E_{Use,PV}$ denotes the energy delivered to the system. [29]

4. Performance Ratio (PR)

Performance Ratio (PR) is seen as one of the key indicators for PV system quality. In simple words, it is the ratio between the final yield and the reference yield. It sort of illustrates the inefficiency in the converting sunlight energy into the useful electricity. This indicates how well the system is performing, at least for high PR values (say 80–85%), otherwise the low values indicate the losses due to physical or mechanical aspects. Reporting PR eliminates the advantages possessed by large solar plants built in ideal locations, which is why it is frequently used [29].

$$PR = \frac{Y_F}{Y_R} \qquad (7)$$

5. Capacity Factor (CF)

The capacity factor (CF) demonstrates how much of the rated capacity of the system was actually deployed over a year. You can consider it the actual power output as divided by the maximum power the plant could have produced if it were operating full power round-the-clock. CF is also widely used in power engineering not just for solar PV but also normal power plants as well as it gives a good idea about how effectively the installed capacity is being utilized. Depending on the solar radiation and performance of the solar PV devices, the CF is typically Only 15–25% for PV systems [16].

$$CF = \frac{E_{AC,a}}{8760 \times p_{PV,rated}} \quad (8)$$

Where $E_{AC,a}$ is the total energy produced year-round, $p_{PV,rated}$ the installed PV power, 8760 is the number of hours in a year[29]

6. System Losses

Losses are essentially what actually prevents a PV system from delivering its maximum energy as in ideal case. It might be heat as when panels are too hot, there some resistance in the cables, modules do not perfectly match in their performance, inverter is not completely efficient, or, just the dust on the modules piling up. For example, in countries such as Iraq, dust is literally an issue — if dust is not removed from the panels, it can reduce annual output by around 30–40%. In many PVsyst studies you can see those loss diagrams that show where most of the energy got lost and what parts can be improved [4].

7. Economic Indicators (NPV, IRR, PBP, LCOE)

In addition to technical metrics, many studies included economic indicators to evaluate the financial viability of PV projects. These metrics are important because a technically efficient system is not always economically attractive

The Net Present Value (NPV) measures the total discounted profit. NPV can be defined as the total of the present values of the outflows (costs) and inflows (profits) over the project's analysis period. Equation (1) can be used to define NPV[33].

$$NPV = \sum_{j=1}^{n} \frac{RL_j}{(1+a)^j} - \sum_{j=0}^{n-1} \frac{I_j}{(1+a)^j} + \frac{V_r}{(1+a)^n} \quad (9)$$

Where the discount rate is denoted by a. n is the project lifetime; Vr is the system's value recovered at the end of the term; The investment for year j is denoted by I_j. RL_j is the amount of money earned in the year j. If NPV is less than zero, the project is refused; if NPV is greater than zero, it is accepted.

The IRR is the rate of return used to measure and assess an investment's profitability in a capital expenditure budget. This means that the rate of return for which NPV is 0 is IRR. Consequently, Equation provides the IRR equation[33].

$$\sum_{j=1}^{n} \frac{RL_j}{(1+IRP)^j} - \sum_{j=0}^{n-1} \frac{I_j}{(1+IRP)^j} + \frac{V_r}{(1+IRP)^n} = 0 \quad (10)$$

The project is not economically profitable if IRR is less than a, and it is economically profitable if IRR is more than a.

The Payback Period (PBP) simply calculates how many years are needed to recover the initial investment. The Payback Period (PBP) could be computed by Equation [33]

$$\sum_{j=1}^{PBP} \frac{RL_j}{(1+a)^j} + \frac{V_r}{(1+a)^n} = \sum_{j=0}^{n-1} \frac{I_j}{(1+a)^j} \quad (11)$$

Within the project's lifespan, the initial investment cannot be recovered if DPP > n; if DPP < n, the project can be approved.

The Levelized Cost of Energy (LCOE) gives the cost per kWh generated during the lifetime of the system, considering investment, operation, and maintenance. Verification of grid parity, which can be accomplished when the cost of solar PV generation equals the resulting household energy price, depends heavily on LCOE . Equation (6) can be used to compute LCOE.[33]

$$LCOE = \frac{\sum_{j=1}^{n} \frac{I_j + d_{O\&M_j}}{(1+a)^j} - \frac{V_r}{(1+a)^n}}{\sum_{j=1}^{n} \frac{E_j}{(1+a)^j} -} \quad (12)$$

The electrical energy generated in year j is denoted by E_j, $d_{o\&Mj}$ operation costs

4. Literature Review

Using of PV software in PV solar system is of great interest to many researchers due to the significant advancements these technologies have brought about in various fields. Recent research in this area has been summarized and presented in Table 1 .

Reem [34,2025] studied the monthly grid performance of a proposed 100 MWp solar plant connected to the system at Al-Khwarizmi College of Engineering. The simulation was carried out using Meteonorm 8.0 data in both PVsyst 7.2 and HelioScope software. The main target of the work was to maximize the energy production, and this was done by using a fixed tilt angle all year. The latitude of the building was taken as a base to set the tilt, or an east–west configuration adjusted by 10 degrees toward the south azimuth. In HelioScope, the 3D visualization made the design process more natural and clearer, allowing good choices in layout and also analyzing shading and orientation effects. According to the results, the annual energy generated by PVsyst was 1,500.303 MWh, while HelioScope showed 849.7653 MWh/year. The combination of PVsyst and HelioScope in the project increased both the accuracy and the efficiency of the design process, and also improved the understanding of solar energy technologies. With these tools, it was possible to design a well-optimized and high-performance system that contributes to clean and sustainable energy. The software tools clearly increased the success rate of this specific project.

Elsaadawi [32, 2025] designed and simulated an off-grid PV system of 4.95 kW for a milking and milk-cooling facility that was facing problems with unstable electricity. A preliminary design step was done to collect all the necessary inputs before applying PVsyst 7.4 for detailed simulation. Running the simulation made it possible to find design flaws and minimize problems or losses in the operation stage. The long-term simulation checked the reliability and performance of the off-grid system and saved both time and costs by solving issues before real installation. The PV array produced 23.42 kWh/day of effective energy, and the system was able to deliver 21.14 kWh/day as useful energy, which matched the actual demand of the facility. The discrepancy was mainly caused by losses, which include both array thermal loss (10.67%) and battery efficiency loss (4.99%). It also allows the life of the battery to be extended, as was evident in the average state of charge level across the course of the year, which was 59%. The solar fraction was 1.000, indicating that the entire load could be supplied by the system with no backup. PVsyst is a program, the combination of design and simulation is well justify, while it reached an optimum balance between the load and resources with respect to human scale, which cannot be achieved with traditional manual calculations, as many parameters are neglected in this method. Therefore, it is most beneficial to incorporate both methods to optimize the design of a solar energy system.

A study: PVsyst simulation of a 5 MWp PV plant and analysis [16, 2-2024]About PVsyst simulation of a 5 MWp PV plant [2-2024]Mishra [2] The thus simulated performance was then compared with actual production of a plant of the same capacity. The comparison considered real and predicted results thus validating PVsyst reliability and applicability as design tools. The standard mentioned that research also evaluates key elements of the performance in line with the IEC 61724 standard. The results demonstrated a tight correlation between the simulated and the actual outputs, providing confidence that PVsyst can accurately characterize PV system performance. The results were confirmed by the fact that the actual plant yield was almost similar to the software projections, proving that PVsyst is capable of forecasting generation profiles. Finally, the study noted that greater accuracy for PVsyst simulation will be useful in future work, especially over climates different than the subtropical climate used to calibrate the model.

MPVL performance testing with PVsyst software focusing on solar harvesting simulation based scenes (Hasan [35, 10-2021]]:Seoul, Cairo, New York The implications of the results were discussed in a way that would feasibility for the solar energy applications of MPVL to building façades. Results substantiated that the use of advanced simulation software have a potential to standardize the facade design procedure and its delivery. The PVsyst simulation again proved the MPVL is applicable to grid-connected systems and that those façades suffered versatility to be examined at diverse topologies and climates. These results provided a solid foundation for the consideration of MPVL construction projects in diverse locations, thus illustrating the usefulness of MPVLs in prospecting future solar harvesting approaches.

Authors Mahmood [36, 2023] simulated and analyzed 20 kW grid-tied PV system through PVsyst at MTU University Baghdad. Meteorological data unsed in the simulation included irradiance, temperature, and wind speed. Hence, software PVsyst was used to estimate grid injected energy, performance ratio (PR), reference yield (Yr), array yield (Ya), final yield (Yf) and various losses. For the system, 96 rooftop monocrystalline panels of 355 Wp quality were utilized. According to the results, the energy injected to the grid was 517 MWh per year, and the annual PR reached 76.5%. July had the highest monthly output of 4919 kWh, because of strong solar radiation and clear weather. The outcomes suggest that Baghdad has a high solar potential thanks to its location. The project results can motivate more universities and institutions in Baghdad to adopt large PV systems, to reduce dependency on the public grid and lower electricity costs. The performance results highlight the possibility to increase PV adoption and make solar more reliable in the city.

Hussain [37, 2021] studied the effect of tilt angles using PVsyst software, and the results showed clearly the relation between solar modules and solar radiation. The main advantage of this simulation tool is that it is not strongly affected by local atmospheric conditions. The study found that the difference between seasonal and monthly tilt angles is small, so seasonal adjustment is better since it is easier than changing angles every month. Also, the difference among fixed, monthly, and seasonal tilt adjustments was not very large, which means that fixed angles can also be chosen in practice. The optimal azimuth angle was found to be zero, but in special cases it can still be oriented up to ±20º or even ±30º. Only small variations in the performance ratio (PR) were observed when tilt and azimuth angles were changed, suggesting that PR does not really depend on these angles. In general, the gap between simulated and real calculated values was also small.

Al-Sarraj[38, 2024] simulated installation of stand-alone PV system using the software PVsyst. By analyzing the outputs of the simulation, the size of the panel and the type of inverter were set so that the required load demand can be met. GIS played a significant role in step sizing process in regards the locations of site. They demonstrated this with detailed set-up diagrams, performance metrics, and loss analysis. The system was simulated with PVsyst, to size the system theoretically based on reasonable watt hour demands, it would operate with 220 V AC and 48 V DC. The report also highlighted the silicon heterojunction technology (HJT), which allows very high open circuit voltage values (VOC above the 700 mV range). Recent improvements in the efficiency of HJT solar cells have achieved a record efficiency of 24.03% These panels with high energy yield fits well with the high temperature and sunshine of Basra climate. This allows them to decrease costs and increase production at the same time. Furthermore, HJT technology helps achieve sustainability objectives, reduces environmental burden, and strengthens ambient air quality. It also facilitates expansion of infrastructure and around the shelters and it also brings power to the outlying areas.

Pvsyst software was utilized by Islam [39, 2022] to design and assess a grid-connected rooftop PV system in a Tetulia, Panchagarh, Bangladesh. A shift of energy towards renewable energy sources (PV) and its environmental impacts was the primary impetus of this research. The output from a PV cell is primarily a function of the solar irradiance level, module type and orientation. Grid-connected PV continues to be seen as the most favorable option for renewables on a large scale. A Roof Top System of 3kW for Domestic Utilization of 8.1 kWh/day were simulated with PVsyst software in this case study. The PV panels generated about 4172 kWh/year of AC energy, from which 1871 kWh/year was surplus and exported to the grid after meeting the daytime load. The yearly global horizontal irradiation in Tetulia was measured at 1485.4 kWh/m². During night hours, around 1050 kWh/year of electricity was imported from the grid. The technology also helps in predicting outages and managing backup storage, since the stored battery energy can be used when needed.

Sami [40, 3-2021] designed and simulated a stand-alone PV system to supply power for a base transceiver station (BTS) in Iraq. The case study was a BTS located in Jadriyah, Baghdad, belonging to Zain Telecommunication Company, with a load demand of 4.177 kW. Meteorological data for this area were collected from the Ministry of Science and Technology's weather station for the year 2017. The PVsyst program was used to simulate the BTS system performance. The financial analysis showed that the cost of energy was quite low at $0.108/kWh. The results demonstrated that a stand-alone PV system could be a suitable alternative for powering transmission and receiving stations of mobile networks. A deeper analysis revealed that the PV system produced energy at $0.1081527/kWh, which is much lower compared to diesel generators, where the cost for the same load was about $0.3641/kWh (calculated using the site https://power-calculation.com).

Overall, the PVsyst simulation confirmed the feasibility of replacing diesel-based systems with stand-alone PV for telecom stations.

Tuama [41, 2021] investigated the influence of different PV tilt angles, orientations, and configurations on system productivity. According to the authors, such a broad study over Baghdad city was not presented before. In the simulation, the azimuth angle was varied from -90° to 90° while keeping tilt constant at 30°, and then the tilt angle was changed from 0° to 90° with azimuth kept at 0°. Results showed that the best PV performance occurred at 30° tilt with 0° azimuth. It was also found that small azimuth changes, up to ±30°, have almost no effect on PV output. The study concluded that small azimuth offsets are acceptable in design. In addition, low tilt angles improve summer productivity, while higher tilt angles improve winter output. But overall, the optimum angle through the whole year was 30°, explained by the sun latitude changes across the months. Furthermore, the 2-season configuration achieved better performance than all fixed setups, with about 5% higher energy. The highest performance, however, was given by the tracking configuration, which produced nearly 25% more energy compared to other configurations.

Kumar [42, 2021] presented a study about load requirements in the mechanical engineering department office at Bikaner College, and based on that, designed and installed a standalone solar PV system. Performance ratio (PR) and system losses were analyzed using PVsyst software. The average annual energy demand of the office was 1086.24 kWh, while the solar panels could generate 1143.6 kWh, and the energy delivered to users was 1068.12 kWh, which is slightly lower than the demand. The reduction was caused by different losses. PR analysis showed the highest value in December at 86%, and the lowest in April at 64%, with an average yearly PR of 72.8%. The lower power output was attributed to module performance, material technology, and other loss mechanisms. While PVsyst analyzed all losses—each component of the system had its model—the Meteo data fluctuations and the module specification do not provide certainty. The research found that rooftop solar panels installed as per load requirements can help small offices, homes and factories become more self-reliant. The paper also contains valuable references on the design of future off-grid PV.

In Saudi Arabia, Alkahtani [42, 2024] made a work on solar energy in which he basically tried to analyze the potential of solar energy for the utility and micro PV projects. The 400 MW grid-connected PV system was simulated and sized in PVsyst 8 in Riyadh, KSA) [45]. It uses maps and geographic data of the location to size the components under near real conditions which means the software gives you a snapshot of how that PV system will perform at that site. As expected, they had similar results from sites with similar latitude when they also played with panel tilt and orientation. There are three kinds of PV modules, 255 Wp, 330 Wp, and 580 Wp. They used the 580 Wp modules in the main design and from their comparison, it was obvious that the bigger modules are better as the big modules are more efficient than the smaller.

Moustafa [30, 2024] investigated a 130 kWp PV grid-connected system for the factory located in Al Obour City, Egypt (30.19373 N, 31.44213 E). Fixed-tilt installation of the system. The design phase was to verify the energy consumption of the factory and by that to select suitable components. The model used PVsyst and considered the geography, climate, irradiance, and load of the site. It would reduce the system output to approximately 212.7 MWh per year. Next, techno-economic analysis based on capital, operating, and energy price were performed. Analysis results demonstrated that the PV system was sufficient to meet the load demand, resulting in a monthly bill reduction of approximately 20%. PVsyst was a comprehensive power output and losses modelling tool with a quick and dirty approach in terms of its user interface, but reliable approach in terms of its output. Finally PVsyst display not only production but also assist in adding economic value to the project and render more realistic. Table. 1 summary the above works.

Cite	Metrics Used	Methodology	Strengths	Limitations
[41] Tua-ma	Energy yield vs tilt/azimuth/config; tracking gain	Baghdad-wide scenario sweep; PVsyst	Tracking ≈ +25%; 2-season ≈ +5%; 30°/0° best on annual	CAPEX/complexity of tracking not assessed
[42] Ku-mar	PR (monthly & annual), losses, demand vs supply	Stand-alone for office (Bikaner); PVsyst	Loss disaggregation; design by real load	Meteo/module spec uncertainties; small-scale
[42] Alkahtani	PR, module efficiency/CF (implied via sizing)	400 MW grid-tie (Riyadh); PVsyst 8; module rating compare	Large-scale sizing; 580 Wp vs 330/255 Wp comparison	Simulation only; cost/ROI not treated
[30] Moustafa	Energy production, techno-economics (bill −20%)	130 kWp factory (Egypt); PVsyst; fixed tilt; LCOE/NPV/IRR (study-level)	Practical bill savings; clear component choices	One load profile; no long-term degradation modeled
[34] Reem	Annual energy, PR (implicit), shading/orientation impacts	100 MWp proposal at Al-Khwarizmi; Meteonorm 8.0; PVsyst 7.2 vs Helio-Scope; fixed tilt; 3D layout	Dual-tool cross-check; detailed 3D shading; clear layout decisions	Big gap PVsyst vs HelioScope; fixed-tilt only (no seasonal/tracking)
El- [32] saadawi	Energy yield (kWh/day), loss breakdown (array thermal %, battery eff. %), Solar Fraction (SF), battery SOC	4.95 kW off-grid; PVsyst 7.4; pre-design data then long-term sim	Found and quantified losses; SF = 1; SOC ≈ 59% (life extension)	Sensitive to battery/thermal models; case-specific facility
[16] Mishra	PR (IEC 61724 KPIs), plant yield	5 MWp grid-tie; PVsyst vs actual plant	Good agreement with real data; validates PVsyst use	Single climate/site; model tuning needed for other climates
[35] Hasan	Energy yield, PR, temperature & inverter losses	MPVL façade; PVsyst across Seoul/Cairo/NYC	Novel façade use; multi-city comparison	No field validation; limited cost/econ detail
Mah- [36] mood	Grid-injected energy, PR, Yr, Ya, Yf, losses	20 kW rooftop at MTU/Baghdad; PVsyst with meteo inputs	Reports full KPI set; July peak characterized; local relevance	One site/campus; short time window
Hus- [37] sain	PR vs tilt/azimuth; seasonal vs monthly tilt	Baghdad study; PVsyst scenarios (fixed/monthly/seasonal)	Shows small PR sensitivity; practical guidance (±30° azimuth ok)	Sim-heavy; minimal real-world validation

Table 1. Related Works Summary

Cite	Metrics Used	Methodology	Strengths	Limitations
[34] Reem	Annual energy, PR (implicit), shading/orientation impacts	100 MWp proposal at Al-Khwarizmi; Meteonorm 8.0; PVsyst 7.2 vs HelioScope; fixed tilt; 3D layout	Dual-tool cross-check; detailed 3D shading; clear layout decisions	Big gap PVsyst vs HelioScope; fixed-tilt only (no seasonal/tracking)
El-saadawi [32]	Energy yield (kWh/day), loss breakdown (array thermal %, battery eff. %), Solar Fraction (SF), battery SOC	4.95 kW off-grid; PVsyst 7.4; pre-design data then long-term sim	Found and quantified losses; SF = 1; SOC ≈ 59% (life extension)	Sensitive to battery/thermal models; case-specific facility
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Mahmood [36]	Grid-injected energy, PR, Yr, Ya, Yf, losses	20 kW rooftop at MTU/Baghdad; PVsyst with meteo inputs	Reports full KPI set; July peak characterized; local relevance	One site/campus; short time window
Hussain [37]	PR vs tilt/azimuth; seasonal vs monthly tilt	Baghdad study; PVsyst scenarios (fixed/monthly/seasonal)	Shows small PR sensitivity; practical guidance (±30° azimuth ok)	Sim-heavy; minimal real-world validation
[38] Al-Sarraj	Sizing outcomes, performance results, loss analysis	Stand-alone with HJT panels (Basra); PVsyst + load sizing	Context-fit tech (HJT VOC>700 mV); clear configuration	Economic analysis light; depends on assumed demand
Islam [39]	Annual AC energy, surplus export, night imports, GHI	3 kW grid-tie (Tetulia); PVsyst; load vs supply balance	Captures surplus/deficit flows; operational realism	Residential scale; locality-specific irradiance
Sami [40]	LCOE/energy cost; technical feasibility	Stand-alone for BTS (Baghdad); PVsyst; cost compare vs diesel	Much lower $/kWh than diesel; telecom use-case	Uses web calc for diesel; single-site assumptions

I. If we pay attention to the previous studies together, we can list similar points. To date, nearly all of them still heavily rely on energy yield and performance ratio (PR) as the primary performance metrics, and typically utilize PVsyst software for the modeling. But, while beneficial for comparisons, it also makes the results somewhat limited, because not many works actually validated their predictions against long-term field data. A second reoccurring problem is that a lot of papers simply consider constant tilt angles. All the seasonal tilt or tracking systems were very rare as well, although tracking increases energy by 20–25% or more. Some studies also analysed losses (i.e., due to inverter or temperature losses), and a few included dust/soiling. However, there is, frankly, very limited true measured data regarding dust and high temperature effects on the PV system in Iraq. A couple of works (eg degradation research in basra/baghdad) have approached this, but we need more of these. This is another weak area in terms of the economic part. NPV, IRR, Payback or LCOE were only calculated in a handful of studies. So even if a system is technically on point, it may not be enticing for investors due to a gaggle of ghostly financial metrics. I think therefore the next logical step is to add economics next to technical performance. Eventually, researchers may want to observe for the long term, too. A lot of results we see are based on very short simulation time, perhaps one single year. However, the real question is not how the system performs on a peak summer day, but how the system performs over a 10 or 20 year period, which includes degradation and cleaning costs. Another valuable concept consists in integrating the use of PVsyst with other softwares such as HelioScope or PV*SOL or even with ML models, to mitigate the risk of relying solely on a particular software tool.

In short, future work should be about :Additional field measurements in Iraq (especially soiling, temperature, and extended degradation measurements). Live and breathe Economic indicators, in every single technical report publish that includes testing in more mature setups such as tracking, bifacial or HJT modules potentially better suited to hot climates.

5. Conclusion

From all the papers we reviewed, one could say that PVsyst has been almost the de facto software for PV system studies in Iraq. It provides almost instantaneous and fairly accurate energy yield and loss predictions, together with essential KPIs (like PR and Yf). Several works demonstrated that Iraq has great solar resources and PVsyst could provide a platform for initial system design matching the local conditions before spending money on the real projects. However, there are voids that continue to occur. Many studies focused only on testing fixed tilt systems and did not even study tracking or even seasonal tilts, though these yield higher energy, sometimes more than 20%. Moreover, much of the work is still purely simulation-driven, with limited experimental validation. That said, the results are very much a little too theoretical without that. Financially however, since so many papers lacked sufficient NPV, IRR, LCOE, or payback analysis, it is more difficult to demonstrate that the projects are not just viable from a technical perspective but also a financial one. In the future, PVsyst should be combined with other tools and also with real monitoring data from several years instead of only one year perturbation since monitoring data would be more representative of the actual performance. It should always also include the economic side of things, because investors care at least as much about the economic side as the technical success of the project. Emerging technologies such as bifacial or HJT modules, and inexpensive tracking systems hardly have been addressed while there may be a niche for them in Iraq hot and dusty climate. Related: In short, PVsyst is very powerful but the success of solar in Iraq does not only depend on powering software runs. Field data, improved economic assessments, and validation of advanced PV technologies will be needed It will also render more realistic outcomes that are more relevant to policy and real world investments.

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