Applied Engineering Letters Vol.2, No.3, 91-97 (2017) e-ISSN: 2466-4847

TELOS FEASIBILITY ANALYSIS OF PHOTOVOLTAIC POWER PLANT

Bojan Šerman[1], Hrvoje Glavaš[1], Marko Vukobratović[1], Zorislav Kraus[1]

[1] Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Republic of Croatia

Abstract:
Energy independence as the goal of EU energy policy encourages energy efficiency measures and renewable energy sources (RES) implementation. Photovoltaic (PV) plants represent the usual technical solution when reconstructing/maintaining a roof or as an investment that is expected to result with a material gain. The viability of the investment is unquestionable, but when the means of implementation are provided by an external institution, a cost-effectiveness analysis is necessary. When a financial institution has no experience with similar projects, the complete TELOS analysis is required. This paper provides a complete TELOS analysis (Technology Feasibility, Economic, Legal, Operational and Schedule Feasibility) of the PV power plant implementation.

ARTICLE HISTORY
Received: 30.04.2017.
Accepted: 25.06.2017.
Available: 30.09.2017.

KEYWORDS
TELOS, PV, Energy Efficiency

1. INTRODUCTION

Reducing imported energy and energy products dependency is the goal of EU energy policy that promotes energy efficiency measures and renewable energy sources (RES) integration, [1,2]. Nowadays, photovoltaic (PV) plants integration represents routine procedure in roofs reconstruction, [3,4]. The cost-effectiveness of the investment has been proven over the past 10 years and it is unquestionable [4,5]. When the implementation project is supported by a financial institution that has no experience with similar projects, TELOS analysis is required.

2. TELOS ANALYSIS

TELOS analysis asissts in determining the investment justification and risk reduction for the investor [6]. Every investment venture requires knowledge for the resources needed, the degree of equity and the knowledge of the investment risk. TELOS analysis is acronym of:
Technological Feasibility–describes whether the given project is technically doable.
Economic Feasibility–proof that the given project meets economic profitability.
Legal Feasibility–proof that the project is in compliance with the legal framework.
Operational Feasibility–shows how much the project is well suited to the needs of the investor.
Schedule Feasibility–Indicates whether a project is feasible within a given deadline.

Although the TELOS analysis consists of up to five stages if the technical, economic and legal aspects are not met, the project will not enter the feasibility phase, Fig.1 [7].

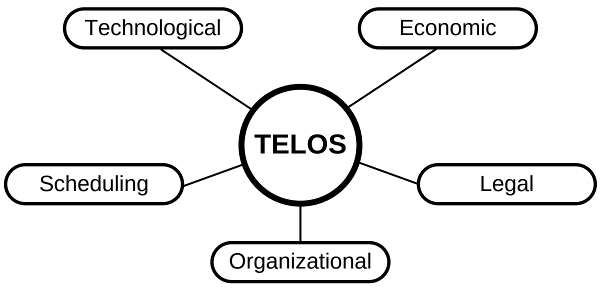

Fig.1. The basic elements of TELOS analysis

CONTACT: Zorislav Kraus, zorislav.kraus@ferit.hr

3. TECHNICAL REALIZATION OF PV SYSTEM ≤ 10 kW

PV power plant grid connection is planned to the 0.4 kV low voltage distribution network. For optimal operation of photovoltaic systems, it is necessary to determine the optimal arrangement of photovoltaic modules on the roof of the building. The optimum layout includes parameters such as the number of the modules, the appropriate orientation of the modules to the side exposed to solar radiation, the possibility of mounting the aluminum support structure, the vicinity of the transformer station, and the possibility of planning the control/conversion space. The Republic of Croatia has a favorable solar irradiation geographic position with the lowest value of solar radiation of about 1,200 kWh/m^2. With the help of PVGIS (Photovoltaic Geographical Information System) appropriate approximation of the power generation from the PV system can be obtained [8].

Fig.2 shows daily solar radiation Fig.3 provides information on the monthly optimum angle for the photovoltaic panel.

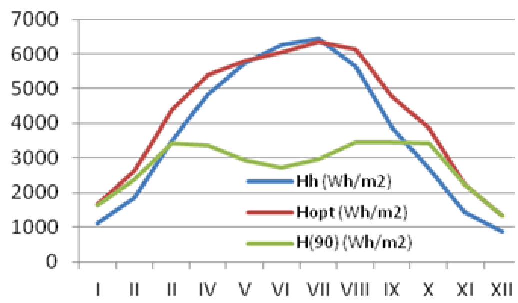

Fig.2. Solar radiation for the Osijek area [8]

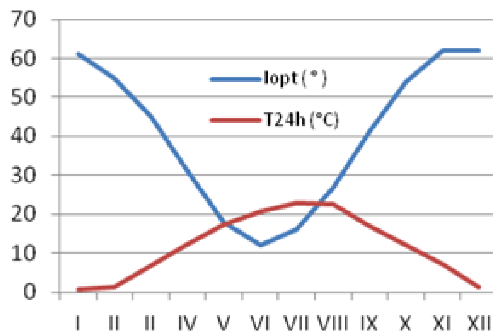

Fig.3. Optimal angle and average temperature for Osijek area [8]

The usable roof surface for the installation of PV modules totals to 70 m^2 and the azimuth of the roof surface is 22.2°, while the roof is tilted at 2°. Usable roof space determines total number of 40 polycrystalline photovoltaic modules, the AXIpower AC260P/156-60S 260 W, with total installed power of 10.4 kWp [9]. The manufacturer guarantees efficiency over 90% in the first 10 years, and the lowest efficiency in the amount of 85 % of the nominal output power in the 25th year of operation. Combining modules in two 20-module strings, with the individual module voltage of 30.92 V, a mean voltage value of 573 V can be obtained, which satisfies the condition for the inverter's maximum input voltage of 900 V. The maximum voltage that can occur in the system is 849 V. The modules are connected by fine stranded conductors with cross-section of 4 mm^2 insulated by silicon or PVC UV resistant insulation. PVC insulated copper conductors of 10 mm^2 are used to connect inverter with the distribution network. The highest current of a single string is 18 A, and the average current is 16.8 A, which is within the permitted current load range of the planned conductors and protection devices. Conductor losses are insignificant and amount to 0.18%. SMA Sunny Design 3 software was used for all necccessary calculations and PV system planning and compatibility check [10]. The energy obtained from the PV modules equals irradiated energy (1,320 kWh/m^2) multiplied by the efficiency of the module (ηm = 0.159) and the surface area of all modules (64 m^2).

Table 1 provides basic information on: EZ – irradiated solar energy on inclined modules, EPV - energy obtained from photovoltaic modules, EST - electric energy obtained from the photovoltaic system, EG - specific annual electrical energy production.

Table 1. Electrical energy obtained by the PV system

City	E_Z (kWh/m^2)	E_{PV} (kWh)	E_{ST} (kWh)	E_G (kWh/kW$_p$)
Osijek	1,320	13,432.32	12,089.08	1,208.90

4. ECONOMIC FEASIBILITY

Input data for economic feasibility assessment are based entirely on self-financing without using commercial loans.

Simple Payback Period (SPBP) is the time needed to return the investment to the project and is calculated by dividing the investment cost with the annual savings that will occur after the implementation of the measure. SPBP is most

often the only indicator of investment justification in Energy Efficiency used by technical experts.
To calculate a SPBP it is necessary to calculate the total costs of the photovoltaic system, and use the Table 2 to determine the price coefficient of electric energy. For the PV system integrated into a building, the incentive price C is used, and in case the domestic hot water (DHW) system is added to the integrated PV system, the incentive price C is increased for coefficient k_1. The investment return period method takes into account cumulative revenue over the year of the project, and the year of investment return is considered the one in which the cumulative amount of revenue exceeds the investment. Since it is possible to use variety of methods, this revenue is presented linearly (no discount) and with no interest charges.

Table 2. Incentive prices for integrated PV≤10kW for 2017, [11]

Type of integrated solar power plant	C	k_1	$C \cdot k_1$
Power plants with installed power up to 10 kW	1.91 HRK	1.2	2.29 HRK

The annual fee for the supplied electricity to the power grid without the DHW system is: 12,089.08 kWh x 1.91 HRK/kWh – 20 % profit tax = 18,472.11 HRK. In the case of the PV system with the DHW system the calculation is: 12,089.08 kWh x 2.29 HRK/kWh – 20 % profit tax = 22,147.12 HRK.

Estimated total investment is: Modules: 40 x 1,500 HRK = 60,000.00 HRK, Inverter: 19,190.40 HRK, Wiring, measuring cabinets, string cabinets, overvoltage and overcurrent protectors, meters and equipment: 10,000.00 HRK, Cables: 5,000.00 HRK, Construction assembly: 20,000 HRK, Replacing the inverter of PV system after 10 years: 19,190.40 HRK, Total cost of PV system without DHW: 114,190.04 HRK + VAT =142,737.55 HRK. DHW-a cost: 20,000.00 HRK + VAT. Total cost of PV system with DHW: 107,180.80 + VAT =167,737.55 HRK, Table 3.

Table 3. Simple Payback Period (SPBP) for PV system with and without DHW

PV system	PV system with DHW	PV system without DHW
Investment (HRK)	167,737.55	142,737.55
Income (HRK)	22,147.12	18,472.11
SPBP (years)	7.57	7.72

Table 3 shows that SPBP is somewhat less than 8 years, which means that the investment will receive a positive cash flow after 8 years.

Cash Flow *(CF)* Cash flows is the difference between cash inflows and outflows over a given period of time, and a positive trend is achieved by reducing investment costs, accumulation for energy savings, slower repayment and feed-in tariffs. It is not an indicator of project feasibility. Fig.4 represetns cash flow in blue, monthly income in green, and the total cash flow by red line. The point of intersection of the red line with the abscissa represents investment repayment moment.

The net present value method (NPV) is the calculation of the future cash flows discounted at the discount rate, thus encompassing the overall effects over the economic life.

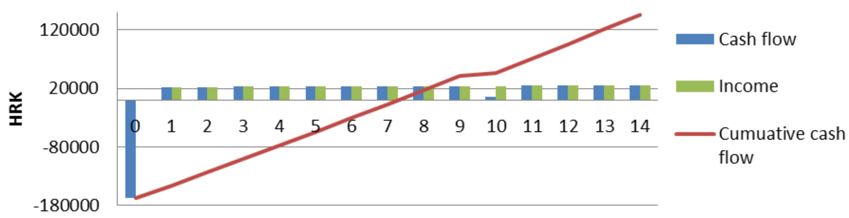

Fig.4. Graphic display of cash flows PV ≤ 10 kW

The analysis takes into account the projection of the business activity over the life of the asset. This takes into account the time settings, and the discounting technique reduces future investment effects to the present value, i.e. to the value of the investment period. NPV is one of the best investment analysis indicators because it represents the difference between the present value of cash outflows and the present value of cash inflows. This means that any money unit (e.g.

euro) earned in the future will not be as worth as one earned today due to the value change of money over time. If NPV is greater than zero, we have gained profit, and less than 0 is a loss.

$$NPV = \sum_{n=0}^{t} INV_{base} - \frac{(SAVING_t - INV_t)}{(1+k)^t} \quad (1)$$

Where:
INV_{base} - Initial investment (Cost of Equipment at "Location" + Workforce - Remaining Equipment Value)
$SAVING_t$ - Savings for year "t" (economic savings on bills)
INV_t- Additional investment for year "t"
n - Considered period in years
k- Discount rate

The benefits of the NPV in relation to the single return period are taking into account the time value of money and cash flows, and the risk and profitability are given high priority, Table 4. Limits of the net present value are not taking the initial investments into account as well as the duration of the project.

Table 4. Calculation of net present value for PV system ≤ 10 kW

Year	Cash inflow	Initial investment / Cash outflow	Net cash flow	Discount cash flow
0	0.00	167,737.55	-167,738.00	-167,738.00
1	22,147.12	0.00	22,147.12	-145,591.00
2	22,590.06	0.00	22,590.06	-123,001.00
3	22,811.53	0.00	22,811.53	-100,189.00
4	23,033.00	0.00	23,033.00	-77,156.30
5	23,254.48	0.00	23,254.48	-53,901.80
6	23,475.95	0.00	23,475.95	-30,425.90
7	23,697.42	0.00	23,697.42	-6,728.44
8	23,918.89	0.00	23,918.89	17,190.45
9	24,140.36	0.00	24,140.36	41,330.81
10	24,361.83	19,190.40	5,171.43	46,502.24
11	24,583.30	0.00	24,583.30	71,085.55
12	24,804.77	0.00	24,804.77	95,890.32
13	25,026.25	0.00	25,026.25	120,916.60
14	25,247.72	0.00	25,247.72	146,164.30
	Total cash input	Total cash output	Total net flow	
Total	333,093.00	186,928.40	146,164.00	
Results				
NPV	304,040.28			
Profitability Index (PI)	1.63			
IRR from operating income	13.54 %			
IRR from the cash flow	12.61 %			

Internal Rate of Return - IRR is the discount rate to be applied to future project savings in order to equalize investment costs. By applying the internal rate of return method, the discount rate is determined which equals the current value of the net investment cash flow receipts with the zero. The criterion for assessing the eligibility of the project is that the discount rate that net receipts is reduced to zero must be, in order for the project to be acceptable, higher than the interest rate on which the loan for financing this project is planned. The internal rate of profitability is calculated by iterations so that for each discount rate the net present value is calculated. When the net present value becomes zero, this means that the discount rate applied is equal to the internal rate of profitability of the project. Internal Rate of Return (IRR) is the discount rate to be applied to future savings in order to equalize investment costs.

$$0 = \sum_{t=0}^{n} \frac{(SAVING_t - INV_t)}{(1+IRR)^t} - INV_{base} \quad (2)$$

Where:
INV_{base} - Initial investment (Cost of Equipment at "Location" + Workforce - Remaining Equipment Value)

$SAVING_t$ - Savings for year "t" (economic savings on bills)
INV_t- Additional investment for year "t"
n - Considered period in years
IRR- Internal rate of return

Higher the internal rate of profitability is, implementation of the project is more preferable. IRR values are given in percentages. The advantage of IRR method is the project's value representing simplicity, and if the result is favorable, there is no need to evaluate the required return, which is a very difficult task. The same project can have a different internal rate of return because, mathematically, there can be different solutions for equation NPV = 0.

Return On Investment (ROI) assesses the effectiveness of the investment. For ROI calculation, the benefit of an investment is divided by investment cost. If the investment does not have a positive ROI, or there are other measures with higher ROI, then the investment should not be taken.

$$ROI\,(\%) = \frac{net\ cash\ flow}{investment\ cost} = 78.19\ \% \quad (3)$$

The advantage is a very simple and common criterion in the analysis of investment decisions. The disadvantages for ROI calculation can easily be changed based on the goal of the analysis. Depending on what is involved in earnings and costs.

5. LEGAL FEASIBILITY

The legal feasibility of a project is important because it can lead to constraints on realization or inability to realize the project. Analysis of laws that could jeopardize technical realization is necessary. Any law that may have an impact on the project must be studied and determine the impact on the success of the realization, [12,13]. It is important to study the constraints imposed on public procurement. Some of the more important legal aspects that need to be met [7] are: Energy Regulations, Environmental Regulations, Financial Regulations, Tax Regulations, Labor Law, Administrative Regulations and Special Sector Regulations. The strategic and legislative framework for investment in renewable energy sources has been ensured by the legal regulation of the Republic of Croatia. The Energy Act and the Electricity Market Act define a set of Ordinances and Decrees that encourage the construction of power plants on renewable energy sources and the production of electricity from RES. The particular importance of renewable energy sources is also reflected in the Energy Act which clearly expresses a positive attitude towards them and expressly states in Article 14 paragraph 1 that their use is in the interest of the Republic of Croatia. The regulations that came into force on 1 July 2007 are of crucial importance for renewable energy systems. Some of them include the Decree on the minimum share of electricity produced from renewable energy sources and cogeneration whose production is encouraged, the Decree on incentives to promote the production of electricity from renewable energy sources and cogeneration, the Rulebook on Use of Renewable Energy Sources and Cogeneration, the Rule on Acquisition of Status of the eligible electricity producers and in particular the Tariff system for the production of electricity from renewable energy sources and cogeneration. The tariff system establishes the right of the eligible producer to the incentive price paid by the market operator for the supplied electricity and is based on the justified costs of operating, maintaining, replacing, constructing or reconstructing installations that use renewable energy sources or cogeneration. The fundraising and asset allocation mechanism is managed by the market operator (supervised by the relevant ministry) and concludes contractual relations with eligible producers. The tariff system determines the tariff items and their amount for the supplied electricity from installations that use renewable energy sources. The tariff system differentiates the plants according to the type of technology i.e. the renewable source that the power plant uses and the size or installed power of the power plant. Division according to the installed power recognizes power plants up to 1 MW and power plants over 1 MW.

6. OPERATIONAL FEASIBILITY

An analysis of operational feasibility gives an answer as to how much the investment fits into existing needs i.e. how much the project will increase savings. Operational feasibility gives the answer whether the existing resources can be implemented to PV systems, that is, which profession are lacking and which equipment is needed for practical implementation of the project. If the installation of the PV system retraces the reconstruction of the roof, the reconstruction cost must be included in the investment what may lead to the evaluation of the project as unenforceable.

7. SCHEDULE FEASIBILITY

The time aspect is the last step in the feasibility analysis. It analyzes the realistic timeframe for the project design and also helps in assessing the sustainability. PV system does not require a long installation time. But if a PV system is planned on a new facility, it should be taken into account that all precessions have to be made on time, i.e. whether the timing of the loan realization will be breached. In case that the deadlines are not met, there are possibilities such as: employing additional workforce to speed up work on the project or introduce some types of training to existing staff to make the project run within the given deadline.

8. CONCLUSION

Capital investment in renewable energy sources considers financial resources to be provided. Financial institutions supporting the project want the security of their investments. One way of demonstrating the viability of the project is the implementation of the TELOS analysis. There are three parts of the TELOS analysis that must be met, technical, economic and legal. From the technical perspective the PV system is well known. The technical profession often uses a simple payback period. A simple payback period states only when the cash flow will change from negative to positive. SPBP does not provide an answer about the quality of investment in the project. The best indicator for investment profitability analysis is NPV. If NPV is greater than zero, profit is obtained. IRR represents the discount rate to be applied to future project savings in order to equalize investment costs. IRR is a good economic indicator for assessing investment viability. In the case of investment indecision, it is advisable to analyze NVP or IRR because they are based on cash flows and take into account the rate of reinvestment. Return of investment (ROI) assesses investment effectiveness. In the case of a negative ROI investment should not be implemented. It should be always decided to invest with a larger ROI. The project can get the rating unproductive if the analysis of operational feasibility and schedule feasibility according indicates the existence of insurmountable problems. TELOS analysis is an excellent tool for assessing the realization of all EIA measures, not just RES.

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