Steps for the Realization of a Medium-power Photovoltaic Park

SORIN IOAN DEACONU[1], MARCEL TOPOR[1], ALEXANDRU MIHAI BLAJ[2], FEIFEI BU[3]
[1]Electrical Engineering and Industrial Informatics Department, Politechnica University of Timisoara, Timisoara, ROMANIA
[2]College of Engineering, Al Asal University, Dammam, SAUDI ARABIA
[3]Nanjing University of Aeronautics and Astronautics, Nanjing, CHINA

Abstract: - The design of photovoltaic parks has become in Romania, now, one of the most profitable and safe investments in the field of renewable energy sources, not only at present, but even more so in the future. Solar photovoltaic parks are favored by maximum exposure to solar radiation, a minimal impact on the environment, allowing the production of energy with a cost per kWp lower than that of other installations. The execution period of a photovoltaic park varies between 3-6 months depending on location and weather conditions. Romania has a high degree of solar radiation, suitable for investment in photovoltaic parks. There are three categories of documents required for the establishment of a photovoltaic park: those related of the land on which the park is build, the solution study for obtaining the technical approval for connection (ATR) to the electrical grid and obtaining the establishment authorization. The realization costs involved in building and designing a photovoltaic park are between 1.1-1.9 Euro/Watt. The quality of the equipment used in construction, the shape of the land, the costs of connection to the national electrical grid, are factors that can constitute the cost of realization. Another important factor in terms of income is the level of operational expenses, which is between 2% and 8% of the annual income and includes security, equipment and land maintenance, system monitoring. The paper will present a technical and economic calculation for a photovoltaic park with a power of 400 kW.

Keywords: -photovoltaic park, irradiation and solar electricity potential, green certificate, RETScreen Expert Software

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1. Introduction

Numerous countries and regions have incorporated substantial solar energy capacity into their electricity grids to complement or provide an alternative to traditional energy sources. Solar power facilities utilize one of two technologies: photovoltaic (PV) systems, which employ solar panels placed on rooftops or in ground-based solar farms to directly convert sunlight into electrical power, and concentrated solar power (CSP, also known as "concentrated solar thermal") plants, which harness solar thermal energy to produce steam, subsequently transformed into electricity using a turbine [1], [2]. The global expansion of photovoltaics exhibits significant dynamism and varies considerably from one country to another. As of the conclusion of 2019, a cumulative total of 629 GW of solar power had been installed worldwide [3]. By early 2020, China led the world in solar power capacity with 208 GW [4], [5], constituting one-third of the global solar energy capacity. In 2020, at least 37 countries across the globe had a cumulative PV capacity exceeding one gigawatt. The prominent solar power installers from 2016 to 2019 were China, the United States, and India. The first 10 countries in photovoltaics industry, [4-7], are presented in figure 1.

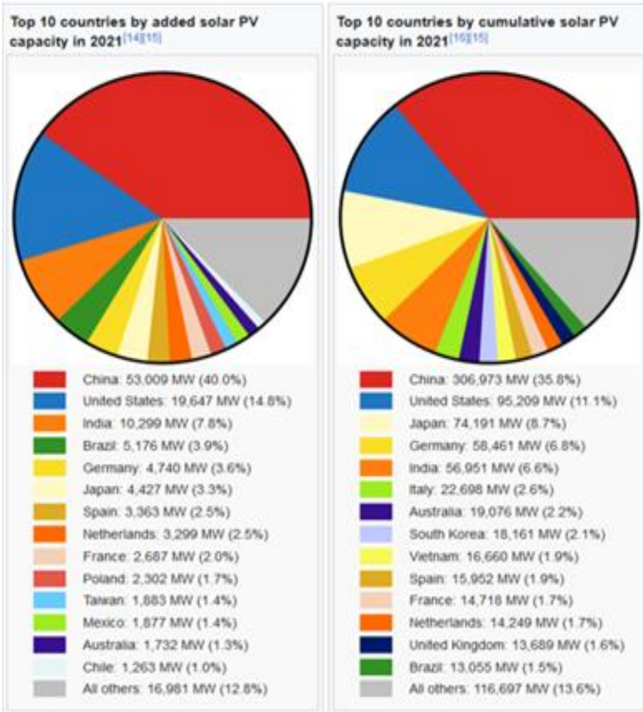

Fig. 1. The first 10 countries in photovoltaics industry in 2021

In Romania, there are more and more solar power plants based on photovoltaic panels and a tripling of the photovoltaic capacity is expected, until the year 2030, when coal-based energy will be almost completely eliminated - shows a Global Data report, which estimates that, in the next 8 years, Romania will have a photovoltaic capacity of 4250 MW, compared to the 1400 MW it currently has [8].

Speaking of the advantages of solar panels, the list is quite comprehensive. First, the energy produced is free. Lighting and heating the house or domestic water will have very low costs. Depending on the size of the photovoltaic system used, the savings on electricity bills can be very large. Moreover, if the system generates more energy than you can consume and you are connected to the electricity grid, the surplus can be exported and you will be rewarded for it. Secondly, solar panels are easy to mount and maintain. They can be placed on the roof of the house or even on open fields. They have an extended lifespan, over 20 years, and their maintenance is not complicated at all. In addition, the components that deteriorate or break over time can be replaced very easily. The inverter has a somewhat shorter lifespan, between 5 and 10 years, because it works continuously. The other elements used for connections and cables can also deteriorate over time, but they can be easily replaced. Finally yet importantly, another great advantage of photovoltaic panels and systems is the reduction of pollution. Because they use an inexhaustible resource, such as sunlight, they are considered the friendliest solutions for the environment. Classic fuels, such as gas or coal, with the help of which electricity is obtained, are increasingly limited, more expensive and more polluting resources [9].

On-grid photovoltaic systems require some essential conditions for a good operation, related to the national electrical grid to which it is connected. Thus, an on-grid photovoltaic system, even if it represents an electrical energy production unit, implies a permanent connection to the electrical grid, like an ordinary consumer. However, unlike consumers, the connection to the network of an on-grid photovoltaic system is used in order to deliver the surplus energy produced by it. The national electricity grid takes the place of a battery in an off-grid type system. This brings both advantages and disadvantages. The main advantage is the significantly lower cost of a system that does not involve batteries. Another advantage is the lack of risks associated with larger capacity batteries, such as the risk of explosion, overheating, low performance in different weather conditions, etc. In addition, an accumulator has a limited storage capacity, and if the energy in it is not consumed, the production potential of the panels is lost. However, there are disadvantages related to connecting a photovoltaic system to the national electricity grid. The main disadvantage is related to the fact that the voltage in the electricity grid differs greatly depending on the area. The causes that lead to the appearance of voltages over 240V are: the location of the house where the photovoltaic system is mounted relatively close to the transformer station, several photovoltaic systems installed on the same street mean, on the one hand, a source of clean energy, but in the absence of consumption, they negatively influence the level of electrical voltage in the grid, another reason for the increase in voltage may not be related to the power lines of the national grid but to the cable used by the final customers, respectively the cable between the output of the bidirectional meter and the input to the general electrical panel of each customer; if the section of this cable is too small, the voltage drop will be greater and then the inverter is forced to increase the voltage level more than it would normally be in order to inject the voltage into the grid, and last but not least, there are specific problems because the electrical network infrastructure is precarious and where there are problems even without photovoltaic installations, and adding them only worsens the already existing situation [9-16].

2. Project Location, Irradiation and Solar Electricity Potential

Optimal sun exposure and minimal environmental impact make photovoltaic parks an attractive energy source, with profitability hinging on factors like income-to-construction costs ratio. Primary revenue sources include energy sales and green certificate trading.

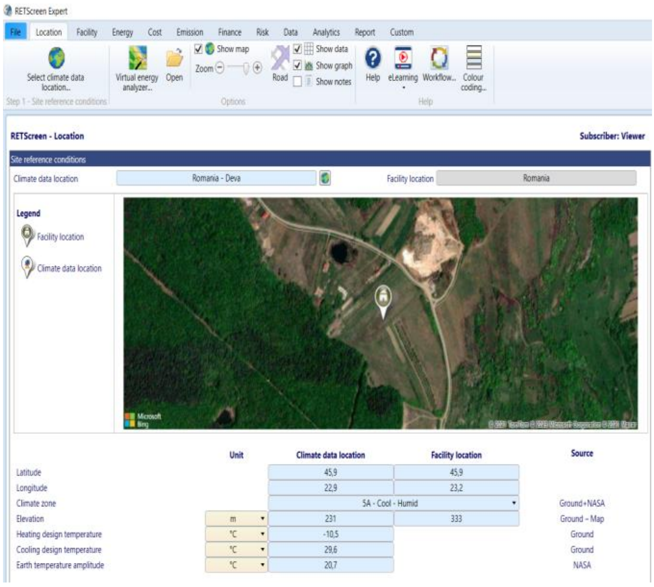

Fig. 2. The location and the corresponding climatic data

The green certificate signifies the production of 1MWh of renewable electricity. These purchased certificates cover the obligatory renewable energy portion in total consumer supply, determined annually by ANRE. They remain valid for 16 months. The Environmental Fund Authority imposes a 110 euro fine per unpurchased certificate on non-compliant suppliers and producers. Solar energy producers (comprising power plants and photovoltaic parks) receive six green certificates per 1MWh of delivered electricity. Presently, a green certificate's maximum market value is 50 euros.

The project is situated near Geoagiu Bai town, with a southern orientation. Figure 2 depicts the location and associated climatic data, while figure 3 illustrates daily solar radiation and temperature. A 20 kV medium voltage electric line traverses the area.

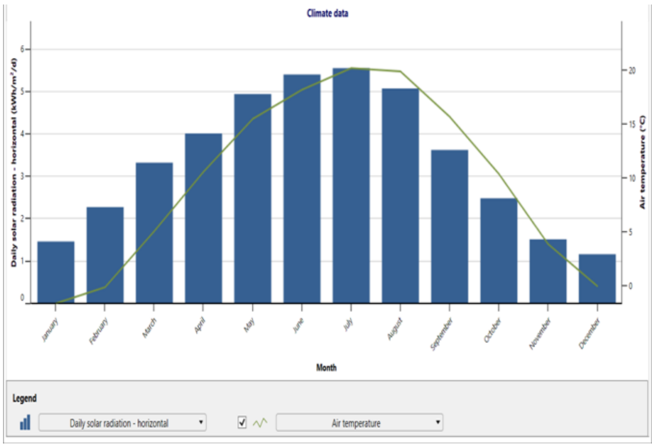

Fig. 3. Daily solar radiation and temperature in the location of the project

3. Categories of Documents Required for the Establishment of a Photovoltaic Park and the Steps Required Becoming a Prosumer

There are three categories of documents required for the establishment of a photovoltaic park: those related to the land on which the park is built, the solution study for obtaining the technical approval for connection (ATR) to the electrical grid and obtaining the establishment authorization [13].

The first category includes the deed of sale, purchase of the land, concession or lease, then the zonal urban plan (PUZ) if the land is removed from the agricultural circuit, the urban planning certificate (with the approvals requested by it) and the opportunity study for the evacuation of the power in the existing grid [13].

The second category includes the technical documentation for the construction authorization (DTAC), obtaining the construction authorization, the technical project that starts with the DTAC and the technical project for the power evacuation in the grid [14].

The third category of documents involves obtaining the ATR, then obtaining the establishment authorization (given by ANRE), obtaining the commercial exploitation license, registration on the regulated electricity market (OPCOM) with (accreditation for green energy), obtaining the Transelectrica approval for the transport of electricity, if the connection is made directly to their grids [15].

If you produce electricity from renewable sources and, apart from your own consumption, but not necessarily deliver the surplus electricity to the national electricity distribution network, this means that you can become a prosumer. The regulatory authority in the field (ANRE) monitors the evolution of prosumers based on data and information collected monthly from distribution operators. The distribution operators have duties regarding the connection to the electricity grid, the certification of the prosumer quality, the measurement of the electricity consumed/injected from/into the grid and the transmission of information to the supplier in order to bill the electricity.

In order to become a prosumer, you must go through several necessary steps: a connection request is submitted to the electricity distributor; following the submitted request, a connection solution is established and the technical connection approval (ATR) is received from the distribution operator; the connection contract is signed; the system of photovoltaic panels with an installed power of no more than 400 kW per place of consumption is installed by specialized personnel; the file of the usage facility and the request to energize the usage facility for tests are submitted to the electricity distributor; the report of receipt of commissioning of the user facility is sent, after tests, to the electricity distributor; it receives the connection certificate from the distribution operator and the prosumer certification; a sale-purchase contract for the electricity produced and delivered in the grid is signed with the electricity supplier [10].

If it is not necessary to change the connection solution for the installation of the photovoltaic panel system at the place of consumption, then the notification regarding the connection to the existing place of consumption of the photovoltaic panel system is sent to the distribution operator, after its installation. In this case, the distribution operator updates the existing connection certificate without the need to issue the technical connection approval [11].

4. Using the RETscreen Expert Software for Design and Economic Assessment

RETScreen is a Clean Energy Management Software system designed for assessing the feasibility of energy efficiency, renewable energy, and cogeneration projects, encompassing power, heating, and cooling. It empowers professionals and decision-makers to swiftly evaluate the technical and financial viability of potential clean energy projects, aiding in decision-making. This software platform also simplifies performance measurement and verification for facilities while identifying additional energy savings and production opportunities. RETScreen stands as the most comprehensive tool of its kind, enabling engineers, architects, and financial planners to model and analyze a wide range of clean energy projects. Decision-makers can conduct a five step standard analysis, including energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis. Fully integrated into these analytical tools are benchmark, product, project, hydrology and climate databases (the latter with 6,700 ground-station locations plus NASA satellite data covering the entire surface of the planet), as well as links to worldwide energy resource maps. Moreover, to help the user rapidly commence analysis, RETScreen has built in an extensive database of generic clean energy project templates [17].

We will divide the park into four modules with equal power of 100 kW each. We will do the analysis with the RETScreen program for one module and then generalize the conclusions for all four modules. Figure 4 shows information about a module of the facility and Figure 5 shows the production cost in Canadian dollars of energy, compared to other types of power plants.

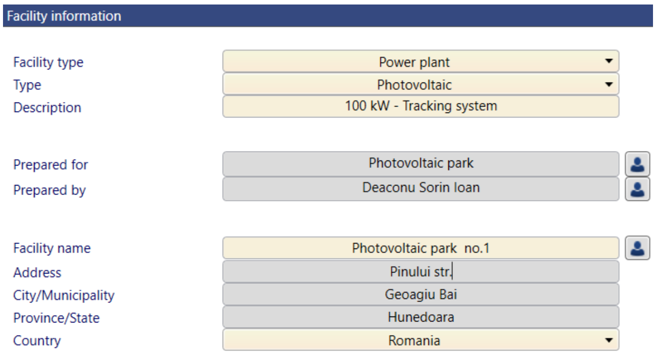

Fig. 4. Information about a module of the facility

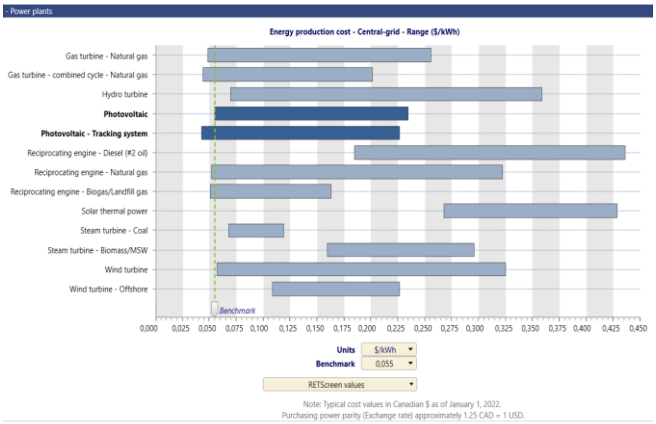

Fig. 5. The production cost in Canadian dollars of energy, compared to other types of power plants

It is observed that for a photovoltaic park with fixed panels the cost of electricity production is 0.05 CAD = 0.044 USD = 0.199 RON / kWh. The following figures (6, 7, 8, 9, and 10) show the results of the analysis with the RETScreen program for a 100 kW module of the fixed photovoltaic park.

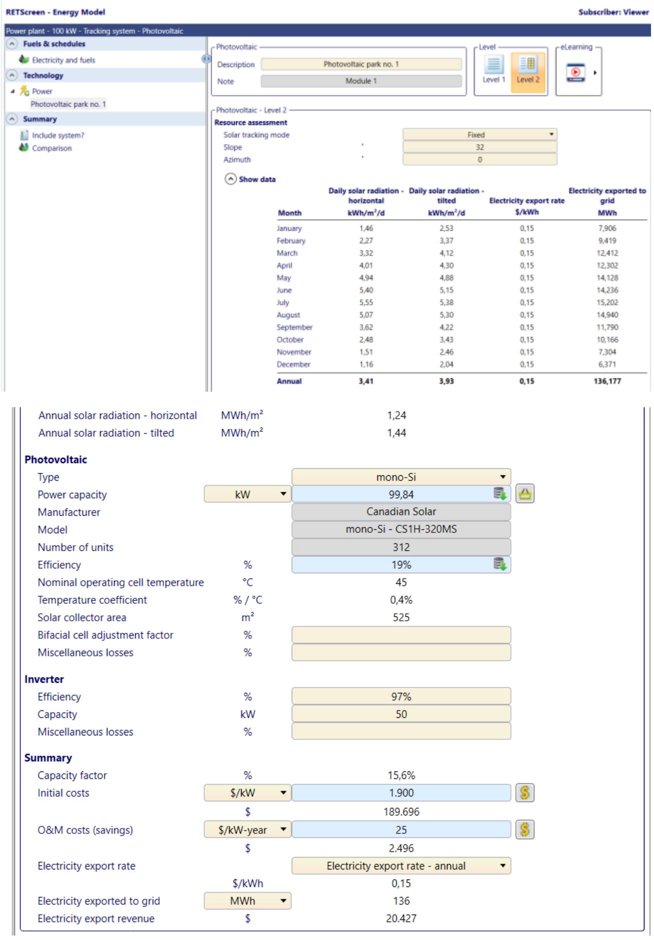

Fig. 6. Energy calculation data power plants

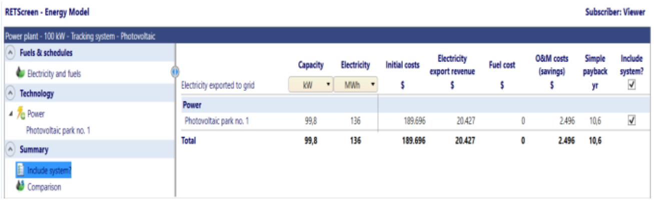

Fig. 7. The proceeds from the energy produced, the annual costs and the investment recovery period without green certificates

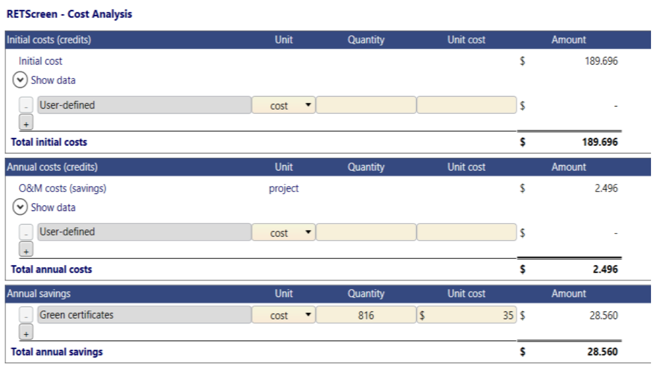

Fig. 8. The receipts from green certificates, the initial cost and the annual cost

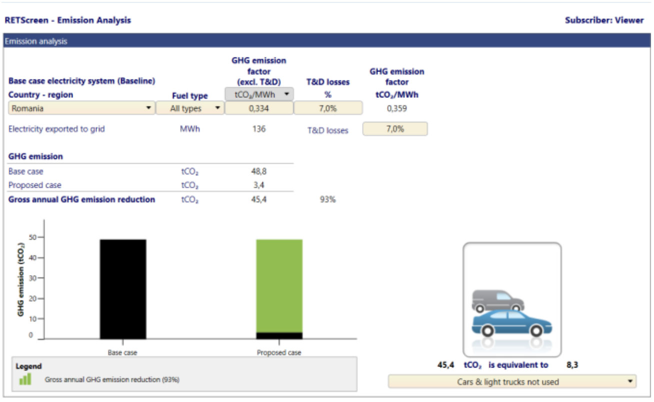

Fig. 9. Emission Analysis

Fig. 10. The final values of the analysis

Equipment chosen for execution: The photovoltaic panels used are of the Canadian Solar monocrystalline type, with an efficiency of 19% and a power of 320 W. 1248 panels are used. The MPPT type regulators are from Victron type MPPT150/70. 100 such regulators are used for the entire park. The inverters used are HUAWEI-SUN 200-50 KTL-M3 three-phase with a power of 50 kW. In total, there are 8 such inverters.

5. Conclusions

With the data corresponding to the chosen location, the annual electricity production of a 100 kW module is 136 MWh. An average cost of 1900 CAD / kW was chosen, resulting in a total investment cost of 758784 CAD. For the electricity produced, an average price of 0.15 CAD / kWh = 0.12 USD / kWh = 0.54 RON / kWh was chosen. It results in an amount of 20427 CAD collected per year for one module, respectively 84708 CAD for the entire photovoltaic park. If the green certificates are not taken into account, the annual park maintenance cost of 9984 CAD and the payment of the loan in the amount of 58316 CAD per year (for 15 years), the investment recovery period is 10.6 years. If we take into account the green certificates at a market price of 34 CAD, 3264 certificates will be collected annually for the whole park, which gives us an annual income of 144240 CAD. In this situation, the investment recovery period is 4.1 years.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.