# Feasibility Study of Technical and Economic Aspects for the Construction of a 1.1 MWp Photovoltaic Power Plant in a District of Tehran

Mohammad-Reza Nickpay[1•], Roohallah Amirabadifarahani[1] and Karim Goudarzikia[1]

***Abstract*-- Considering the existing issues of electricity shortages in Iran and the problems caused by air pollution due to the use of fossil fuels, designing a solar power plant with a capacity of 1.1 MWp in the Sa'adat Abad district of Tehran using PVsyst software could be an appropriate solution for providing sustainable and clean energy. Photovoltaic power plants, as renewable energy sources, harness sunlight to generate electrical energy, the use of which can help reduce dependence on fossil fuels and improve air quality. Especially in a city like Tehran, which faces air pollution and traffic problems, the utilization of clean energy can have significant positive effects on public health and the environment. Furthermore, given the growing energy demand in Iran, establishing power plants with suitable capacities, particularly solar ones, can help meet the increasing energy needs of the country while also alleviating the burden on electricity distribution networks during peak consumption hours. Ultimately, the use of solar energy not only contributes to enhancing the country's energy security but also paves the way for sustainable development and improved quality of life in urban areas.**

***Index Terms*- Renewable energy, Photovoltaic panel, solar, Inverter, PVsyst**

## I. Introduction

Solar energy has become one of the most significant challenges and necessities of the modern era. Fossil fuel sources such as oil, gas, and coal have been criticized for their greenhouse gas emissions and environmental pollution, with their adverse effects on human health and ecosystems evident. As a result, the global focus has shifted toward sustainable and renewable resources like solar energy. Photovoltaic (PV) technology is recognized as an effective and sustainable solution for generating electricity from renewable sources. Recent advancements have significantly improved its efficiency [1]. The solar energy reaching Earth is approximately 170 trillion watts, equating to about 1.3 kW/m² under ideal conditions (without clouds or other obstructions) [2]. Depending on the technology and circumstances, a percentage of this radiant energy can be captured. Generally, PV panels convert this energy into electricity with an efficiency ranging from 15% to 22% [3]. Assuming an average efficiency of 20%, approximately 0.25 kW/m² of solar energy can be converted to electrical energy. Weather conditions and air quality can significantly influence the efficiency and performance of PV power plants. In desert regions with high dust levels, various factors can impact PV plant efficiency. Dust can reduce sunlight absorption by PV panels, leading to an annual efficiency drop of 1.5% to 6.2% [4], and in highly dusty areas, this reduction can reach 20% to 30% or even more [5]. Other factors such as temperature, humidity, and solar angle also play critical roles. However, measures like regular panel cleaning and using advanced technologies can mitigate these effects [6]. Thus, maintaining and cleaning systems is essential to preserve efficiency in dusty conditions.

The Sa'adat Abad district in Tehran, as a populous and developed region, has high potential for solar energy utilization. Given the adequate sunlight in this district and the urgent need for clean and sustainable energy, constructing a 1.1 MWp PV power plant is a practical and attractive option [7]. This project would not only meet energy demands but also reduce reliance on fossil fuels and improve air quality. In the Kuye Faraz district of Sa'adat Abad, several factors stand out. Cooler temperatures typically enhance PV panel efficiency, as higher temperatures can reduce their performance. Consequently, relatively cooler conditions can lead to better PV system performance [8]. Additionally, areas with less pollution experience reduced accumulation of particulates on PV panel surfaces, helping maintain or even increase sunlight absorption and system efficiency. With lower pollution levels, these systems often receive more direct sunlight, positively impacting their performance [9]. Overall, the climatic and air quality conditions in Kuye Faraz, Sa'adat Abad, can effectively boost the efficiency of PV power plants. This paper explores the feasibility of establishing a 1.1 MWp PV power plant in Sa'adat Abad, Tehran. The analysis includes both technical and economic evaluations to better understand the potential of such energy generation on a local scale.

## II. Solar power source

Solar energy is one of the most important renewable energy sources, capable of generating electricity through efficient utilization. One of the most common technologies for converting solar energy into electricity is PV technology. Here, we explain how this system and PV cells work.

The conversion of solar energy into electrical energy occurs through the PV effect. This process involves transforming sunlight into electricity using semiconductor materials.

Photovoltaic (PV) cells are primarily composed of two layers of semiconductor materials, each with distinct electrical properties [10-12]:

- N-layer (Negative Layer): This layer is typically made of silicon doped with phosphorus, which introduces extra free electrons, thereby enhancing its conductivity.

1. Tehran Regional Electric Company, Tehran, Iran.
• Corresponding author Email: mr-nickpay@trec.co.ir

- P-layer (Positive Layer): This layer consists of silicon doped with boron, which creates electron deficiencies known as "holes," making it more receptive to electron movement.

These two layers are arranged to form a p-n junction, a fundamental structure in semiconductor devices that exhibits unique electrical behavior. When sunlight strikes the surface of the PV cell, photons transfer their energy to electrons in the semiconductor material. This energy absorption excites the electrons, generating electron-hole pairs. The free electrons move toward the N-layer, while the holes migrate toward the P-layer, initiating charge separation.

At the p-n junction, an internal electric field is established due to the difference in electron and hole concentrations between the two layers. This electric field facilitates the directed movement of charge carriers, ensuring that electrons and holes travel in opposite directions. As a result, an electric current is generated.

The electricity produced by PV cells is in the form of direct current (DC). To enable compatibility with power grids and household appliances, this DC electricity is converted into alternating current (AC) using an inverter. This conversion allows the efficient integration of solar-generated power into existing electrical infrastructure, promoting the widespread adoption of solar energy [13].

## III. Design and Installation of a Photovoltaic Power Plant

Designing and installing a PV power plant involves several key stages, each requiring meticulous planning and execution. The main steps are as follows:

- Preliminary Study and Site Analysis
  - Site Identification: Selecting a location with high solar irradiation and access to natural resources.
  - Climatic Analysis: Evaluating available weather data, such as solar radiation, temperature, and humidity.
  - Geological Analysis: Examining the geological characteristics of the chosen site.
- System Design
  - Capacity Calculation: Determining the desired capacity based on consumer demand and solar radiation levels.
  - Equipment Selection: Choosing photovoltaic panels, inverters, and other electrical and mechanical components.
  - Electrical and Mechanical Design: Designing the layout of panels, cabling systems, and electrical protection.
- Permits and Plan Approval
  - Permit Applications: Obtaining necessary approvals from governmental, environmental, and local authorities.
  - Financial Estimation: Preparing an economic feasibility study and estimating project costs.
- Implementation and Commissioning
  - Equipment Procurement: Purchasing panels, inverters, and other required equipment.
  - System Installation: Installing panels, wiring, and necessary infrastructure.
  - Testing and Commissioning: Conducting tests to ensure proper system functionality.
- Operation and Maintenance
  - Performance Monitoring: Tracking and recording system performance to ensure it meets design capacity.
  - Regular Maintenance: Performing periodic repairs and maintenance to maintain system efficiency.
- Evaluation and Optimization
  - Performance Analysis: Reviewing system performance data and implementing changes for optimization.
  - Reporting: Providing periodic reports to investors and government authorities.
- Development and Expansion
  - Expansion Feasibility: Exploring opportunities for future system expansion.

These steps may vary depending on local regulations, plant type, and specific conditions, but this framework serves as a comprehensive guideline for designing and installing PV power plants.

In this paper, the PVsyst software is utilized for simulating the PV system.

### *A. PVsyst Software*

PVsyst is a renowned and advanced software tool for designing and analyzing PV power systems. It assists engineers and designers in creating precise models of PV systems, considering components such as PV panels, inverters, and other elements like power distribution and energy storage under various climatic conditions [14].

The process of designing and simulating a PV power plant using PVsyst includes several stages as outlined below:

- Inputting Project Information
  - Installation Site: Geographic details of the project, including latitude and longitude.
  - Climatic Conditions: Climate data such as solar irradiation, temperature, humidity, and wind speed (accessible from the software's database).
  - System Type and Dimensions: Selection of PV module types, inverters, and other equipment.
- System Modeling
  - Module Arrangement: Defining the layout and orientation of modules (e.g., horizontal or vertical).
  - Mounting Structure Selection: Choosing the type of support structures and foundations.
- Performance Analysis
  - The software automatically calculates energy production, system losses, shading effects, and temperature impacts to determine system performance.
- Simulations are conducted on solar irradiation, output voltage and current, and the project's economic feasibility.
- PVsyst Output Categories:
  - Energy Production Report: Annual energy yield estimation based on weather conditions and system specifications.
  - Economic Analysis: Evaluation of costs, revenue, and return on investment.
  - System Performance Report: Insights on losses

due to temperature, shading, and other factors.

- Shadow Maps: Simulated shading effects on modules at different times of the day and year.
- Graphs and Charts: Visualization of energy production, input and output currents, and other analyses.

Using this data, engineers and designers can make informed decisions and design more efficient systems.

*B. Geographic Coordinates and Climatic Conditions of the Study Area*

To examine the geographic coordinates and climatic conditions of the Kuye Faraz Sa'adat Abad district in Tehran for the construction of a PV power plant, the following information is provided in the form of a table:

TABLE I
Geographic Coordinates and Climatic Conditions of the Kuye Faraz Sa'adat Abad Area, Tehran.

| Parameter | Information |
|---|---|
| Location | Kuye Faraz, Sa'adat Abad, Tehran |
| Latitude | 35.7942° N |
| Longitude | 51.3685° E |
| Elevation | ~1753 meters above sea level |
| Average Solar Irradiation | 5.5–6 kWh per square meter per day |
| Average Annual Temperature | 17°C |
| Maximum Summer Temperature | 38°C |
| Minimum Winter Temperature | -5°C |
| Relative Humidity | 30%–60% |
| Average Wind Speed | 3–5 meters per second |
| Dust and Pollution Levels | Moderate (requires regular panel cleaning) |

This table provides the necessary data for designing and simulating a PV power plant. These parameters are essential for selecting equipment, module arrangement, and analyzing system performance under various weather conditions.
Fig. 1 shows the geographic location of the PV power plant installation site within the Tehran Regional Electric Company area, located in the Kuye Faraz Sa'adat Abad region.


Fig. 1. Geographic Location of the PV Power Plant Installation Site within the Tehran Regional Electric Company Area in Kuye Faraz Sa'adat Abad.

*C. Angle and Orientation Adjustment of Photovoltaic Panels*

The optimal performance of PV panels depends on a range of factors, with the angle and orientation of the panels playing a significant role in determining the amount of solar radiation absorbed and, consequently, the energy produced. Typically, panels should be installed facing south (in the northern hemisphere) and at an optimal angle to capture the most sunlight. The closer the angle of solar radiation to a perpendicular angle (90º) relative to the surface of the panels, the more solar energy will be absorbed. The closer the geographic location is to the equator, the more favorable the sun's position is for energy absorption. In the summer, the sun is positioned higher in the sky, which can enhance solar energy capture. Additionally, the position of the sun changes throughout the day, and the best time for maximum energy absorption usually occurs during peak sunlight hours (midday).

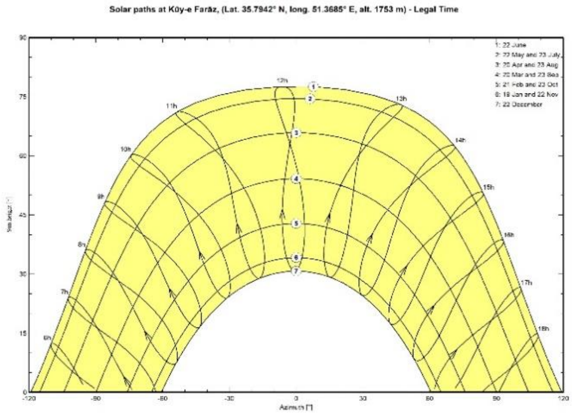



Fig. 2. Solar Radiation Path in Tehran (Kuye Faraz Sa'adat Abad).

The shadow created by nearby structures or trees can have a negative impact on the performance of PV systems. Shadow calculation generally involves the height and width of the shadow, and based on the height and position of the sun, the shadow can be calculated.

The optimal tilt angle of PV panels depends on the geographical latitude of the region. In different regions with varying latitudes, the angle of solar radiation changes. In general, to optimize the performance of PV panels, they should be installed in a way that maximizes sunlight exposure. Throughout the year, the tilt angle can be chosen close to the latitude of the location. For example, in Tehran, where the geographical latitude is approximately 35º, the appropriate installation angle could range from 30º to 40º. It is also advisable to adjust the angle of the panels according to the different seasons to achieve better performance. For instance, in winter, a higher angle might be required to capture more sunlight.

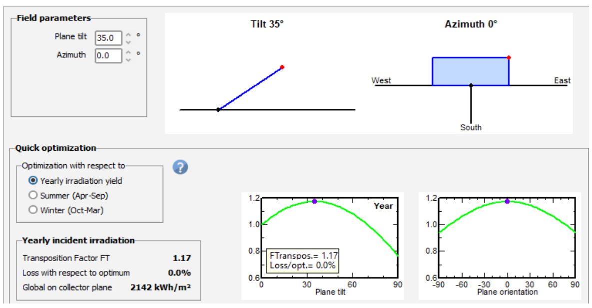



Fig. 3. Adjustment of the Angle and Orientation of PV Panels.

### D. Components of a Photovoltaic System

The overall schematic diagram of a PV system is shown in Fig. 4.

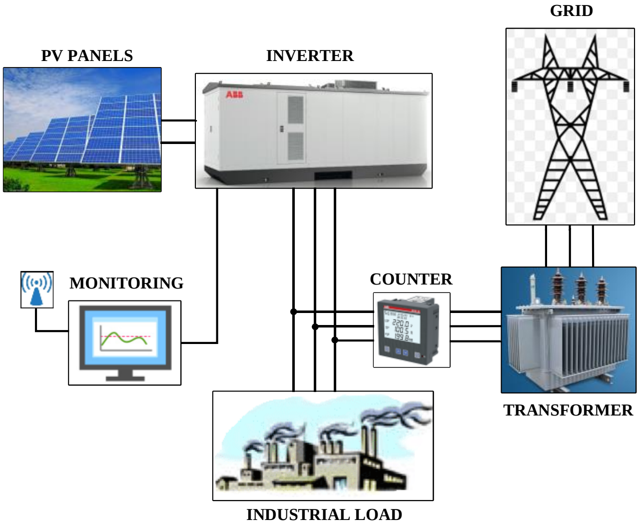



Fig.4. Schematic Diagram of a PV Power Plant.

The PV system is designed to convert sunlight into electrical energy. The main components of this system include several key sections, each playing an important role in the overall operation of the system. Below, we will introduce the components and explain the functioning of each:

PV Panels: PV panels, also known as solar cells, are the main components of the system and are responsible for converting sunlight into electrical energy. These panels are typically made of silicon and have electrodes that convert solar energy into electrical current. When sunlight strikes the surface of the panel, photons (light particles) collide with electrons in the semiconductor material (such as silicon), causing the electrons to be released. These free electrons create an electric current. The LONGi LR5-54HPH-425M is a strong PV module with a high fill factor, meaning it can make the most of solar radiation and generate more electricity per unit area. The LR5-54HPH-425M panels feature advanced technology, high efficiency, and durability [15].

Considering the available land area, there was no limitation in terms of space for panel installation. However, we opted for the LONGi LR5-54HPH-425M panel instead of higher-capacity panels due to its more cost-effective price. Although higher-capacity panels could be used, their higher cost did not justify the investment given the available land and the economic considerations of the project.

Inverter: The inverter plays a crucial role in converting the DC generated by the PV panels into AC required for the power grid and electrical devices. After the direct current is produced, the inverter converts it into alternating current. This process allows the system to transfer the generated energy to the power grid or domestic and industrial devices. ABB is one of the most reputable inverter manufacturers, and its central inverter range covers a wide range of power capacities. The high-speed MPPT feature ensures maximum efficiency. The central inverter offers several advantages, such as managing large-scale loads, reducing system complexity, and providing cost-effective installation. The advanced MPPT feature ensures that the system extracts the maximum power possible from the panels, even under fluctuating light conditions. Additionally, central inverters are designed to be highly durable, making them ideal for large-scale commercial and industrial projects. The PVS800-MWS-1000kW is one of the best power inverters in ABB's product line with an efficiency of up to 98.7% [16].

Transformer: The ABB RESIBLOC Dry-Type Transformer is an ideal option for converting the 400V output voltage from the PVS800-MWS-1000KW inverter to 20 kV for injection into the power grid. This transformer, in addition to increasing the voltage for reduced current and transmission losses, naturally reduces high-frequency harmonics due to its appropriate impedance. It also manages heating and additional losses caused by harmonics thanks to its high thermal class and design resistant to harmonic currents. These features, along with high compatibility with inverter systems, ensure the stable operation of the power plant and compliance with grid standards [17].

Wiring and Connections: The PV system requires appropriate wiring and connections to transfer the generated energy to different points. Wires and connections facilitate the transmission of electrical current between the components (panels, inverter, and loads). Reliable and appropriate connections can prevent energy loss.

Mounting Structure: The mounting structure holds the PV panels in the optimal position for maximum sunlight exposure. These structures can be fixed or adjustable and are usually designed to increase sunlight capture.

Monitoring System: Monitoring systems are used to track the performance of the PV system and collect data on its energy production and efficiency. These systems can provide information about energy production and overall system performance and help users ensure optimal system operation. To ensure proper, reliable, and stable operation of the power plant, a robust communication network for real-time monitoring is necessary. The monitoring and data collection system must function effectively to track the status of equipment in real-time and gather measurements. An internet gateway for secure and reliable data transfer can be used to monitor and record data.

By combining these components, the PV system can effectively and efficiently convert solar energy into electrical energy, making it suitable for various applications.

TABLE II

Specifications of the Components of the PV System Under Study.

| Component | Specification |
|---|---|
| Connection Type | Grid-connected |
| Nominal Power Capacity | 1.1 MW |
| Panel Type | Monocrystalline |
| PV Panel Model | LONGi LR5-54HPH-425M |
| Inverter Model | PVS800-MWS-1000KW |
| Transformer Model | ABB RESIBLOC Dry-Type |
| Panel Area | 5054 m² |

### E. Efficiency of Photovoltaic Panels

The efficiency of PV panels is defined as the amount of electrical energy produced relative to the amount of solar radiation input. In other words, efficiency indicates what percentage of the solar energy reaching the panel is converted into electrical energy.

$$\eta = \frac{P_{max}}{P_{in}} \times 100 = \frac{V_{oc} \times I_{sc} \times FF}{P_{in}} \quad (1)$$

In the above formula, $P_{max}$ is the maximum output power of the panel at the maximum power point, $P_{in}$ is the incoming irradiance power (which is the product of solar irradiance $G$ and the panel area $A$), $I_{sc}$ is the short-circuit current, $V_{oc}$ is the open-circuit voltage, and $FF$ is the fill factor (indicating the panel's performance quality). This formula relates the electrical parameters of the panel to the incoming irradiance power and expresses the conversion efficiency of solar energy to electrical energy as a percentage. Panel build quality, solar irradiance, and panel area are the key factors affecting the efficiency.

Fig. 5 illustrates the relationship between irradiance on the surface, voltage, and the output current of a PV panel, which is the output power. As shown in the figure, at a constant temperature, the current increases with increasing irradiance. However, if the irradiance remains constant, increasing the voltage does not significantly change the current, but in the range of 34 to 38 volts, an increase in voltage leads to a sharp decrease in current.

Fig. 6 shows the relationship between voltage and current at a fixed irradiance intensity. As indicated in the figure, at a fixed irradiance level, as the temperature increases, the area under the voltage-current curve (which represents the output power of the panel) decreases, thus reducing the system efficiency.

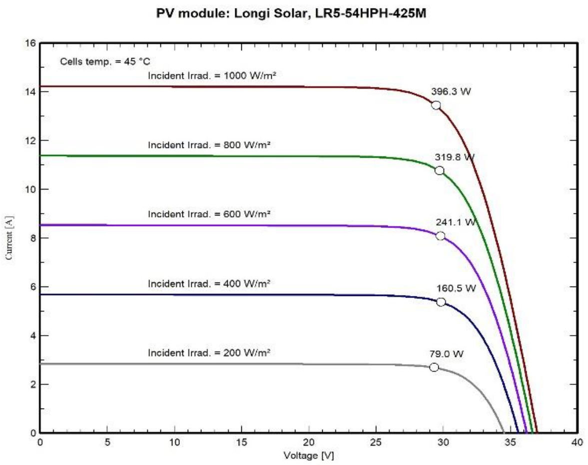



Fig. 5. Voltage-Current Curve of the PV Module at Different Irradiance Levels and a Constant Temperature of 45º.

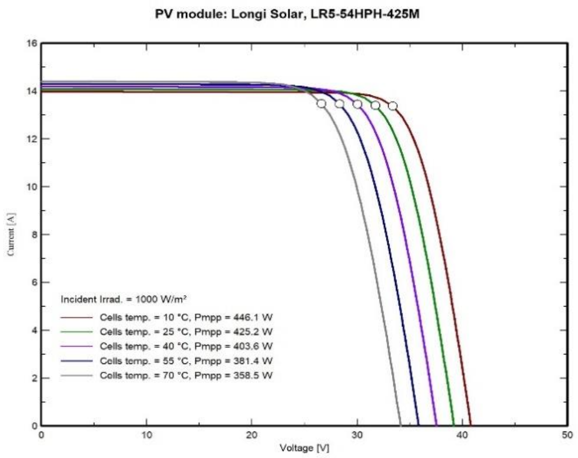



Fig. 6. Voltage-Current Curve of the PV Module at Constant Irradiance and Different Temperatures.

PV panels made from different materials (such as monocrystalline silicon, polycrystalline, and thin-film) have varying efficiencies. An increase in temperature can reduce the efficiency of the panels. Typically, PV panels perform better at lower temperatures. The installation position of the panels and the angle of solar irradiance on the panel surface significantly affect their performance. Defects in the materials and structure of the panels can negatively impact their efficiency. Pollution, dust, and other obstacles on the panel's surface can reduce its performance, as can clouds, precipitation, and humidity, which can decrease the intensity of solar radiation. Defects in areas where light should be absorbed can lead to efficiency reduction. Considering these factors, proper design, the use of high-quality materials, and regular maintenance can help improve the efficiency of PV panels.

### F. *Inverter Efficiency*

The inverter efficiency represents the ratio of the $AC$ output power ($P_{out,\,AC}$) to the $DC$ input power ($P_{in,\,DC}$) and is expressed as a percentage.

$$\eta = \frac{P_{out,\,AC}}{P_{in,\,DC}} \times 100 \tag{2}$$

$P_{out,\,AC}$ is the electrical power delivered to the grid or load, and $P_{in,\,DC}$ is the electrical power input from the PV panels or batteries to the inverter [18]. This efficiency depends on the quality of the inverter's design, losses during the conversion stages (such as switching losses, resistance, and cooling), and operating conditions such as temperature and loading [19].

Modern inverters typically have efficiencies ranging from 95% to 99%, playing a critical role in optimizing the overall performance of the PV system. Some of the factors influencing inverter efficiency can be categorized as follows:

- Temperature: The operating temperature of the inverter significantly affects its efficiency. As the temperature increases, efficiency generally decreases.
- Quality of Equipment: Using high-quality inverters and advanced technologies can lead to improved efficiency.
- Electrical Load: The efficiency of the inverter is typically optimized at specific load levels. Lower or higher loads can cause a decrease in efficiency.
- Operating Conditions: Environmental conditions such as humidity, direct sunlight exposure, and the amount of dust can influence the performance of the inverter.
- Input Voltage Range: Inverters operate within a specific voltage range for the input. Operating outside this range can reduce efficiency.
- System Design and Size: Proper system design and matching the inverter size with the PV panels can have a significant impact on overall efficiency.

By considering these factors, you can optimize the efficiency of your PV inverter and make better use of more efficient PV systems.

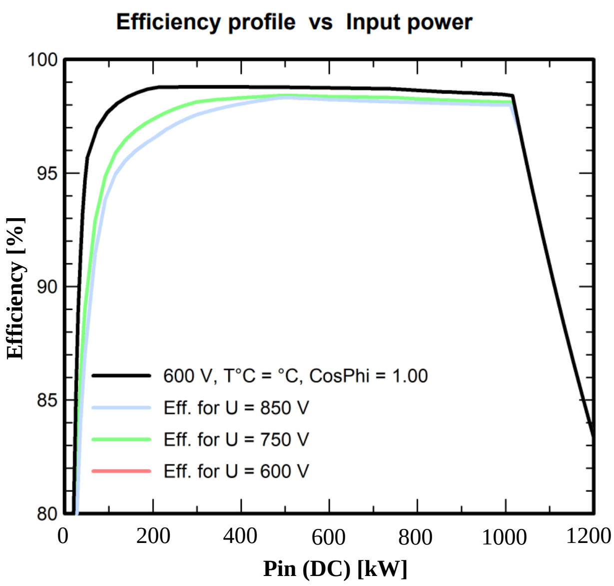



Fig. 7. Inverter Efficiency vs. Input Power Chart.

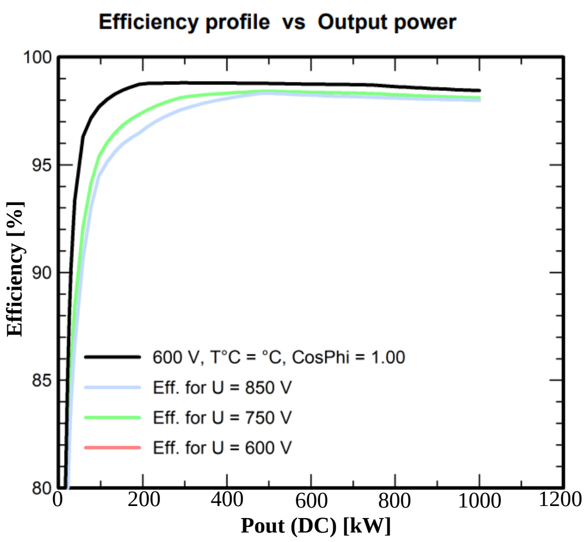



Fig. 8. Inverter Efficiency vs. Output Power Chart.

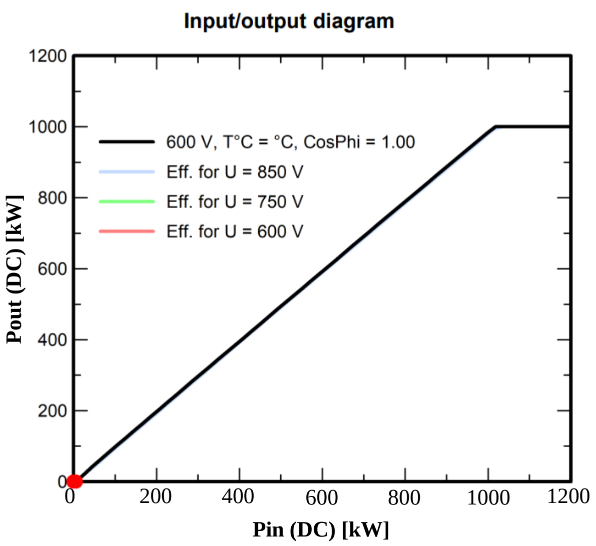



Fig. 9. Inverter Output Power vs. Inverter Input Power Chart.

The high efficiency of the inverter is a critical factor in renewable energy systems, particularly in PV systems. The higher the efficiency, the more energy is transferred from the PV panels to the grid or load, thereby enhancing the overall system's productivity. The performance of the inverter under the mentioned conditions is presented in Fig.s 7, 8, and 9.

## IV. Simulation and Result Analysis

The PVsyst software has been used as a reliable tool for evaluating the performance of PV systems. In this study, the results from the simulation of the PV system have been analyzed, with various parameters such as energy production and system efficiency being assessed.

- Key and Normalized Results: The summarized simulation results are shown in TABLE III, including parameters such as global irradiance on a horizontal plane, average ambient temperature, global irradiance on a collector plate without optical corrections, and effective global PV irradiance considering losses (pollution and shading). For the proposed location, the global irradiance on the horizontal plane is 1827.4 kWh/m², and the annual global irradiance on the collector without optical corrections and the effective global irradiance with optical losses are 2090.6 kWh/m² and 2053.4 kWh/m², respectively. The average diffuse irradiance is 596.29 kWh/m², and the average ambient temperature is 14.52°C. With this effective PV irradiance, the annual direct current electricity produced by the PV array and the annual alternating current electricity delivered to the grid are 2065.46 MWh and 2027.364 MWh, respectively. The average system performance ratio is 88%.
- Daily Input/Output of the PV Plant: In the case of Fig. 10, the scatter of points in the Daily Input/Output graph indicates the system’s performance and energy production stability throughout the day. Low scatter usually indicates stable performance and good equipment efficiency, such as modules and inverters. High scatter can result from rapid changes in solar irradiance (such as transient clouds), environmental factors like shading or dust, and even technical issues such as module misalignment or inverter performance fluctuations. Overall, the low scatter in this graph indicates that with appropriate equipment selection, the designed PV system has an optimal performance.
- Normalized Energy Production (Output): Fig. 11 shows the normalized energy production of a PV system throughout the year. The red section represents the useful energy produced (Produced Useful Energy), which is 5.04 kWh per kW of installed power per day, indicating the net energy available to the consumer after accounting for losses. The purple section shows the collection loss (Collection Loss), which is 0.59 kWh per kW of installed power per day, caused by environmental factors such as lower panel efficiency due to temperature, dust, and solar irradiance angle. The green section shows the system loss (System Loss), which is 0.09 kWh per kW of installed power per day and includes losses due to energy conversion by the inverter and other electrical components. The highest energy production occurs during the summer months (June to August), and the lowest occurs during the winter months (December and January). These values indicate that despite collection and

system losses, the system maintains optimal efficiency and produces significant useful energy.

- Performance Ratio: The Performance Ratio (PR) of the PV system for the entire year is 88%, indicating the overall efficiency of the system and the conversion of received solar energy into usable electrical energy. Monthly analysis shows that the performance ratio is higher in winter (such as January and December with values above 0.93) than in summer (such as July with a value of 0.838). This difference results from factors such as higher temperatures in summer, which reduce panel performance, better solar irradiance angle in winter, and increased thermal losses and low angle irradiance (IAM) in summer. The calculated performance ratio indicates optimal system performance, showing that its design, installation, and operation are in line with industry standards.
- System Efficiency: Power loss in various parts of the PV system occurs due to several factors. In PV arrays, multiple losses result from module mismatch, module quality, resistive losses in wiring, conversion losses during operation, losses due to threshold power, battery efficiency losses, charging/discharging current losses, inverter threshold losses, and so on. Fig. 13 presents the loss diagram throughout the electricity production process on an annual basis. This graph shows the energy losses in a PV system over a year. The horizontal solar irradiance is 1827 kWh/m², which increases by 14.4% to 2053 kWh/m² at the collector level due to the collector angle. Losses due to irradiance angle (IAM) are calculated as -1.8%, and the efficiency under standard test conditions (STC) is 21.78%. The energy produced at this stage is 2,263,205 kWh, which is subject to thermal losses of 6.8%, module mismatch losses of 2.1%, resistive losses in wiring of 1.2%, and inverter efficiency losses of 1.8%. In contrast, improved module quality and system performance result in an overall energy increase of +1.3%. The final output energy from the inverter is 2,027,364 kWh, which is delivered to the grid without further losses. This diagram clearly shows that thermal losses and module mismatch contribute the most to the system's efficiency reduction.

TABLE III

Key Simulation Results and Normalization.

| | GlobHor | DiffHor | T_Amb | GlobInc | GlobEff | EArray | E_Grid | PR |
|---|---|---|---|---|---|---|---|---|
| | kWh/m² | kWh/m² | °C | kWh/m² | kWh/m² | kWh | kWh | ratio |
| January | 81.0 | 29.87 | 0.82 | 132.9 | 131.4 | 141049 | 138239 | 0.944 |
| February | 97.7 | 38.22 | 3.16 | 136.4 | 134.7 | 142856 | 140084 | 0.932 |
| March | 142.0 | 49.27 | 8.80 | 171.2 | 168.4 | 174408 | 171055 | 0.907 |
| April | 173.8 | 62.36 | 13.64 | 182.2 | 178.6 | 180636 | 177246 | 0.883 |
| May | 208.6 | 67.78 | 19.58 | 196.7 | 192.1 | 190091 | 186531 | 0.861 |
| June | 223.1 | 69.96 | 24.79 | 199.7 | 195.0 | 189959 | 186582 | 0.848 |
| July | 221.3 | 69.89 | 27.82 | 201.4 | 196.7 | 189301 | 185976 | 0.838 |
| August | 209.0 | 66.50 | 26.76 | 211.8 | 207.5 | 199546 | 196173 | 0.841 |
| September | 173.8 | 49.58 | 22.26 | 201.8 | 198.0 | 192368 | 189068 | 0.851 |
| October | 131.4 | 37.50 | 15.98 | 182.5 | 180.2 | 180395 | 177200 | 0.881 |
| November | 91.1 | 32.23 | 7.43 | 144.6 | 142.8 | 149420 | 146570 | 0.920 |
| December | 74.7 | 23.13 | 2.44 | 129.3 | 128.1 | 135431 | 132641 | 0.932 |
| Year | 1827.4 | 596.29 | 14.52 | 2090.6 | 2053.4 | 2065460 | 2027364 | 0.880 |

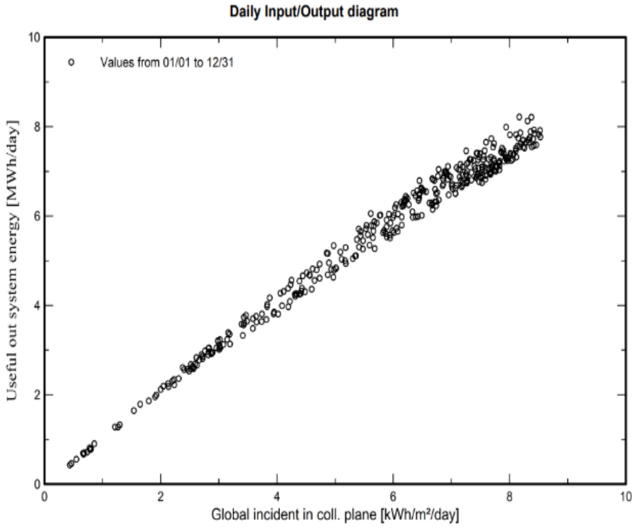



Fig. 10. Useful Energy Injected into the Grid as a Function of Energy Received by the Collector Panel.

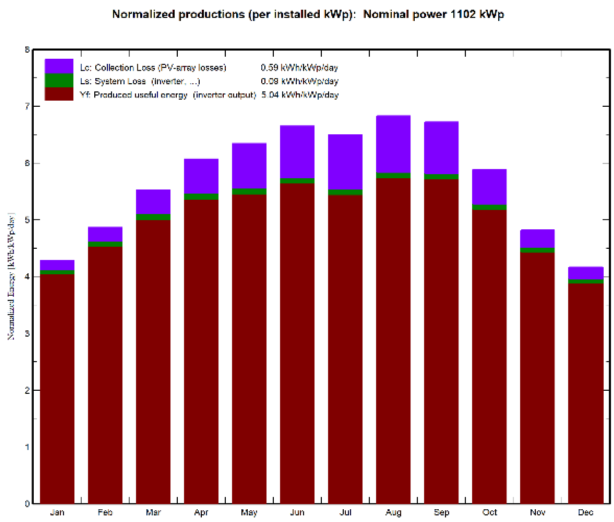



Fig. 11. Normalized Energy Production.

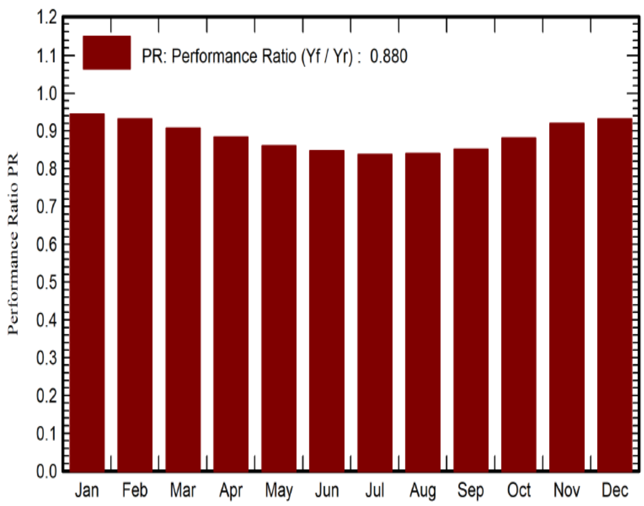



Fig. 12. System Performance Ratio (Efficiency).

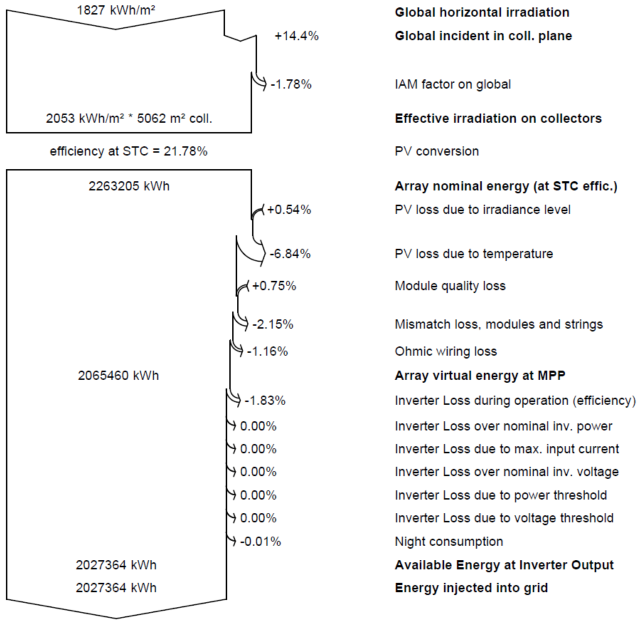



Fig. 13. System Power Diagram.

## V. Economic Analysis

Table IV summarizes the estimated financial parameters for the proposed PV power plant. Although the initial investment in a PV power plant is high, this project will be attractive with appropriate tariffs and good revenue. Based on cost calculations, the PV power plant in Kuye Faraz Sa'adat Abad, Tehran, has a short payback period, positive net present value (NPV), and a favorable return on investment (ROI), making it economically beneficial. These parameters are crucial for addressing the sustainability aspects of the project.

In this section, to have the flexibility to calculate economic parameters in MATLAB, we will write code. The total investment in this PV power plant is approximately 426,031 euros, equivalent to 340 billion Rials, which includes the costs of purchasing, installing, and commissioning the system. The total revenue of the project from electricity generation will reach 704 trillion Rials, and its payback period is around 6.5 years, meaning that after approximately 7 years, the project will recover its initial costs and start generating profit. (It should be noted that the payback period is calculated based on net income and without the effect of inflation, which would increase revenue.) These figures indicate the good profitability potential of the project, as the payback period is short and its long-term revenue will be significant.

The NPV generated by the project, after deducting the initial investment and considering the discount rate, is 592,169 euros. The project is profitable because the NPV is positive, indicating that the return on the project exceeds the discount rate, and therefore, investing in this project is favorable for the investor.

If the NPV is positive, the project is generally feasible unless there are other constraints, such as high risk, budget limitations, or the selection between alternative projects with higher NPVs.

ROI is a financial ratio used to assess the efficiency of an investment or project. This metric helps to understand how much profit has been earned relative to the cost of the investment.

If the ROI is 433%, it means that for every unit of currency invested, 4.33 units of profit have been earned. In other words, the investor has earned 433% more than the amount invested. This figure indicates a very successful investment, as it is greater than 100%, meaning the investment is profitable.

An increase in inflation directly and significantly impacts income levels. As inflation rises, the prices of products and services also increase. Therefore, for solar energy projects, annual income will also increase in proportion to inflation. For example, as shown in Fig. 14, which shows revenue for two periods (1 to 10 years and 11 to 25 years), if the inflation rate is assumed to be 45%, your income gradually increases over time with rising inflation. With a 45% inflation rate, revenue in the 25th year will be 7462 times higher than in the first year.

TABLE IV
Estimated Financial Parameters.

| Parameter | Value |
|---|---|
| Nominal Capacity of the Power Plant (MW) | 1.1 |
| Annual Energy Injected to the Grid (MWh) | 2027 |
| Purchase Rate per kWh (Rial) | 35,000 |
| Inflation Rate | 30% |
| Interest Rate | 24% |
| Discount Rate | 10% |
| Tariff Increase Rate | Inflation Rate |
| Annual Land Rent (Billion Rial) | 1 |
| Land Rent Increase Rate | Inflation Rate |
| Panel Cost (Euros) | 180,000 |
| Inverter Cost (Euros) | 99,200 |
| Transformer Cost (Euros) | 53,320 |
| Advanced Monitoring System Cost (Euros) | 35,000 |
| Other Equipment Costs | 10% of the main equipment investment |
| Installation Cost | 5% of the main equipment investment |
| Annual Insurance Rate | 1% of the main equipment investment and installation cost |
| Insurance Increase Rate | Inflation Rate |
| Annual Maintenance Cost | 0.5% of the main equipment investment and installation cost |
| Maintenance Cost Increase Rate | Inflation Rate |
| Annual Efficiency Decrease | 0.5% |
| Production Decrease Due to Dust | 1% |
| Useful Life of the Power Plant (Years) | 25 |
| Residual Value of Equipment | 10% of the main equipment investment |
| Euro to Rial Exchange Rate | 800,000 |

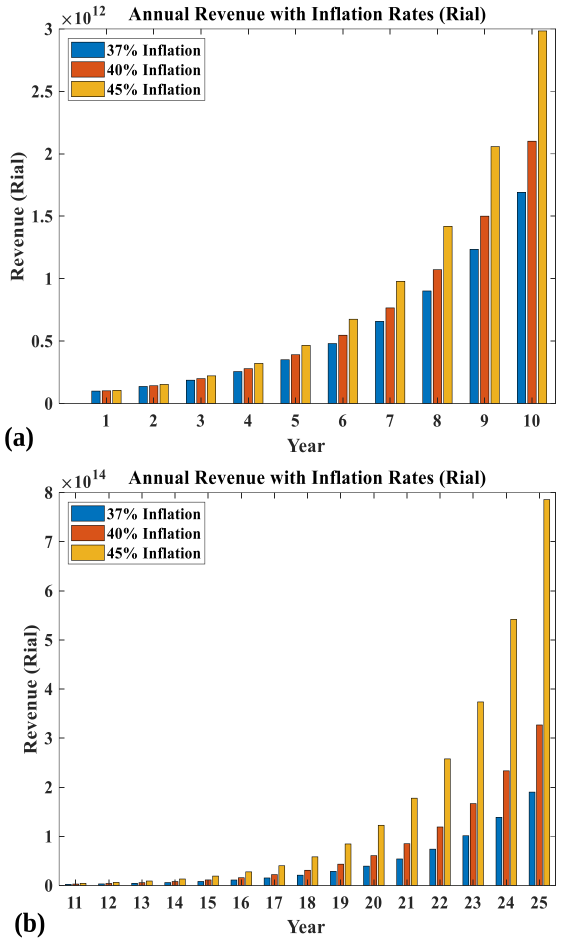



Fig. 14. Annual Revenue with Inflation Rates (Rial).

Considering the high inflation rates in Iran, the sensitivity results of NPV and payback period to inflation rates in Rials show the significant impact of these rates on investment projects. With an increase in the inflation rate and as shown in Fig. 15, the NPV of the project increases significantly. For example, at a 37% inflation rate, the NPV is 720,027,426,753 rials, while at a 40% inflation rate, it reaches 739,804,027,693 rials, and at a 45% inflation rate, it rises to 772,765,029,259 rials. This increase in NPV is due to higher income from inflation and rising energy prices, which directly affect the financial return of the project.

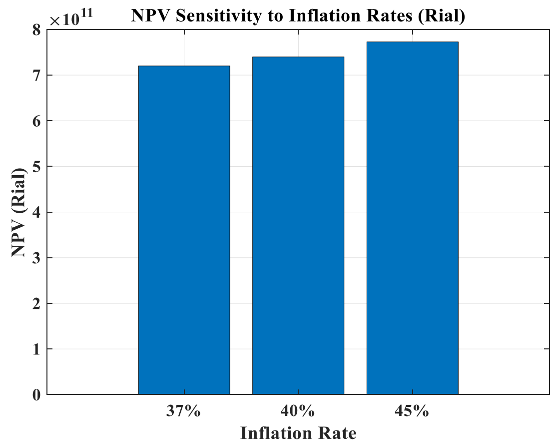
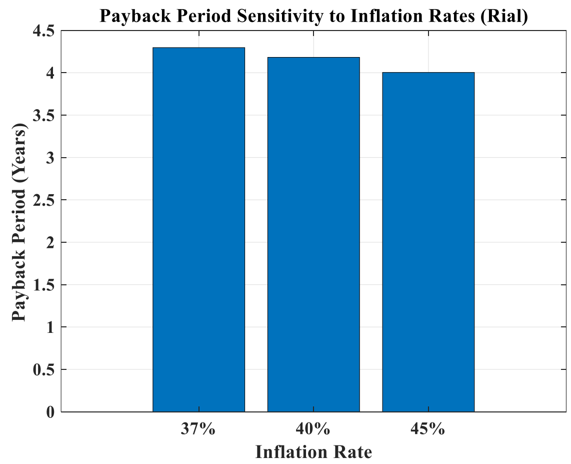



Fig. 15. NPV to Inflation Rates (Rial)

As for the payback period, with an increase in inflation, the payback period decreases. For instance, at a 37% inflation rate, the payback period is 4.3 years, while at 40%, it drops to 4.18 years, and at 45%, it becomes 4 years. This shows that with increased inflation, the project reaches the break-even point more quickly, and investors can recover their investment faster.




. 16. Payback Period to Inflation Rates (Rial)

Thus, these data suggest that in high inflationary economic conditions, projects may become more financially attractive and have a quicker return on investment. It should also be noted that choosing equipment from different brands can have a significant impact on the initial investment cost. For example, if choosing equipment from different brands results in a 20% reduction in the initial investment, this would reduce the payback period by at least one year for various inflation rates, bringing it down to around 3 years.

## VI. Conclusion

The design and performance evaluation of a grid-connected PV system with a nominal capacity of 1.1 MWp in the Tehran Regional Electricity Company area, located in the Kuye Faraz Sa'adat Abad district of Tehran, was conducted using the PVsyst software. The power plant was designed with PV panels with a nominal capacity of 425 watts and a central inverter with a capacity of 1000 kW. The following results were obtained:

- The amount of energy injected into the grid is 2027.364 MWh per year.
- The highest energy supplied to the grid is 196.173 MWh in August, and the lowest amount is 132.641 MWh in December.
- The average annual performance ratio of this PV power plant is 88% for the pre-designated location simulated.
- At the current inflation rate of approximately 37% in Iran, the payback period is 4.3 years. However, at an inflation rate of 40%, it decreases to 4.18 years, and at 45% inflation, it decreases further to 4 years. This indicates that with an increase in inflation, the project reaches the breakeven point more quickly, allowing investors to recover their investment sooner.

The results show that the design of this simulated PV system will provide significant operational benefits to the operator, making it advantageous for the investor.

## REFERENCES


[1] J. Smith and J. Doe, "Advances in Photovoltaic Technology," Solar Energy Journal, 2023.

[2] A. Jones and B. Brown, "Solar Irradiance and its Effects on Photovoltaic Efficiency," Journal of Renewable Energy, 2024.

[3] J. Doe and R. Roe, "Photovoltaic Systems and Their Applications," Energy Conversion Journal, 2024.

[4] Sadeghi, and Thana, 2023. "Design and Analysis of a 30 kW Grid-Connected Photovoltaic System Using PVsyst Software," Iranian Journal of Electrical and Electronics Engineering, vol. 20, no. 4, pp. 47-54.

[5] M. Alvarez, et al., "Impact of Dust on Solar Panel Efficiency in Desert Regions," Environmental Science and Technology, 2023.

[6] J. Smith and J. Doe, "Recent Innovations in Solar Panel Cleaning Technologies," Solar Power Journal, 2024.

[7] L. Johnson, et al., "Potential of Solar Energy Utilization in Urban Areas," Energy and Environment Journal, 2024.

[8] T. Brown and S. White, "The Effect of Temperature on Solar Panel Performance," Renewable Energy Journal, 2023.

[9] J. Doe and B. Brown, "Development of New Photovoltaic Materials," Journal of Solar Energy, 2024.

[10] Geravand, A., Sharbati, S. and Danaie, M., 2017, May. Optimize the parameters of the new fabricated n-CdTe/p-CdTe solar cell. In 2017 Iranian Conference on Electrical Engineering (ICEE) (pp. 412-416). IEEE.

[11] Danaie, M., Khani, S., Noorozzadeh, E. and Vahdani, M., 2019. Improving the performance of cadmium telluride solar cells (CdTe) with different buffer layers. Iranian Journal of Physics Research, 19(1), pp.139-147.

[12] Danaie, M., Khani, Sh., Norouz-Zadeh, E. and Vahdani, M., 2019. Enhancing the performance of cadmium telluride (CdTe) solar cells with different buffer layers.

[13] S. Green and L. Blue, "Converting DC to AC in Photovoltaic Systems," Energy Systems Journal, 2023.

[14] PVsyst.com

[15] LONGi, LR5-54HPH-425M Solar Module Specifications.

[16] ABB, PVS800-MWS-1000kW Central Inverter Specifications.

[17] ABB, RESIBLOC Dry-Type Transformer Specifications.

[18] Banki T, Faghihi F, Soleymani S. Robust frequency control of provisional microgrid by using a combined fuzzy reset approach. Journal of Electrical Engineering & Technology. 2024 Jan;19(1):125-32.

[19] Shahroudi MM, Faghihi F, Mozafari B. A novel control scheme for load current components sharing improvement, and unbalanced and harmonic voltage compensation, in islanded provisional microgrids. Electric Power Systems Research. 2023 Oct 1;223:109560.