Technical Aspects of Procuring Availability Services for Photovoltaic Plants

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***Abstract*—This article delves into the technical aspects of procuring availability services for photovoltaic (PV) plants, with a specific focus on a recent contract established in Croatia. The contract involves the procurement of a PV plant under an availability service model, where the service provider is responsible for ensuring the plant's availability in accordance with the standards set by the procurer. Under this contract, the provider must supply, install, test, finance, and maintain the PV plant for a specified period, typically up to 10 years. This article examines the technical specifications, design, implementation, and maintenance challenges of PV plants, highlighting the importance of maintaining high availability standards. Additionally, it provides a practical example from Croatia, outlining the technical and operational challenges encountered during the execution of such contracts. The goal is to offer insights into the technical complexities and best practices for successfully implementing and maintaining PV plants under availability service contracts.**

***Keywords*—availability, solar power plants, QoS.**

I. Introduction

Public procurers increasingly use the availability service procurement model for renewable energy projects. This model allows specialized private partners to take on technical responsibilities for designing, building, and maintaining plants, while public procurers provide financial and operational support. In Croatia, this model has been applied to photovoltaic plants to enhance energy efficiency and sustainability. The procurement process utilized the life cycle cost (LCC) criterion [1], as specified in Articles 287 and 288 of the Croatian Public Procurement Act, to ensure cost-effectiveness and sustainability [2].

Contracting authorities may procure public investment projects (construction and non-construction – plants, equipment, appliances, etc.) in different ways. Each way has different effects on transparency, durability of quality in lifetime, price, financial sustainability, availability of public service delivered by the project to citizens and the like. The procurement method (or model of procurement of public investment projects) that contracting authorities most often apply is traditional procurement of works. Within this procurement model, the contracting authority shall conclude a contract for the procurement of works with the contractor and the supplied works shall be paid from its own (budgetary) sources or from other mainly debt sources of financing. An important feature of this procurement model is that the contracting authority maintains the construction or installation in its lifecycle by taking on a predominant part of the overall risks to the construction or installation in its lifecycle.

Another model increasingly applied by contracting authorities in the developed world is the procurement of a building or plant availability service. The difference of this model of procurement of public investment projects is that the contracting authority does not only procure works, but also related to them maintenance. Therefore, in the procurement model, availability services, works and maintenance are inseparably linked. By availability is understood the obligation of the operator of the service of availability to keep the building or plant in an accessible (functional) state during the contract period, which is usually in the range of 20 to 30 years for buildings and for installations from 5 to 15 years. The contracting authority shall not pay for the works carried out, but periodically, during the contract period, the services of availability supplied if, within the accounting period (month, quarter, half-year, or year), the construction or installation was available. In this sense, the executor of the availability service, in addition to construction and maintenance, most often assumes the obligations of financing the construction of a public project.

Each model of procurement of public investment projects has advantages and disadvantages, and the task of public management is to determine whether the advantages are greater than the disadvantages and in such a process of comparison choose the one with which the highest probability of achieving value for money can be expected.

The contract on the procurement of availability, specifically the availability of a photovoltaic plant [3], regulates the relations between the client (municipality) and the executor (entrepreneur). The most often covered elements by the contract are definitions of terms; introductory remarks; plant definition; definition of plant availability; the rights and obligations of the parties; availability fee; the calculation, payment, and reconciliation of the availability fee; the duration and modification of the contract; financing, refinancing, and co-financing procedures; termination of the contract; final provisions; contributions and so on.

For the operationalization of the availability service, the establishment of trust and transparency in the contracting entity-executor relationship is essential, and in this context, it is necessary to establish a platform that will enable the verification of contract elements and agreed availability indicators. Availability in the solar industry refers to the technical ability of solar systems to produce energy in each period.

II. Photovoltaic Plants and Availability Standards

Although the construction of photovoltaic plants today is clearly defined by regulations, the components are standardized and there are many designers and contractors, in practice one can often encounter the fact that the plant does not produce electricity in accordance with the design specifications. The reasons for this could be inadequate or suboptimal positioning of the system, selection of suboptimal components, failure to maintain the system or external influences. In technical terms, each of the components of a photovoltaic plant can be the cause of its failure and unavailability [4]. Photovoltaic plants consist of several key components:

- Photovoltaic Modules: Convert solar energy into electrical energy. Key specifications include conversion efficiency, power, and weather resistance.
- Inverters: Convert direct current from modules into alternating current for use in the power grid.
- Energy Storage Systems: Enable storage of generated energy for later use. Batteries are the most common form of storage.
- Monitoring and Control Systems: Software and hardware solutions that allow real-time monitoring and optimization of plant operations.

The technical standards that a photovoltaic plant must meet include IEC (International Electrotechnical Commission) standards, such as IEC 61215 for modules and IEC 61730 for safety, however, they can also be extended to additional national standards or user requirements.

Linking a standard to the contractual obligations of a service provider is essential to ensure that a supplier of a service of availability meets certain quality, safety or any other relevant standards specified in the contract. The first step is to clearly define the standards that will apply to the delivered service. These can be industry standards, legal regulations, international standards, or internal standards applied by the organization. It should be determined what specific requirements the standards place and how those requirements will be integrated into the provision of services. For example, there may be a standard that specifies the necessary indicators or reporting obligations to the competent control authorities, some organizations have internal standards on safety, for regular maintenance of equipment or for the training of personnel. Safety standards are especially important if the clients are public institutions (kindergartens, schools, hospitals) with special requirements. Open communication between the client and the supplier of services on standards and their application is crucial, i.e. that both contractual partners understand expectations and obligations.

The next step is to select the appropriate measurement method for each identified critical point or component, and what exactly we monitor (plant uptime before the next failure, analysis of the causes of failures, maintenance monitoring, and the like.). The collection of data for the purpose of measuring the standards supplied should certainly be automated wherever possible to minimize human error and ensure data consistency.

Quality of Service (QoS) in a photovoltaic (PV) power plant is closely related to availability, which refers to the proportion of time that the PV plant is operational and capable of producing energy. High availability is crucial for maximizing the return on investment and ensuring a reliable supply of renewable energy. The automated availability monitoring platform enables regular analysis of the collected data and the identification of patterns, trends, or potential system availability delays. This is carried out through reliability reports that provide an overview of key KPIs and performance indicators and compare actual results with set (contracted) reliability goals. If there are discrepancies, reasons are usually investigated and strategies for improvement are developed. Reliability measurement often requires an integrated approach that includes technical, operational and management aspects. Regular monitoring and adaptation of measurement methods are essential to maintain high system or process reliability.

III. Availability Standards and Technical Challenges

Availability standards define the minimum levels of operational efficiency that a plant must maintain and is often measured as the percentage of time the plant is fully functional and capable of producing energy.

The first step in the selection and design of the availability monitoring system is certainly to define and harmonize expectations between the client and the supplier. In doing so, it is important to understand the technological and financial effects of standardization on the final facility cost. Expectations materialize in the form of key performance indicators (KPIs) that allow reliability to be measured, such as downtime or time between maintenance. For proper and realistic determination of KPIs, critical points in the system or key components that have the greatest impact on reliability should be identified, and scenarios of failures or problems that could affect the reliability of the system.

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Photovoltaic plants face several technical challenges that can impact their availability and performance. These challenges can be broadly categorized into seasonal variations, operational failures, and maintenance issues.

A. Seasonal variations

Photovoltaic energy production is inherently dependent on solar radiation, which varies seasonally [5]. Fluctuations in sunlight intensity throughout the year affect energy output. During winter months, reduced daylight hours and lower solar angles decrease energy production (Fig 1.). Cloud cover, rain, and snow can significantly reduce solar irradiance reaching the PV modules. Snow accumulation on panels can obstruct sunlight and needs timely removal. PV module efficiency decreases with higher temperatures. Conversely, cold temperatures can enhance efficiency but may also lead to other issues like condensation and frost.

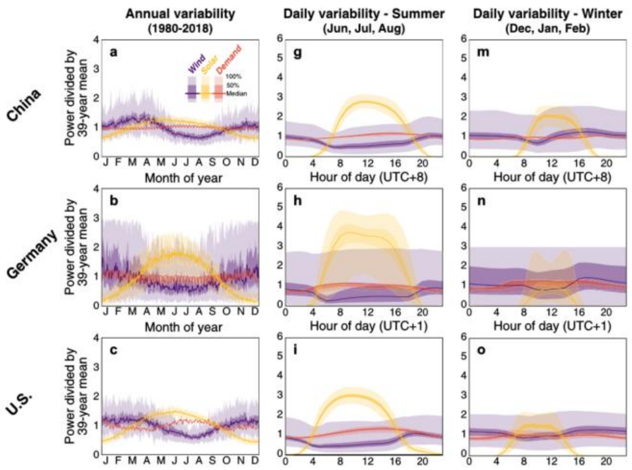

Fig. 1 Temporal variability of solar and wind resources and electricity demand (Source: Nature)

B. Operational Failures

Operational failures can result from various component malfunctions or external factors. Over time, PV modules can degrade, leading to a gradual reduction in energy output [6]. This degradation can be accelerated by factors like UV exposure, thermal cycling, and humidity. Inverters are critical components that convert DC to AC power. Failures can occur due to component aging, overheating, or electrical faults. In systems with energy storage, batteries can suffer from capacity degradation, charge/discharge inefficiencies, and thermal management problems. Issues with grid connectivity, such as voltage fluctuations, frequency deviations, and grid outages, can disrupt the operation of PV plants. Advanced inverters with grid support functionalities can mitigate some of these challenges.

C. Maintenance

Effective maintenance is vital for ensuring high availability and optimal performance of PV plants. Regular inspections and routine servicing of components like modules, inverters, and cabling are necessary to prevent unexpected failures. This includes cleaning panels to remove dirt and debris, which can obstruct sunlight and reduce efficiency. Quick response to repair faults and malfunctions is essential to minimize downtime. This requires a well-organized maintenance team and readily available spare parts. Implementing advanced monitoring systems to track performance in real-time helps identify issues early. This includes using sensors and data analytics to monitor parameters such as power output, temperature, and system health. Maintenance personnel need to be well-trained and knowledgeable about the specific technologies used in the PV plant. Ongoing training and certification are necessary to keep up with technological advancements.

By addressing these technical challenges through proactive maintenance, advanced monitoring, and strategic planning, PV plants can achieve high availability and reliability, ensuring consistent energy production and financial viability.

IV. Practical Example: Photovoltaic Plant in Croatia

One of the first examples in Croatia involves a municipality that entered a contract with a private partner for the procurement of a photovoltaic plant [8]. Availability standards are set at 98% of operational time annually.

A. Site Optimisation Challenges observed during implementation

Selecting the best location for maximum solar exposure can be challenging. In the observed power plant, the challenge is also represented by tall coniferous trees, which obscure one of the sectors of the photovoltaic plant in the morning and late afternoon. An additional challenge is the potential accumulation of leaves and needles on solar panels, so it was necessary to ensure adequate proactive monitoring of the plant.

A typical day on an observed solar plant (Fig 2.) shows that the often-presented ideal production curves have little to do with reality and that the production of the power plant in typical weather conditions in the Northern Adriatic is 5% to 15% less than ideal conditions.

The measurement and correlation of production and insolation data ensures verification of agreed availability and assurance to the client that the plant has produced the maximum amount of energy in the given weather conditions and that there were no technical outages of the plant in the observed period.

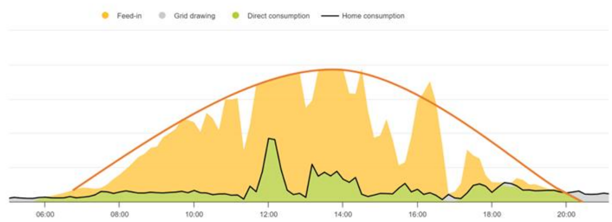

Fig. 2 PV Plant typical production diagram (Source: Innerga)

B. Grid Integration: Ensuring compatibility with the local power grid

The functioning of the photovoltaic plant must be in accordance with the parameters of the energy grid defined by Croatian Transmission System Operator (for large plants) or HEP Distribution System Operator (for smaller plants). Network parameters are determined by maximum voltages, frequency stability and the like, and, if the plant or network is not aligned, safety systems turn off the plant until the parameters are brought back into regular frames. This can be a significant challenge and is visible in (Fig 3.), which shows multiple overvoltage incidents on a photovoltaic plant on the Croatian coast. In this case, the cause of the outage of the plant was network voltage at individual RST phases above standards 230V+10% (voltage was higher than 252 V), which caused the automatic shutdown of the plant. Each interruption lasts typically 5 minutes leading to significant losses in the production of the photovoltaic plant (in the observed case, 1450 minutes of production were lost in observed 6 months period).

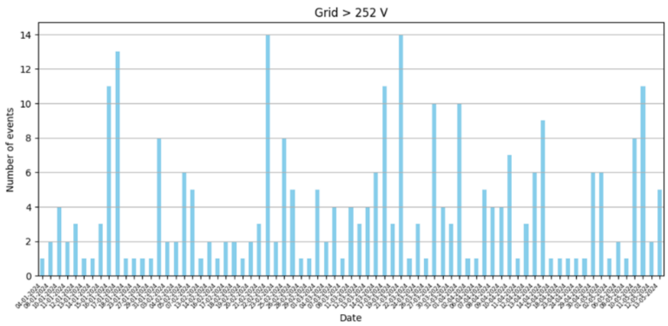

Fig. 3 Overvoltage incidents in observed Northern Adriatic PV plant (Source: Innerga)

C. Maintaining High Availability Standards

Measuring the reliability of a photovoltaic plant involves the use of various components and devices to properly monitor and evaluate the performance of the system. As already emphasized in the introduction of the chapter, the monitoring platform must ensure the measurement of a whole range of internal and external parameters, for which specific sensors and measuring equipment are used [7]. Components for monitoring the quality of energy production and network quality monitor electricity production, system efficiency and other key indicators. For example, inverters convert direct current (DC) produced by solar panels into alternating current (AC) used in households or connected to the electrical grid. Monitoring the operation of the inverter helps to identify problems with energy conversion. Voltage controllers and power monitoring systems provide the optimal operating point of solar panels, which helps to increase the efficiency of the system. Current meters and sensors monitor the flow of electricity through the system, helping to identify deviations or problems with electricity (voltage or frequency).

The integration of these components allows for systematic monitoring and analysis of the performance of photovoltaic plants, helping to maintain a reliable operation and identify potential problems in time. Today, monitoring and management of the photovoltaic plant through remote access is mandatory, thus facilitating diagnostics and interventions in case of problems. The block scheme of the Availability Monitoring Platform (AMP) by Innerga Ltd. is used to monitor the agreed parameters of the plant that is the subject of this article is shown on (Fig 4.).

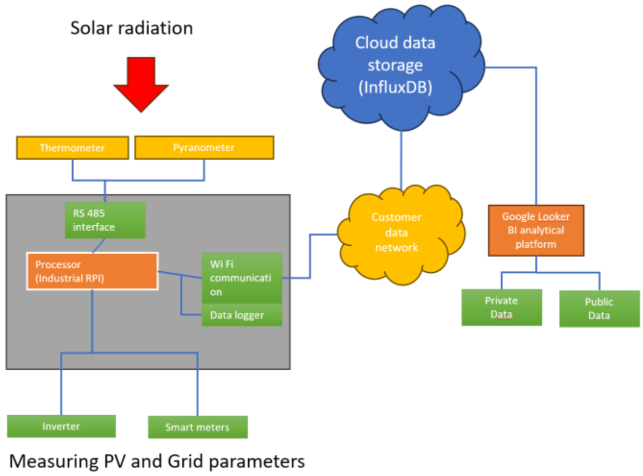

Fig. 4 Components of the Availability Monitoring Platform (Source: Innerga)

The AMP platform is relatively simply conceived, cost and implementation efficient, consisting of a processing unit based on Raspberry Pi Industrial components to which the measuring equipment is connected. The basic idea is to establish an independent monitoring system based on pyranometer, which will read the real insolation at the location of the photovoltaic plant. The measurement equipment is temperature calibrated. In addition to insolation, operational data of the photovoltaic plant itself are collected and the RST voltages of the power grid are measured. All data is stored on Influx DB located on a virtualized cloud network server. Data redundancy, cloud mirroring has been guaranteed, and local metering storage has been implemented in case of interruption of communication between the measurement equipment and the cloud platform. The visualization of the collected data is realized through the flexible Google Looker BI platform.

Analytics and data visualization are critical for the correct interpretation of plant availability. In the observed case, it can be determined that correlation between PV plant production and Pyranometer measurements is 0,96. The high degree of correlation can also be visually determined given that the PV power plant production curves and the onsite measurements of insulation are practically identical (Fig 5.).

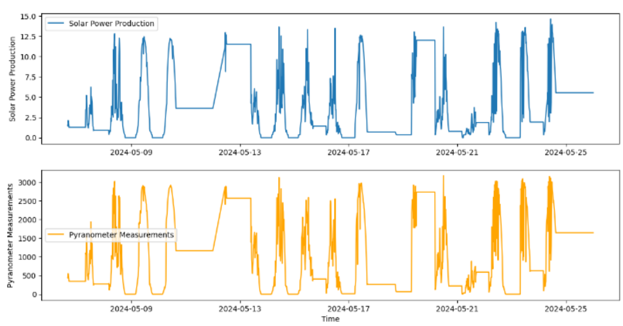

Fig. 5 PV plant production and Insulation diagrams (Source: Innerga)

Measurement of insolations with independent instruments in combination with data collected from the photovoltaic plant itself together with measurements of grid parameters allow precise identification of plant availability and thus whether the contractual obligation is fulfilled (Fig 6.).

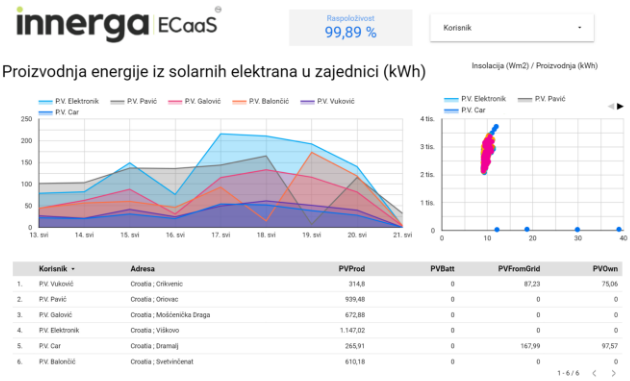

Fig. 6 Availability dashboard from implemented AMP platform (Source: Innerga)

V. Conclusion

The procurement of availability services for photovoltaic plants represents a technically challenging but highly beneficial approach that can significantly increase energy efficiency and sustainability of PV plant investments.

The procurement of the availability service of installations, appliances, or equipment to contracting authorities could be an acceptable procurement model because there is a high probability of achieving higher value for money, procurement does not have to be recorded in public debt, there are generally no initial payments and in the contract period administrative supervision and records are significantly simplified. Added to this should be the benefit for those contracting entities that do not have the administrative capacity necessary to procure more complex installations, devices, or equipment.

Environmental and external factors can also pose significant technical challenges, koji often exceeds the competencies of the client. Events like storms, floods, and earthquakes can cause severe damage to PV infrastructure. Designing robust systems and implementing disaster recovery plans are essential for resilience. Birds, rodents, and other wildlife can cause damage to PV components and cabling. Protective measures such as bird deterrents and robust cable management systems can mitigate these issues.

In Croatia, there is an additional problem of often inadequate transposition of European regulations and slow adoption of bylaws. Changes in policy or regulatory requirements can necessitate technical adjustments and upgrades to the plant.

Keeping pace with technological advancements and integrating new technologies can be challenging for smaller organisations. As newer, more efficient PV modules and inverters become available, upgrading existing systems can be complex and costly. Integrating PV systems with other renewable energy sources, storage solutions, and smart grid technologies requires advanced engineering and interoperability standards. With increased digitalization and remote monitoring, PV plants become vulnerable to cyber-attacks. Implementing robust cybersecurity measures is critical to protect the infrastructure.

These are all additional arguments for considering alternative procurement models by which the contracting entity reduces operational risks and leaves their avoidance to specialised organisations. Through analysis of alternative procurement models, availability standards, and practical examples, this article hopefully provides fresh ideas for successful implementation and maintenance of PV plants in Croatia.

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