

# Evaluating the technical and the economic potential of PV systems through feasibility studies

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*The growing demand of photovoltaic (PV) systems, driven by the increasing price of electrical energy, necessitates thorough feasibility studies and system optimization to ensure optimal performance and economic viability. A feasibility study assesses solar resource availability, site suitability, system sizing, and financial aspects to determine the practicality of a PV installation. Additionally, economic considerations extend beyond energy yield, particularly for self-consumption and energy trading applications. Tailoring feasibility studies and optimization measures to investor-specific requirements is crucial for maximizing financial returns. This paper highlights the critical role of feasibility assessments in improving the overall effectiveness of PV installations. The importance of following key steps while performing the feasibility studies are discussed.*

**Keywords – PV systems, feasibility, optimization, economic viability**

**Оценка на техническия и икономическия потенциал на фотоволтаичните системи чрез предпроектни проучвания (Николай Куртев).** Нарастващото търсене на фотоволтаични (PV) системи, обусловено от нарастващата цена на електрическата енергия, налага задълбочени проучвания за осъществимост и оптимизация на системата, за да се осигури оптимална производителност и икономическа жизнеспособност. Проучването за осъществимост оценява наличността на слънчеви ресурси, пригодността на мястото, оразмеряването на системата и финансовите аспекти, за да определи практичността на фотоволтаичната инсталация. Освен това, икономическите съображения се простират отвъд добива на енергия, особено за приложения за собствено потребление и търговия с енергия. Адаптирането на проучванията за осъществимост и мерките за оптимизация към специфичните изисквания на инвеститора е от решаващо значение за максимизиране на финансовата възвръщаемост. Тази статия подчертава критичната роля на проучванията за осъществимост за подобряване на цялостната ефективност на фотоволтаичните инсталации. Обсъжда се значението на следването на ключови стъпки при извършване на проучванията за осъществимост.

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## I. Introduction

The increasing demand for clean and sustainable energy sources has propelled the widespread implementation of photovoltaic (PV) installations as a viable solution for generating electricity from sunlight. This trend was also pushed by the significant drop in the price of solar modules in recent years [1, 2]. However, the successful implementation of PV systems requires careful consideration of various factors, including feasibility assessment and system optimization. This paper aims to explore the importance of conducting a feasibility study by following predefined steps while exploring the potential to create new PV installations and to maximize their performance and economic viability.

A review of the main steps in a feasibility study and optimization of PV plants is presented.

A feasibility study serves as a key step in evaluating the practicality and economic effect of installing a PV system in a specific site. It involves assessing factors such as solar resource availability, site suitability, system sizing and financial analysis. Accurate assessments of solar radiation data, considering variables such as shading limit angle, tilt angle and azimuth are essential for determining the potential energy generation of the PV system. Evaluating the site's characteristics, including available space, terrain characteristics and potential obstructions, helps identify any limitations or constraints that may impact the installation [3].

In the case of PV installations dedicated for self-consumption purposes a system sizing should be done

by investigating several factors. Analyzing load profiles, electricity consumption patterns and peak power requirements helps determine the optimal capacity and size of the PV system and thus ensures that the PV system is appropriately dimensioned to meet the energy demand of the site effectively. Moreover, a thorough financial analysis, encompassing upfront costs, operational and maintenance expenses and potential incentives or tax benefits, enables investors to assess the economic viability and return on investment of the proposed installation.

Once the feasibility study is completed, system optimization becomes a critical aspect of maximizing the performance and efficiency of the PV installation. Optimization strategies encompass various aspects, including component selection, system design and performance monitoring. Selecting high-efficiency and cost-effective solar modules, inverters and mounting systems can significantly impact the overall system performance. Optimizing the layout and orientation of the solar panels minimizes shading effects and maximizes solar energy capture. Additionally, designing the electrical system and implementing performance monitoring mechanisms help identify underperforming components and ensure prompt maintenance and corrective actions [4].

As the two main types of PV installation are for energy trading and for self-consumption the feasibility study should be carefully adopted to the specific investors requirements and must conduct a system optimization measures which maximizes the economic effect of the PV installations, which is not necessarily straightforward to the yield optimization.

## **II. Main steps when performing analysis**

### *A. Site inspection*

Site inspection is a fundamental component of the feasibility study and system optimization process for photovoltaic installations. It involves a comprehensive assessment of the site's physical characteristics, which provides important information for the maximum possible installed power and the performance of the PV system.

Site inspection could start with the evaluation of the solar resource potential at the location. This assessment involves the analysis and in rare cases the measurement of solar radiation data, considering factors such as shading, tilt, orientation and local weather patterns. By accurately assessing the solar resource availability, potential issues such as shading from nearby structures or vegetation can be identified,

enabling the optimal placement and orientation of the solar panels to maximize solar energy capture.

The site inspection also encompasses a detailed evaluation of the site's suitability for PV installations. Factors such as available space, topography and proximity to potential obstructions are considered. The available space is assessed to determine if it can accommodate the desired capacity and configuration of the PV system. Moreover, the orientation and inclination of the land are analyzed to optimize the solar panel placement and maximize energy generation. Potential obstructions such as trees, buildings or other structures are identified to reduce shading and ensure unobstructed access to sunlight.

The geology of the site should be evaluated in case of ground mounted PV installations. This evaluation includes assessing the stability and structure of the ground. The load-bearing capacity of the structures in the case of rooftop PV installations should also be studied. Structural considerations ensure that the structure can support the weight of the solar modules, mounting structures and associated equipment. Additionally, proper evaluation of the structural conditions helps reduce potential risks, ensuring the long-term durability and stability of the PV system.

The existing electrical infrastructure at the site is another important aspect of the site inspection. This assessment involves evaluating the capacity of the electrical panels, availability of suitable interconnection points and assessing any potential grid connection requirements. Understanding the electrical infrastructure ensures compatibility with the PV system, facilitates a smooth integration process and avoids potential electrical limitations or complications.

Site inspections also include an evaluation of environmental and regulatory factors that may impact the PV installation. This includes assessing local zoning regulations, obtaining necessary permits and considering any environmental sensitivities or restrictions. Compliance with applicable regulations and obtaining the required approvals is essential to ensure a legally compliant and environmentally responsible PV installation.

The information gathered during the site inspection forms the basis for informed decision-making regarding the feasibility and optimization of the PV system. It provides critical insights into the solar resource potential, site suitability, structural integrity, electrical compatibility and regulatory considerations. These findings guide the subsequent steps of system design, configuration and optimization, ensuring the

successful implementation and long-term performance of the PV installation at the specific location.

### *B. Shading considerations*

Shading objects can have a significant impact on the performance and energy production of photovoltaic (PV) plants. Shading can be classified into two main categories: far shading and nearby shading.

Far shadings refer to obstructions that are located at a relatively large distance from the PV plant, such as large trees or tall buildings, hills etc. These shading objects can cast shadows on the solar panels during specific times of the day, causing localized reductions in solar irradiation and energy generation. The impact of far shadings depends on the position of the shading objects in relation to the PV plant's orientation and the movement of the sun throughout the day – respectively of the year time.

Normally the far shading should be avoided because there is no efficient way to optimize the PV plant regarding the far shadings. On the other hand, nearby shadings refer to obstructions that are in close proximity or into the PV plant, such as adjacent buildings, vegetation or other structures. These shadings can cast shadows directly on the solar panels, causing localized and frequent reductions in solar irradiation. Nearby shading objects can have a more pronounced impact on energy generation compared to far shadings, but during the design steps the impact of those shadings could be significantly reduced [5].

Optimizing the tilt and spacing for nearby shading requires careful consideration of the specific shading patterns and the location of the shading objects. One approach is to design the PV system with a larger tilt angle, reducing the likelihood of direct shadowing on the solar panels. However, a higher tilt angle may also increase the potential for self-shading among the panels. Hence, finding the right balance between reducing nearby shading and optimizing self-shading is essential.

Spacing between adjacent rows of solar panels is critical for minimizing shading from nearby objects. Increasing the spacing between rows can help reduce the shadowing effect, allowing more sunlight to reach the solar panels. However, it is essential to strike a balance between maximizing the spacing and utilizing the available space efficiently to optimize the overall energy production capacity of the PV plant.

### *C. Market investigation*

Market investigation is component of the feasibility study which helps the investors and

engineers to choose the most suitable key components of the equipment regarding the specific requirements of the project. It involves assessing the current market conditions and trends, technological advancements, pricing and the performance characteristics of PV modules and inverters. Several key factors should be considered during market analysis, including availability, warranty, customer support and lead time [2].

Availability is a crucial aspect to evaluate when analyzing the market for PV modules and inverters. This involves assessing the production capacity and supply chain capabilities of manufacturers and suppliers. Determining the availability of desired modules and inverters within the project timeline is essential. Factors such as lead time, stock availability and the ability to meet specific project requirements need to be considered, particularly for larger-scale installations.

Warranty terms offered by PV module and inverter manufacturers should also be thoroughly examined during market analysis. Comparing warranty durations, coverage for different types of failures and the reputation of manufacturers for honoring warranty claims is important. A comprehensive warranty provides assurance against defects or performance issues during the specified period, protecting against unexpected expenses and ensuring peace of mind.

Customer support services offered by PV module and inverter manufacturers or suppliers are a crucial consideration. Reliable and responsive customer support is vital for addressing technical issues, troubleshooting and resolving any concerns that may arise during installation, commissioning or operation of the PV system. Prompt and effective customer support contributes to a positive user experience and helps maintain optimal system performance.

Lead time, the time required from placing an order to the delivery of equipment is another key factor in market analysis. Analyzing lead times allows project planners to align procurement timelines with project schedules and installation timelines. Assessing lead times is particularly important for time-sensitive projects, as shorter lead times can be advantageous. Longer lead times may require careful planning to ensure that equipment availability does not cause project delays.

By considering availability, warranty, customer support and lead time during market investigation, stakeholders can make informed decisions about PV module and inverter selection. Opting for suppliers that offer favorable warranty terms, robust customer support, reasonable lead times and readily available

equipment contributes to the overall success and satisfaction of the PV system.

#### *D. Modeling of the PV plant*

Modeling of a PV plant is a next step in the feasibility study. The main goal of this step is to estimate the energy yield and optimization of various parameters to maximize performance. To estimate the yield of a PV plant, various factors are considered. Solar resource data, such as solar radiation and weather patterns, are incorporated into the modeling process. This data is combined with information about the PV modules' characteristics, including efficiency, temperature coefficients, and degradation rates. Additionally, the modeling considers the system's orientation, tilt angle and shading effects from nearby objects [6, 7].

Simulation tools and software are commonly used to create accurate models of PV plants. These tools utilize mathematical algorithms and consider various parameters to generate reliable yield estimates. By inputting the specific parameters of the PV system and the environmental conditions of the site, the model calculates the expected energy generation, allowing stakeholders to assess the system's performance under different scenarios.

Depending on the metrological data used the calculated yield and other parameters of the PV plant could vary. This data is typically derived from meteorological databases or collected from on-site weather stations. One commonly used dataset is the Typical Meteorological Year (TMY), which represents a statistically generated year that captures the long-term weather patterns and characteristics of a specific location.

The TMY dataset consists of hourly or sub-hourly data for various meteorological parameters, including solar radiation, temperature, wind speed and atmospheric conditions. These parameters are essential inputs for PV plant software models, allowing for accurate simulation of energy production and performance.

Solar radiation data is particularly crucial as it directly affects the energy generation of the PV system. The TMY dataset provides information about the global horizontal irradiance (GHI) and direct normal irradiance (DNI), which are essential for estimating the solar energy incident on the PV modules. This data helps model the shading effects, the impact of cloud cover and the variation in solar radiation throughout the day and across the seasons.

Temperature data is another significant parameter included in the TMY dataset. Temperature affects the

efficiency of PV modules, as higher temperatures can lead to decreased performance. By incorporating temperature data, the software model can accurately estimate the temperature coefficients and the impact of temperature on the energy yield of the PV system.

Wind speed and atmospheric conditions are also considered in the TMY dataset. These parameters are relevant for determining the impact of wind on the PV system, such as the cooling effect it provides and the potential for mechanical stress on the components. By including wind speed and atmospheric data, the software model can assess the system's performance under various wind conditions and optimize the design and layout for enhanced durability.

Modeling also plays a crucial role in optimizing the parameters of a PV plant. For example, the tilt angle and orientation of the solar panels can be adjusted to maximize energy capture based on the specific latitude and climate conditions of the installation site. Optimizing the system's electrical configuration, including the number of modules in strings and number of strings, can improve energy conversion efficiency and minimize losses. Furthermore, modeling can aid in determining the optimal sizing of the PV system to meet the site's energy demand while considering available space and budget constraints.

By conducting sensitivity analyses within the model, the engineers can assess the impact of various factors on energy yield. This includes evaluating the effects of shading, dust accumulation, temperature, and soiling on the performance of the PV plant. Through these analyses, adjustments can be made to optimize the system's design and operation, such as implementing cleaning strategies, adjusting maintenance schedules or considering additional shading reducing measures.

#### *E. Financial analysis*

Financial analysis involves evaluating the economic viability and return on investment of the PV plant. This analysis considers factors such as the initial capital costs, operational and maintenance expenses, electricity prices, incentives and financing options. By incorporating these parameters into financial models, stakeholders can estimate the project's financial performance, including metrics such as payback period, internal rate of return and net present value [9, 10].

Sensitivity analyses are conducted within the financial models to assess the impact of various factors on the project's financial outcomes. These analyses may include variations in electricity tariffs,

changes in system performance or fluctuations in interest rates. By considering different scenarios, the investor can identify risks and optimize the financial parameters to enhance the project's economic feasibility and profitability [8].

PV modules experience a gradual degradation in performance over time due to various factors. The most common degradation mechanism is the gradual decrease in power output, commonly referred to as degradation or power loss. The degradation rate depends on multiple factors, including the module technology, manufacturing quality, environmental conditions and operating conditions.

Industry standards typically define a degradation rate, often expressed as a percentage per year, that represents the expected decrease in power output over the module's lifetime. Degradation rates can vary, but typical values range from 0.3% to 2% per year.

Accounting for degradation is crucial in yield estimation and financial analysis. When modeling the energy yield of a PV plant, the degradation rate is considered to estimate the declining performance over time accurately. By incorporating degradation in the performance modeling, stakeholders can project the expected energy production and assess the long-term financial viability of the PV system.

It is important to note that degradation rates are based on average expectations and actual degradation can vary depending on specific operating conditions and maintenance practices. Regular monitoring and maintenance of the PV system can help identify and mitigate any performance deviations or accelerated degradation.

To account for potential degradation and maintain optimal performance, stakeholders may consider incorporating a degradation warranty or performance guarantee in their procurement agreements. These warranties ensure that the modules will meet or exceed a specified minimum power output over a designated period.

## Conclusion

The feasibility study is a first step in the establishment of a photovoltaic (PV) installation. Through site inspections, market investigations, accurate modeling and financial analysis, investors can gain valuable insights into the viability and potential of installation of PV. The feasibility study provides important input parameters that guide decision-making and optimize system design.

The findings from the feasibility study serve as the foundation for the subsequent technical design phase. Leveraging the data and insights obtained,

stakeholders can proceed to the detailed engineering and layout of the PV system. The technical design phase utilizes the information from the feasibility study to optimize system performance, maximize energy yield and ensure compliance with regulatory requirements.

By seamlessly transitioning from the feasibility study to the technical design phase, the investors can build upon the identified opportunities and challenges. The technical design phase further refines the system parameters, such as capacity, layout optimization and component selection, to meet the specific requirements of the project. This phase integrates the latest technological advancements and simulation tools to fine-tune the design, estimate energy yield and ensure efficient and reliable operation.

The successful completion of the feasibility study lays the groundwork for the technical design phase, allowing investors to proceed with confidence. The insights gained from the feasibility study, including site suitability, solar resource availability, market analysis and financial considerations, inform the technical design process, facilitating the development of an optimized and sustainable PV plant.

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