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KEY PERFORMANCE INDICATORS DETERMINING THE QUALITY OF THE PHOTOVOLTAIC SYSTEMS

In the early stages of the mass adoption of PV modules, manufacturers reduced their costs to make them more affordable, ignoring their carbon footprint, and leading to a huge e-waste. Although reducing the thickness of photovoltaic cells simplifies their application, it completely ignores the durability and maintainability of panels [1], which significantly affect the system's quality.

At the moment, consumers in Ukraine are forced to look for ways to ensure autonomy to maintain basic household needs and ensure technological processes in production due to damage to energy infrastructure facilities. Autonomous and hybrid photovoltaic installations with an energy conservation system are used as an additional power source.

When choosing a hybrid or autonomous inverter, it is necessary to pay attention to the functionality and completeness of the device. Such a station must support various modes of operation, in particular, without batteries. To extend the service life, you should pay attention to lithium-ion or lithium-iron-phosphate accumulators. In addition, the station scheme must include additional devices for adjusting modes during autonomous operation and reducing generation during the active phase of the day [2].

In particular, NREL tests have shown that degradation and peak power losses are almost entirely caused by short-circuit current losses. These losses are almost identical for monocrystalline and polycrystalline panels and strongly depend on the production process [3]. The decline in current module production can be partially explained by visually observable physical defects, including darkening of EVA, delamination at the Si-cell/EVA interface, and localized hot spots.

In general, the main factors that influence the quality of PV systems are listed below [4]:

• The efficiency of a PV system is affected by module temperature, which usually decreases with increasing temperature. Recommendations to reduce the impact of this problem: keep a sufficient gap between the modules and the roof (or ground) to allow convective air flow to cool them; ensure that panels and supporting structure are light-colored so that heat absorption will be less; use perforated base structure to increase cooling; do not keep inverters below and close to the modules; and use cooling fans [5].

• Almost all types of modules show a decrease in efficiency at low light intensity. The strength of this effect depends on the type of module.

• Some light is reflected from the surface of the modules and never reaches the actual photovoltaic material. There is a strong dependence on the angle at which the light falls on the module. The more light that comes in from the side, the higher the percentage of reflected light. This effect varies somewhat between module types.

• The conversion efficiency depends on the spectrum of solar radiation. While almost all photovoltaic technologies have good performance for visible light, there are large differences in efficiency for near-infrared radiation. If the light spectrum were always the same, then this effect would be considered part of the nominal efficiency of the modules. But the spectrum changes depending on the time of day and year and the amount of scattered light.

• Some module types have long-term performance changes. In particular, modules made of amorphous silicon are prone to seasonal fluctuations in performance caused by prolonged exposure to light and excessively high temperatures. Solar PV panels usually degrade faster in the first few years of their life. In general, the rated power output of solar panels typically degrades at about 0.5 %/year [6].

• Mounting position. For fixed systems, the way the modules are mounted will affect the temperature of the module, which in turn affects efficiency. It has been experimentally proven that if the movement of air behind the modules is limited, the modules can heat up significantly.

• Angle of inclination. This is the angle of inclination of the photovoltaic modules to the horizontal plane for stationary installation. It is also noted that measurements of global radiation are carried out on a horizontal surface. Maximum radiation can be obtained by tilting the surface at an optimal angle, which is determined by the latitude of the location.

• Parasitic resistances. The series and shunt resistances of a PV cell, called "parasitic resistances", lead to increased power losses, which ultimately lead to reduced module efficiency.

• Losses in PV Solar systems. There are several causes for this loss, such as losses in cables, power inverters, dirt (sometimes snow) on the modules, ambient temperature, varying insolation levels, and so on. In addition, reflection losses due to larger incidence angles result in higher reflection losses than accounted for in the rated power. In particular, the contamination of the solar cells due to the accumulation of dust and dirt, especially on the lower edge of the module. Also, mismatch losses are caused by the series and parallel connection of solar modules, since the power of the entire photovoltaic array under the worst conditions is determined by the solar module with the lowest power. Finally, maximum power point tracking (MPPT) losses, as the output power of the PV module varies with sun direction, solar insolation level, and temperature.

The use of different MPPT algorithms can significantly affect the level of power losses in the inverter-based PV systems, but the complexity of the MPPT algorithm is usually taken into account within consideration of the optimal solution for particular application [7].

In summary, PV power plants play an important role in wartime, so it is important to control the quality indicators to increase the energy efficiency of these systems. These include temperature and other climatic conditions, radiation levels, energy conversion efficiency, panel placement, system losses, parasitic resistances, and module degradation due to aging. Obviously, with an increase in the service life of the system, there is a better return on investment.

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