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Renewable electricity sources selection based on the economy applied approach

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***Abstract*— The aim of the work is to develop an economically justified approach to the selection of renewable sources of electricity. This aim is achieved by construction an automated algorithm that takes into account a set of restrictions for creating the optimal structure of a photovoltaic station. The work confirms the influence of such factors on project implementation as: electricity consumption schedule, built-up area, photovoltaic station mounting system type, allocated amount of money for project implementation, fixed and variable costs for maintenance of photovoltaic station, cost of electricity. The results of an economically justified approach to the selection of renewable sources of electricity at a real photovoltaic station are given. Indicators such as pay-back period and cash flow were calculated, which show the feasibility of the proposed approach.**

***Keywords*— renewable, energy, photovoltaic, electricity, station, pay-back period, cash flow**

I. Introduction

In modern conditions, the share of electricity in the unit cost of production is quite significant and with the increase in electricity tariffs, it becomes even more significant.

It is possible to achieve the minimization of electricity consumption in production, increase environmental standards and profitability of production by introducing renewable energy facilities into existing technological processes [1, 2].

The above is in line with the aim set by 2030 to make all sectors of the European Union's (EU) economy climate neutral [3, 4, 5].

At the same time, the widespread use of renewable energy facilities significantly reduces dependence on hydrocarbons, which in 2022 has become a means of energy blackmail.

The development of renewable energy creates new opportunities for [6, 7]:

- development of science and technology;

- attraction of investments;

- creation of new jobs;

- reduction of energy dependence;

- improvement of health and well-being;

- transition to ecological mobility.

The European Green Deal opens up great opportunities for European industry and the industries of those countries that are integrating into the European Union [8].

New technologies annually make it possible to make renewable energy facilities more flexible and functional. This allows you to influence entire value-added chains: energy, transport, production, agriculture and construction [9, 10].

II. The Main Materail

Photovoltaic (PV) stations are the most effective, cheap and simple source of electricity. Which are scalable systems, the functioning of which can be carried out both in autonomous, hybrid and fully synchronized with the power system mode.

Of course, the use of PV stations as autonomous power supply systems is quite complicated and expensive, due to the need to store the produced electricity in batteries and the variability of generation of electricity.

Therefore, the most flexible and effective way of using PV stations is to use them for partial compensation of one's own electricity needs. The investment climate of such an event significantly increases when the legislation on Net Metering or Net Billing is in force in the country [11].

At the same time, the appearance of a large number of players in the electricity market will create a supply that will lead to a decrease in the cost of electricity. At this stage, hydrogen energy becomes relevant as a means of storing cheap energy for use at times of peak consumption [12].

Of course, for the political leadership, the departure from carbon energy is difficult and even dangerous, from the point of view of the structure of some countries' economy. But the rate of spread of renewable sources of electrical energy will in any case encourage the development of green hydrogen [13].

Building close relationships and clear coordination of actions between the energy sector and other sectors of the economy will ensure the greatest efficiency from the use of energy from renewable sources.

Such a structure will have a positive impact not only on the development of industry, but also on the improvement of the situation on the labor market, social protection of the population and the training of qualified personnel at all stages of training in educational institutions.

The construction of a PV station to compensate for one's own needs is an investment project designed to solve several problems at once:

- compensation of electricity consumption;

- increasing energy independence;

- reducing the impact on the environment during production;

- improvement of the quality indicators of electricity in the power system;

- making a positive impact on the electricity market;

- stimulating the development of green energy in general.

Accordingly, for each such project, it is necessary to carry out a technical and economic justification, which should show its attractiveness.

Thus, the main indicators for assessing the rate of return on investment of such a project are the investment payback period (PBP) and CASH FLOW.

It is possible to achieve the optimization of which by taking into account all the factors that affect the efficiency of the photovoltaic plant in question.

The PBP can be calculated using the formula:

$$\mathrm{PBP} = \frac{\mathrm{CAPEX}}{\mathrm{EBITDA}} \tag{1}$$

where CAPEX – investment amount, €.

EBITDA – Earnings before Interest, Taxes, Depreciation and Amortization, €.

At the same time, the EBITDA can be presented as follows:

$$\mathrm{EBITDA} = \mathrm{SP} \cdot \mathrm{P_{SPP}} \cdot \mathrm{RC} \cdot \mathrm{EP} - \mathrm{OPEX} \tag{2}$$

where SP – Specific Production, kWh/kWp/year, this parameter depends on the type of Mounting System type ($\mathrm{MS_{type}}$), Coverage Area (CA), and the location of the PV station: $\mathrm{SP} = \mathrm{f}\left(\mathrm{MS_{type}}, \mathrm{CA}, \mathrm{Location}\right)$.

OPEX – Operating Expenses, €, are defined as the sum of Fixed Costs (FC) and variable costs (VC);

RC – Restriction Coefficient ($\mathrm{RC} = 1$);

EP – Electricity Price, €.

$\mathrm{P_{SPP}}$ – installed capacity of solar power plant, kW.

Installed capacity of solar power plant is directly dependent on the Estimated Power Consumption (EPC), $\mathrm{MS_{type}}$ and CA : $\mathrm{P_{SPP}} = \mathrm{f}\left(\mathrm{EPC}, \mathrm{MS_{type}}, \mathrm{CA}\right)$.

In this case, credit funds and payment of taxes on profit are not considered, so CASH FLOW will be defined as the difference between CAPEX and EBITDA.

Based on the above, the following can be formulated. For an average PV station, there are a number of parameters that set limits for its construction and evaluation of the efficiency of operation:

- electricity consumption schedule;

- coverage area;

- mounting system type;

- allocated amount of money for the implementation of the project;

- constant and variable costs for maintenance of the photovoltaic installation;

- electricity price.

Accordingly, taking into account these restrictions, such a renewable energy facility as a PV station will bring the most benefit to the owner.

Summarizing the given statements and based on many years of experience, an approach to solving the problems of implementing PV stations has been formed.

It is presented in the form of an algorithm (Fig. 1) and the above formulas. They combine both technical and economic factors that affect the implementation of the project of building a PV station.

Taking them into account makes it possible to achieve the selection of optimal solutions that will satisfy the needs of the customer.

As an example, let's consider the results of this approach at one of the facilities, which was implemented by SOLAR STEELCONSTRUCTION LLC in 2022.

This is a small public facility that operates during daylight hours and provides services to citizens.

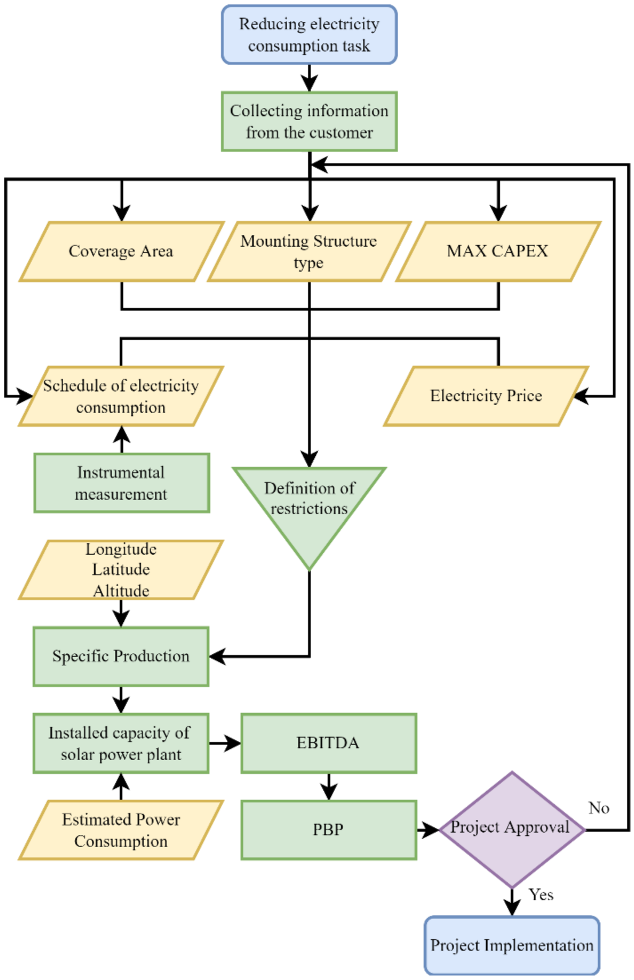

Fig. 1. Algorithm of an economically justified approach to the selection of renewable sources of electricity

The first limitation for this object was the schedule of electric energy consumption, which is built on the basis of the results of instrumental measurement, Fig. 2.

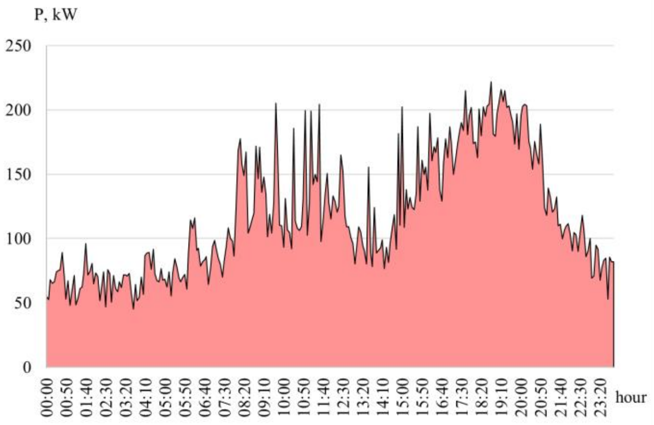

Fig. 2. Schedule of electricity consumption during the day

In the course of a staff survey and analysis of available information on annual electricity consumption, it was established that the constructed consumption schedule is typical for the entire year. There is a slight decrease in electricity consumption on weekends.

The second limitation was the available roofs area of the object, which is 750 m^2 of usable area.

The third limitation was the use of modular mounting system SRS-EW type from SOLARsk, which allow for the most efficient use available roofs area of the object, Fig. 3 (a) SRS-EW type sample, b) photo of the built station).

a)

b)

Fig. 3. Modular mounting system SRS-EW type from SOLARsk

As a result, 140.8 kW of the installed power of photo modules was placed on the roof of the building, on which various equipment was located.

Funding was not a constraint in this case.

As a result, after conducting engineering research, the equipment was selected and calculations were made to forecast the generation of electricity during the year. The calculations took into account the influence of all meteorological factors and losses. The following results were obtained, Fig. 4.

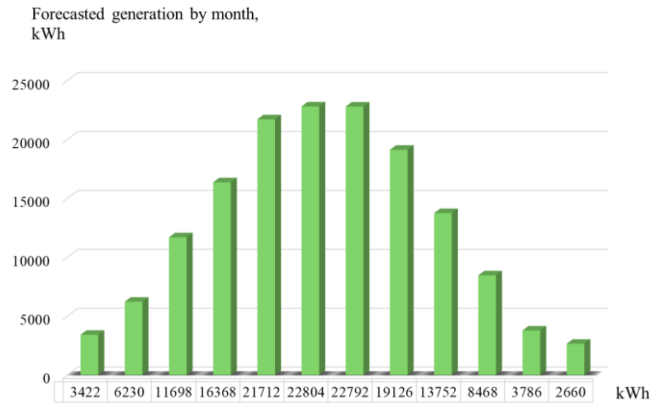

Fig. 4. Forecasted monthly generation of electricity by a PV station

The forecasted electricity generation schedule given is the initial information for conversion into a monetary unit and calculation of monthly EBITDA and CASH FLOW.

Accordingly, taking into account the available information about the company's electricity consumption and project generation, we built a diagram that reflects the CASH FLOW by years, Fig. 5.

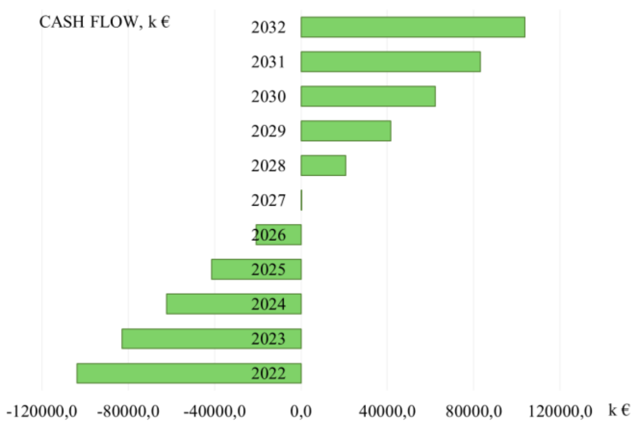

Fig. 5. CASH FLOW for 10 years of PV station operation

The information on the CASH FLOW which presented graphically, clearly shows the rate of return on investments and PBP.

Since this object is built, it is possible to assess how exactly this PV station functions. We present the results of the operation of the PV station on a sunny summer day, Fig. 6.

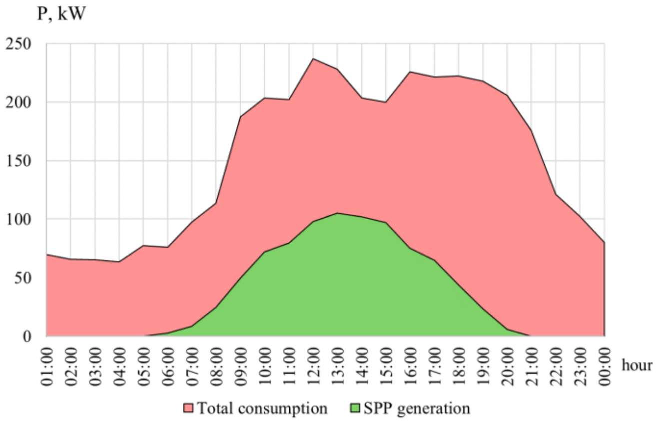

Fig. 6. The results of the electricity producing by PV station during sunny summer day

III. Conclusions

The presented results show that the generated electricity is consumed in full, while it can be noted that the power of the PV station isn't enough to cover the electricity consumption of this object. This is determined by the existing limitation on the roof area.

Of course, not all objects have a schedule of electricity consumption that is related to daylight hours, but for each case, a separate solution can be found.

Taking into account all the restrictions for this object made it possible to select the most optimal PV station from both a technical and an economic point of view

This article confirmed the greatest impact on the implementation of the project of such factors as: schedule of electricity consumption, coverage area, mounting system type, allocated amount of money for the implementation of the project, fixed and variable costs for maintenance of the photovoltaic installation, cost of electricity.

The correctness and expediency of the formed economically justified approach to the selection of renewable sources of electricity is confirmed by the relevant indicators of the rate of return on investment – PBP and CASH FLOW, as well as the physical implementation of this project.

References

[1] Viktor, S., Antonov, A., and other “Increased controllability of the distributed traction system in emergency mode”. 2020 IEEE 7th International Conference on Energy Smart Systems, ESS 2020 - Proceedings, 2020, pp. 58–62.

[2] Bosyi, D. O. “Modeling of the Controlled Traction Power Supply System in the Space-Time Coordinates”. Transport Problems. – 2017. – № 12 (3). – P. 5–19.

[3] IRENA. Renewable Power Generation Costs in 2019; International Renewable Energy Agency: Abu Dhabi, 2020.

[4] IRENA. Global Renewables Outlook: Energy Transformation 2050; International Renewable Energy Agency: Abu Dhabi, 2020.

[5] IEA, Renewables 2018 – Analysis and forecasts to 2023, Organisation for Economic Co-operation and Development/International Energy Agency, Paris, 2018.

[6] ”European Union. Directive (EU) 2019/943 of the European Parliament and of the council of 5 June 2019 on the internal market for electricity”. Off. J. Eur. Union 2019, L158, 54–124.

[7] “European Union. Directive (EU) 2019/944 of the European Parliament and of the council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU”. Off. J. Eur. Union 2019, L158, 125–199.

[8] “The European Green Deal”, Brussels, 11.12.2019.

[9] BNEF, Clean energy investment trends 2018, Bloomberg New Energy Finance, London, 2019.

[10] IEA et al., Tracking SDG 7: The energy progress report 2019, International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank and World Health Organisation.

[11] Law of Ukraine "In the Law of Ukraine "On Alternative Energy Sources". Bulletin of the Verkhovna Rada of Ukraine, 2003, No. 24, Art. 155

[12] Buttler, Alexander, and Hartmut Spliethoff. 2018. “Current status of water electrolysis for energy storage, grid balancing and sector coupling via power-to-gas and power-to-liquids: A review.” Renewable and Sustainable Energy Reviews 82 (Part 3): 2440-2454.

[13] IRENA, Hydrogen: A renewable energy perspective, International Renewable Energy Agency, Abu Dhabi, 2019.