Zavhorodnii Rostyslav Serhiiovich, student, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Kyiv

ORCID: 0009-0009-1656-4015 Rostyslav Zavhorodnii

Solar Radiation Simulators for Measuring Characteristics of Solar Panels

In order to systematically investigate photochemical processes under controlled laboratory conditions, a standardized definition of solar light is required, which consists of waves of different lengths, some of which correspond to the colors we observe. The solar spectrum can be defined as the spectral distribution of the electromagnetic field energy emitted by the Sun. This spectrum covers a range of wavelengths from 350 to 4000 nm.

Artificial sources of solar light, known as solar simulators, are scientific devices used to reproduce solar light under controlled laboratory conditions. The main components of solar simulators are the light source and power supply, optical system and light filters used to modify the output radiation, as well as control elements necessary for the proper operation of the simulator. Solar simulators are divided into two main categories: continuous, stationary, and pulsed. There are two methods of creating "artificial solar light": the first method involves adjusting the spectrum of the light source with a wide range by applying optical filters to approximate it to the spectrum of natural solar light; the second method uses narrow-band light sources that are combined to create the desired spectrum. In most cases, xenon high-pressure lamps with short and long arcs are commonly used as light sources in solar simulators. Additionally, other light sources such as metal halide lamps and light-emitting diodes (LEDs) are also utilized. Xenon arc lamps are the most widely used light source for solar simulators. They have a spectrum that closely approximates the spectrum of a black body at a temperature of 5800 K. However, due to the nature of gas discharge, "parasitic" emission lines appear in the lamp's spectrum in the infrared range from 800 to 1000 nm, which can be partially eliminated using optical filters. Advantages: spectrum stability; maximum resemblance to solar light spectrum; power variation does not affect spectral balance; high radiation intensity. Disadvantages: high xenon gas pressure in the lamp during operation, posing a potential hazard to personnel; instability of light emission level up to 30%; presence of line components in the infrared part of the spectrum caused by the nature of gas discharge; lamps have a short service life and are relatively expensive. Metal halide arc lamps. Metal halide arc lamps are light sources that utilize a mercury arc with metal halide additives, providing illumination that corresponds to spectra typically ranging from 5000 K to 6000 K. Advantages: high stability; spectral quality that closely matches the solar spectrum; lower pressure compared to xenon arc lamps. Disadvantages: emits a significant amount of infrared energy and insufficient ultraviolet radiation; light flux reduction over time; shorter service life compared to xenon lamps; limited implementation power. Light-emitting diodes (LEDs) are semiconductor devices that, when used in solar simulators, can provide more flexible possibilities for simulating solar light. Advantages: adjustable spectrum of the light source within a range of 30 nm - 50 nm; energy efficiency; long service life; LEDs can be controlled rapidly within microseconds or operate steadily at a constant light intensity for an extended period of time; high speed enables the creation of control systems for achieving maximum light flux stability. Disadvantages: to simulate the full spectrum of solar radiation, an array of LEDs with different wavelengths is required; high cost of LEDs for generating light flux below 360 nm and above 1100 nm; complex optical design.

Optics and Filters. To generate a collimated beam, where electromagnetic radiation has parallel rays, a collimating lens can be added to solar simulators. Systems that do not use lenses for light homogenization often require a minimum of two mirrors to change the direction of the beam, homogenize the light beam, and collimate the light, which can result in light loss. Additionally, a Lambertian reflector can be added to solar simulators, which scatters the direction of reflected light and provides more uniform radiation.

Power Supply. Power sources are mainly determined by the type of light source used and have their own parameters, which are determined by the physical principles of the employed light sources.

Solar Simulator for Measuring the Volt-Ampere Characteristics of Solar Panels. For optoelectronic devices equipped with silicon photodiodes, such as solar sensors, there is no need to simulate the ultraviolet region of the spectrum, and stringent requirements for the divergence angle of the light beam are often not imposed. The voltage-current characteristics (V-I curves) are obtained using built-in software and displayed on the system's screen or a computer. The drawbacks of an automated system used for measuring the V-I characteristics of solar cells include: - the presence of complex software with a multitude of functionalities that far exceed the necessary tools required to solve the task at hand; - the inability to measure all available solar elements and solar panels with a single device, necessitating the use of an additional powerful programmable current source; - the inability to directly obtain V-I curves in real-time as an oscillogram on the display (without additional software processing); - the need to create and utilize a powerful solar lighting simulator with a working area of several square meters. It should be noted that the last problem is inherent in all V-I measurement methods and therefore requires a separate solution. The proposed method to overcome it involves utilizing a solar lighting simulator based on distributed sources, constructed from several illuminating lamps. Currently, there is no universal tool for measuring the V-I characteristics of solar elements and solar panels, which prompts the search for the development of a similar system. The search for scientific and technical solutions, in our opinion, should focus on improving pulsed devices by expanding the current range and reducing Joule heating during the measurement cycle, thus reducing the methodological measurement error.

References:

1. Solar Simulation Technology [Електронний ресурс] // G2V – Режим доступу до ресурсу: <https://g2voptics.com/solar-simulation/>.

2. Божко К. М. Дослідження стендових засобів для вимірювання вольт-амперних характеристик сонячних елементів та батарей / К. М. Божко, Г. С. Гуренок, Н. М. Защепкіна // ScienceRise. - 2016. - № 11. - С. 30-32. - Режим доступу: http://nbuv.gov.ua/UJRN/texc\_2016\_11\_8.