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THE SELECTION OF THE OPTIMUM PV MODULES/INVERTER POWER FACTOR FOR SMALL GRID-CONNECTED SOLAR POWER STATIONS

Анотація. *Мета даного дослідження полягає в тому, щоб з'ясувати коефіцієнт потужності фотоелектричних модулів / інвертора, що призведе до максимальної продуктивності сонячної електростанції. Була проведена імітаційна модель з різними параметрами потужності. Результат моделювання показує, що оптимальний коефіцієнт потужності для малих сонячних електростанцій в Україні становить від 1,15 до 1,2.*
Ключові слова: *сонячна електростанція, фотоелектричний модуль, інвертор мережі, коефіцієнт потужності, коефіцієнт продуктивності, ККД СЕС.*

Аннотация. *Целью этого исследования является выяснение соотношения мощности фотоэлектрических модулей / инвертора, которое приведет к максимальному выходу солнечной электростанции. Проведена имитационная модель с различными параметрами коэффициента мощности. Результат моделирования показывает, что оптимальный коэффициент мощности для небольшой солнечной электростанции в Украине составляет от 1,15 до 1,2.*
Ключевые слова: *солнечная электростанция, фотоэлектрический модуль, инвертор сетки, коэффициент мощности, коэффициент производительности, КПД СЭС.*

Abstract. *The aim of this research is to find out the PV modules/inverter power ratio, that will result into maximum of solar power station yield. The simulation model with different power factor parameters was carried out. The result of the modeling shows that the optimal power factor for small solar power plant in Ukraine is between 1.15 and 1.2.*
Keywords: *solar power station, PV module, on grid inverter, power factor, performance ratio, SPS efficiency.*

Introduction

Over the past few years, there has been a significant increase in individuals' investments in the construction of solar power stations (SPS) with an installed capacity of up to 30 kW. This situation became possible due to the implemented amendments to the Law of Ukraine "On Electric Power Industry" [1] and a constant decrease of the SPS main elements specific cost - PV modules and on grid inverters. When designing the SPS installed power and selecting equipment, a potential investor faces the problem of matching characteristics to build the most efficient system. The situation is also complicated by the lack of unified technical recommendations and a wide variety of different manufacturers. In their majority, the market leaders in the solar PV modules and inverters production have their own series of capacities, which differ from each other. For example: the leading manufacturer of inverters (SMA) produces three-phase on grid inverters Sunny Tripower with rated power of 15, 20 and 25 kW, but the manufacturer of solar PV modules Suntech have the most cost-effective polycrystalline modules with the capacity of 240 and 260 watts.

Main part

The research task was to find the optimal ratio of the installation power of the modules/inverter in terms of the minimum electrical losses in the system, the maximum specific production of electrical energy, the minimum payback period. The latter criteria should be decisive when choosing a particular power ratio. The results of the study are obtained on an idealized model in which the losses in transformers, shadows, etc. are neglected.

The initial modeling data are shown below and in Table 1:

Table 1.

Initial modeling data

PV Array Characteristics	Inverter	PV Array loss factors
PV module: *Suntech STP 260-20/Wem Si-poly* 16-21 modules in series, 6 strings in parallel; Nb. Modules - 96-126; Unit Nom. Power - 260 [Wp]; Array global power *25-32,8* [kWp].	Model: *SMA Sunny Tripower 25000TL-30;* Unit Nom. Power - *25.0* [kWac]; Operating Voltage - 390-800 [V]; Nb. of inverters 2 * MPPT 50 %.	Thermal Loss factor - Uc (const) - 29.0 [W/m²K]; Wiring Ohmic Loss – 1.3% at STC; Module Mismatch Losses – 1 % at MPP Strings Mismatch Loss – 0.1% The remaining losses are assumed to be 0 %. User's needs: Unlimited load.

Geographical Site: Latitude48.47° N, Longitude 35.05° E, Altitude 60 m, Albedo 0.20
Meteo data: Meteonorm 7.1 (1991-2010), Sat=100% - Synthetic
Orientation: Azimuth 0°, Tilt 30, Transposition Perez, Free Horizon, No Shadings

To achieve the maximum solvable power of 30 kW for individuals, the use of two inverters with the rated power of 15 kW each is not economically viable, because their total cost is 180% of one 25 kW inverter price, which will significantly increase the amount of CAPEX.

Modeling of power generation process was designed using the PVSyst [2] software product with the parameters specified in Table 1.

Designations taken:

- PV modules total STC power capacity P_{PV}, kWp;
- power factor- the ratio of the PV modules total power and the installed power of the inverter

$$K_p = \frac{P_{PV}}{P_{inv}} \quad (1)$$

- energy, injected into grid per year E_{grid}, MWh;
- performance ratio (PR);
- specific energy produced E_{spec}, kWh/kWp/year.

The modeling results are shown in the table 2.

Table 2.

The main modeling results of the SPS yield

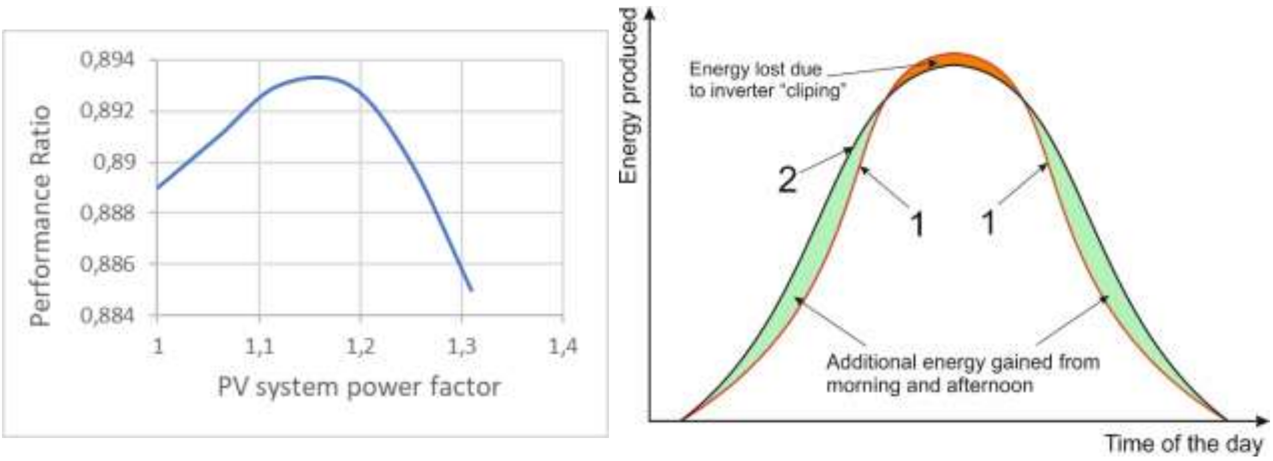
P_{PV}[kWp]	K_p	E_{grid} [MWh]	PR	Total PV modules number	E_{spec} [kWh/kWp/year]
25	1	33,1	0,889	96	1327
26,5	1,06	35,3	0,891	102	1330
28,1	1,12	37,4	0,893	108	1332
29,6	1,19	39,5	0,893	114	1333
31,2	1,25	41,5	0,89	120	1329
32,8	1,31	43,3	0,885	126	1321

Based on the obtained data, the dependence of the performance ratio on the power factor was plotted (Figure 1, a). According to the graph below, it can be concluded that the maximum efficiency of the system, and, therefore, the maximal specific yield will be observed at K_p values of the range 1.15-1.2. By modeling with solar modules of other manufacturers, the similar K_p ration was gained.

These data are explained as follows. The amount of electricity generated by SPS during the day have normal distribution, where the peak falls at noon time (curve 1, Figure 1, b). This curve shape is ideal and corresponds to several days in a year with ideal weather conditions. Curve 2 (Figure. 1, b) shows the distribution of the SPS yield with an inverter of lower power than PV modules (overclocking inverter).

Although the maximum power output of a solar system will be ‘clipped’ back to the inverter’s output through overclocking, there will be gains in the overall amount of energy generated and more energy produced in the early morning and late afternoon. The Figure 1, b shows how the midday losses associated with an ‘undersized’ inverter can be offset by morning and afternoon gains. At this time of day, the not so high solar irradiation intensity is compensated by the low ambient temperature, which positively affects the solar modules efficiency.

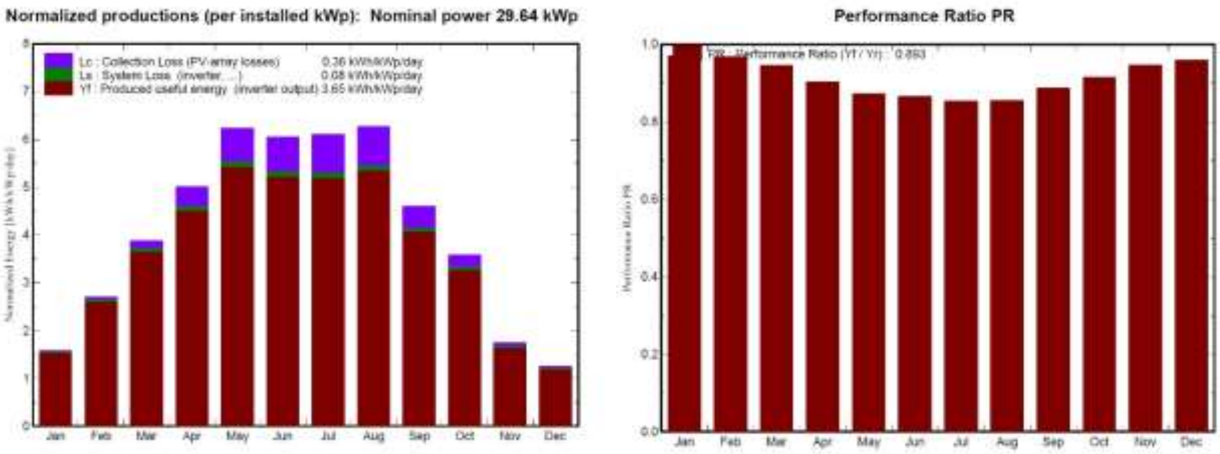
As for the equipment payback period, the SPS with the optimal power factor will pay for the difference in cost from SPS with K_p=1 in less than 2.5 years, including the costs of installing additional PV modules.



a) b)

Fig. 1. a- graph of performance ration versus power factor,
b – SPS yield distribution during the day.

Figure 2 shows diagrams of the annual distribution (Figure 2 , a) of the normalized energy production and the system performance ratio (Figure 2, b) for the optimum K_p.



a) b)

Fig. 2. a – diagram of the annual distribution of the SPS normalized energy production,
b - diagram of the annual distribution of the system performance ratio.

Conclusion

When choosing equipment for solar power station construction with an installed capacity of up to 30 kW, it is optimal to exceed the power of the PV modules by 15-20% over the power of the inverter.

Solar power stations with the optimal power factor are more cost-effective and, therefore, more attractive for a potential investor.

The obtained results are of interest to potential investors, especially in the context of the new Law of Ukraine "On the Electricity Market" [3] main provisions and the constant reduction of the energy net cost, produced at SPS.

References

1. The Law of Ukraine "On Electric Power Industry" № 575/97-ВР from 16.10.1997.
2. Software from http://www.pvsyst.com/en/software/functionalities.
3. The Law of Ukraine "On the Electricity Market" № 2019-VIII from 13.04.2017.

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