Cost-effectiveness Analysis of Roof-top PV Systems in Montenegro and Serbia

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Abstract—The feed-in tariff for PV Systems in many countries have been reduced over the last few years. The purpose of this paper is to determine the level of returns, from the investors perspective, from PV projects in Montenegro and in Serbia. Two case studies are included in this paper with different sizes of solar photovoltaic systems (1.04 kW and 5.20 kW). Each case study includes three different consumption scenarios ranging from 100% self-consumption to 0%. Overall, the results show that the most profit can be made in Serbia. It is possible to triple the investment during the 25-year period with a 5.20 kW PV system. Furthermore, this study provides enormous benefit to various entities namely investors, researchers, and policy makers who are working under the solar energy domain in Montenegro and Serbia.

Keywords—Grid-tied rooftop PV system, Economic assessment; Discounted payback; Internal rate of Return; Energy policy;

I. INTRODUCTION

There is a range of well-known sustainable energy technology solutions for urban regions; ranging from local renewable energy utilization to more efficient fuel use such as co-generation. Solar energy, both as thermal and photovoltaic (PV) is well suitable for the built-environment. In particular, building integrated solar photovoltaics are a highly promising urban energy option, requiring hardly any new infrastructures and offering synergies with building components.

The price of the electricity produced with small scale roof-top PV system is determined based on certain elements such as: the economic state of the region and country, the tax rates, the electricity tariff, the energy policies and programs (incentives, plans, and other investment options), the PV system efficiency, market and technology, and also the solar radiation value of the site-location. Feed-in tariff schemes have been used to support the introduction of new generation of technologies into the market, such as solar based electricity generation [1], but they are being phased out. Measures such as net-metering, self-consumption and lower grid injection tariffs are becoming increasingly popular.

Various studies have explored the economic assessment of PV systems in several countries [2], [3]. The goal of this paper is to determine the level of returns, from the investors perspective, from PV projects in Montenegro and in Serbia. An economic assessment is employed for two distinct case studies: 1.04kW and a 5.2kW grid-connected rooftop PV system, with three self-consumption scenarios (100%, 50% and 0%).

The remainder of this paper is structured as follows: section 2 explains the current solar policies in the selected countries. Section 3 describes the methodology used to make the economic assessment of the PV Systems. The results and the main findings of the data analysis are reported and discussed in section 4. Finally, the main conclusions are described in section 5.

II. CURRENT ELECTRICITY AND RENEWABLE ENERGY POLICIES IN MONTENEGRO AND SERBIA

Montenegro and Serbia joined to Energy Community in 2007 and 2006 and received the EU candidate status in 2010 and 2012, respectively. Energy Community organization has been active since 2006, brings together the European Union and its neighbors to create an integrated Pan-European energy market, aiming to extend the EU internal energy market rules and principles to countries in South East Europe, the Black Sea region and beyond on the basis of a legally binding framework. The Energy Community members as parties to the Treaty (ECT), committed to implementing the EU Third Energy Package by the first of January 2015. In the
context of Renewable Energy Policy, the ECT Contracting Parties have been implementing the 2009 EU Renewable Energy Directive since 2012, including the 2020 binding national targets for renewables deployment [4].

1) Montenegro

The electricity sector in Montenegro is dominated by the utility Elektroprivreda Crne Gore (EPCG), which performs generation, distribution and supply activities. The company is controlled by the State (57% of the shares) and the Italian multi-utility company A2A (42% of the shares). There is substantial transit of electricity from north to south in Montenegro, which nearly equals the average annual consumption of electricity in the country.

Montenegro adopted and submitted the National renewable energy action plan (NREAP) required by Directive 2009/28/EC with delay. Support schemes for various technologies exist and several projects are being implemented. However, no support schemes for renewable energy in heating and cooling or for transport have been adopted yet. The production of electricity from renewable energy sources is mainly promoted through a feed-in tariff. The access to the grid is regulated by the general legislation and renewable energy sources are given priority [5].

2) Serbia

With the adoption of the NREAP by the Government, Serbia strives to achieve a binding 27% share of final energy consumption from renewable energy in 2020. In July 2015, Electric Power Industry of Serbia (EPS) underwent restructuring, unbundled and reorganized into three legal entities. The three legal entities are i) the parent company Public Enterprise Electric Power Industry of Serbia, ii) Distribution System Operator (EPS Distribution), iii) and EPS Supply.

According to the new Law, all customers are free to choose their supplier. The right to be supplied under regulated prices remains only for households and small customers, who may choose to be supplied by a guaranteed supplier. Solar PV Feed-in tariff is contracts have a 12-years duration. In accordance with relevant legislation, since 2013 Solar PV feed-in tariffs are to be revised annually, due to dynamic changes in investment related expenses particular to solar power plants. Nevertheless, the tariffs have not been revised since the beginning of 2013, while the new Regulation on support measures for all RES that was due to be enacted and to take effect as of 2016 is still pending [5].

III. METHODOLOGY

It is essential to take into account several indicators when it comes to a cost-effectiveness analysis of PV systems. The methods used to determine the profitability and economic aspects of the projects are: i) Internal Rate of Return (IRR), ii) Discounted Payback Period (DPP), iii) and the Profitability Index (PI). A brief description of the three economic methods employed herein is presented in the following section. The nomenclature of all the formulas of the economic methods are presented in table 1.

A. IRR, DPBP, and Profitability Index

IRR is commonly used to evaluate the profitability of an investment by calculating the difference between the discounted values of cash flows over the lifetime of projects [6]. The IRR is an indicator that should be compared to a discount or interest rate of an investment in the selected region. In addition, it allows for a performance comparison across regions and technologies for different projects. The size of IRR represents a direct correlation with the investment attractiveness in percentage; in other words, the highest IRR indicates the most favourable investment opportunity. Equation 1 shows the IRR formula.

\[ 0 = \sum_{y=1}^{Y} \frac{C_y}{(1 + IRR)^y} - C_0 \]  

(1)

The time value of money is considered in calculation of IRR, allowing a comparison across Table 1: The nomenclature of the economic method formulas

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Description</th>
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<tbody>
<tr>
<td>( C_y )</td>
<td>Yearly net cash flow [( \mathbf{E} )]</td>
</tr>
<tr>
<td>( C_0 )</td>
<td>Initial investment [( \mathbf{E} )]</td>
</tr>
<tr>
<td>( Y )</td>
<td>System lifetime</td>
</tr>
<tr>
<td>( r )</td>
<td>Interest rate [%]</td>
</tr>
<tr>
<td>( T_s )</td>
<td>Self-consumption tariff [( \mathbf{E}/\text{kWh} )]</td>
</tr>
<tr>
<td>( T_e )</td>
<td>Grid injection tariff [( \mathbf{E}/\text{kWh} )]</td>
</tr>
<tr>
<td>( E_c )</td>
<td>The amount of electricity as self-consumption [kWh]</td>
</tr>
<tr>
<td>( E_e )</td>
<td>The amount of electricity exported into grid [kWh]</td>
</tr>
<tr>
<td>( M )</td>
<td>Maintenance cost [( \mathbf{E} )]</td>
</tr>
<tr>
<td>( E )</td>
<td>Energy output [kWh]</td>
</tr>
<tr>
<td>( d )</td>
<td>Degradation rate [%]</td>
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</tbody>
</table>
locations without considering the regional interest rates, which are typically very difficult to forecast [3].

For the calculations of DPP, PI and IRR it is necessary to first calculate the subtraction of the cash inflow with the cash outflow of the project, so-called the annual Simple Cash Flow (SCF). Equation 2 represents the SCF formula:

$$SCF_y = \sum_{y=1}^{T} (T_s \times E_s + T_e \times E_e) - \sum_{y=1}^{T} (M + C)_y$$  \hspace{1cm} (2)

The Discounted Cash Flow (DCF) contains the time value of money and represents the SCF value in the future. The DCF value is updated with the interest rate and it’s formula is shown in equation 3.

$$DCF_y = \frac{SCF_y}{(1+r)^y}$$  \hspace{1cm} (3)

The DPP considers the value of money over time since it uses the discounted cash flow values to calculate the number of years needed to achieve breakeven. The Profitability Index (PI) indicates the magnitude of profit or loss outcomes within the project lifespan. It is calculated by dividing the Net Present Value (NPV) value by the initial investment and adding 1, as shown in equation 4.

$$PI = \frac{NPV}{Initial \text{ Investment}} + 1$$  \hspace{1cm} (4)

There is a breakeven when PI is equal to 1. The profit is doubled on the investment when PI is equal to 2. The lifespan of the investment assumed for this work is 25 years [7]. The NPV takes the present value of the money into consideration. Its main drawback lies in the need for assuming an interest rate which can change the result significantly.

B. Assumptions

In this section, all the assumptions are defined and for both case studies (1.04kW and 5.20kW PV systems), three scenarios were considered and each of them is associated with the amount of solar production that is used for self-consumption and the amount that is used for grid injection. The scenarios are as follows:

- Scenario 1 - 100% of the solar production is used for self-consumption;
- Scenario 2 - 50% is used for self-consumption and 50% is used to inject into the grid;
- Scenario 3 - 100% is used to inject into the grid;

The Retscreen software, version 4 [8], is a tool that used to calculate the solar production of the PV systems in each of the countries.

1) PV module and Inverter Selection

For this work, the Sunergy 260W polysilicon PV modules were selected, since they have a notable efficiency rate of 16%. The PV system prices used in this work include the delivery, mounting and installation costs. The price of the PV system investment is an average of the quotes (three quotes) of the given country. Among all the components of a roof-top PV system, only the inverter is expected to be replaced, within the lifetime of the investment. According to [9] It is assumed that the inverter replacement takes place in the 10th and the 20th year, and its cost rate for the 1.04kW PV system is 15% of the initial investment and 10% of the initial investment for the 5.20kW PV system.

2) Performance Ratio (PV system losses)

A performance ratio (PR) between 75-90% is commonly considered for PV systems. According to the methodology guidelines on life cycle assessment of PV systems, a value of 0.75 is considered for roof-top installations [10]. Thus, in this work a PR value of 0.75 is assumed.

3) Annual Energy Production

In order to calculate the annual solar production, the Retscreen software based on the PV system parameters is employed. The cities were chosen based on the solar radiation values, namely Bar that is located in south of Montenegro and Surčin, a municipality in north-west Belgrade, Serbia. In order to apply the economical methods, it was essential to have, for every country, the following parameters, also shown in table 2.

4) Degradation Rate

The degradation of the modules reduces the efficiency of the system over time. Accordingly, the predicted generation of the PV system and its economic payback period analysis can be affected by
this phenomenon. Jordan et al. [11] concluded that the average degradation number was 0.7%/year. According to the methodology guidelines on the lifecycle assessment of PV systems, it is recommended to consider a linear degradation, reaching 80% of the initial efficiency at the end of a 30 years lifetime (i.e., 0.7% per year) [10]. Therefore, for the purpose of this analysis, a PV degradation value of 0.7% is assumed.

5) Operating and Maintenance Cost

In economic analysis of PV system, it is necessary to consider the inverter replacement costs as well as the costs associated with the operations and maintenance during the lifecycle of the system. The maintenance cost is estimated between 1-3% of the initial investment per year [11]. In this paper, it is assumed that the O&M cost for the 1.04kW PV system is 2.5% of the initial cost, and for the 5.20kW it is 1.5% of the initial costs, in both the countries.

6) Economical parameters

In order to roughly predict the electricity price during the next 25 years an average evolution rate of the electricity price is calculated based on the past 13 years (as of 2002). The grid injection tariffs and electricity tariffs that are considered for this work are the ones that are practiced in each country at the present moment. To predict the interest rate for the next 25 years an average is calculated based on the past 15 years just as was done to calculate the electricity evolution rate [12]. Table 2 presents all the values mentioned above. In both countries the feed-in tariffs have a contract for 12 years. Since it is considered that the lifetime of the project equals 25 years, it is assumed after the 12th year, only self-consumption (the predicted electricity tariff) would be considered.

IV. RESULTS

The economic calculations were applied to the 1.04kW and the 5.20kW PV systems for each of the three scenarios, for both countries. The inverter replacement costs are considered in year 10th and 20th for both PV systems; applicable expenses are generally higher in percentage for the smaller PV systems.

Montenegro has higher potential solar electricity production than Serbia. The higher electricity tariffs are practiced in Serbia, where the feed-in tariff is also higher than in Montenegro.

As previously stated, the Profitability Index (PI) indicates the amount of profit that an investment can achieve during the system's lifespan. When the Profitability Index is equal to one there breakeven is achieved; this happens on the year of the DPP. In this work, the investment is considered viable when PI equals 2.00. Figure 1 demonstrates the calculated PI value for the 1.04kW PV system for all the three scenarios. As figure 1 shows, none of the scenarios represents a viable investment case neither in

<table>
<thead>
<tr>
<th>Table 2: Related Information of both countries</th>
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<tbody>
<tr>
<td><strong>Serbia</strong></td>
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<tr>
<td><strong>1.04kW</strong></td>
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<tr>
<td>Annual solar production value (kWh)</td>
</tr>
<tr>
<td>Average electricity escalation rate(%)</td>
</tr>
<tr>
<td>Interest rate(%)</td>
</tr>
<tr>
<td>Electricity tariff (€/kWh)</td>
</tr>
<tr>
<td>Grid injection tariff (€/kWh)</td>
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<tr>
<td>Currency exchange rate (as of April 28th, 2016)</td>
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<tr>
<td>PV system cost (€)</td>
</tr>
<tr>
<td>Maintenance and Operations cost rate</td>
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<tr>
<td>Inverter substitution cost rate</td>
</tr>
<tr>
<td>Degradation rate of the PV modules</td>
</tr>
</tbody>
</table>

Figure 1: The PI for the 1.04 kW PV system
In Serbia, the scenario 3 (100% of exporting into the grid) is the most profitable option. Figure 2 presents the PI for the 5.20 kW PV system. Results show that investments can be doubled before the 25th year in both countries. In other words, all the investment options are viable. Figure 3, presents the IRR and the DPP of the 1.04kW PV system for each of the countries according to the different scenarios. It is interesting to see how in Serbia the third scenario DPP is in year 17th, whereas in Montenegro DPP is reached in the 23rd year in all scenarios.

Figure 4 presents the IRR and the DPP of the 5.20kW PV system for each of the countries according to the different scenarios. Generally, the 5kW PV system scenarios achieve better results compared to the 1.04kW PV system scenarios. This happens due to the fact that the larger systems are less expensive than the smaller ones when comparing price per Watt (€/W). For instance, a 1kW PV system costs 2.60€/W and a 5kW PV system costs 1.70€/W. All the scenarios using the 5.20kW PV system in both countries can make more than double the investment within the lifetime of the system. It is worth mentioning that the 3rd scenario in Serbia triples the investment, where the DPP occurs in 8 years and presents the highest IRR (14.7%).

Due to the fact that Serbia has a higher value in both the electricity tariff and the feed-in tariff than Montenegro, a better result with the higher profit can be achieved. The IRR value, which represents the favourability of an investment opportunity, is also higher in Serbia than in Montenegro. Furthermore, the interest rate in Serbia is lower than in Montenegro. Due to these facts, investment in PV systems, Serbia is the more favourable opportunity. The interest rate used for Serbia in this work is 3.19%; it is lower than Serbia’s IRR value in any of the scenarios.

V. CONCLUSION

This paper presents an economic analysis of the main supporting policies for promoting PV systems regulated in Montenegro and Serbia. The aim is to determine if the regulations make it viable to install this kind of system and which of the two countries offers the most viable investment returns associated with small scale PV system. This work considers two case studies based on 1.04kW and 5.20kW PV systems. The economic analysis was calculated for
each of the three types of scenarios for both country case studies. In conclusion, Serbia is the better country to invest in for both sizes, the 1.04kW and the 5.20kW PV systems (taking into account the specific locations considered in this study). The 5.20kW PV systems will foster better investment returns than the 1.04kW PV systems, mainly due to the higher investment costs per installed Watt in the latter PV systems.

The viability of a PV system project depends on the system investment cost, electricity tariffs, government incentives, and solar radiation. The methodology employed in this study can assist regulators in the regions under observation to draw important conclusions and consequently consider fine-tuning their incentive programs in order to improve support for the uptake of this environmentally friendly energy generation technology.

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