

# **Nominal Operating Cell Temperature (NOCT): Effects of module size, power, load and solar spectrum**

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Besides intrinsic properties, the performance of a photovoltaic module is also governed by external parameters - one of the most important of them being the cell temperature. For maximum power output of the module, we need lower operating temperatures but higher irradiance. The typical temperature coefficient of power is  $-0.5\%/^{\circ}\text{C}$  for mono- or polycrystalline silicon cells. The cell temperature of open-rack modules, however, is governed by several external factors such as ambient temperature, irradiance level, wind speed, wind direction, and tilt-angle of the module in the array. NOCT ( Nominal operating cell temperature ) is the cell temperature when irradiance is  $800 \text{ W/m}^2$  , ambient temperature is  $20^{\circ}\text{C}$  and wind speed is  $1 \text{ m/s}$  at a module tilt-angle  $45^{\circ}$ .

NOCT is a very critical parameter that is required by various performance, qualification and energy rating standards/models, and in California Energy Commission's (CEC) rebate program. It could potentially be influenced by testing locations, seasons, size/power and load conditions ( $V_{oc}$ ,  $I_{sc}$  or  $P_{max}$ ). The primary goal of this paper is to analyze if the last two factors have any influence on the NOCT value of crystalline silicon (c-Si) modules. Another investigation in this paper is to see if there is any influence of near infrared part of the solar spectrum on NOCT or not. This study uses the methodology specified by the IEC 61215(2005) standard but: with three different load conditions ( $V_{oc}$ ,  $I_{sc}$  or  $P_{max}$ ) instead of just  $V_{oc}$  load condition, and with two radiometers (pyranometer and reference cell) instead of just pyronometer.

For this study, two photovoltaic modules, one large (designated as LMA, 170 watts) and one small (designated as SMA, 70 Watts) were used in this experiment. As shown in Figure 1, these two test modules were surrounded by other dummy modules to simulate the array environment. LMA is distinguished by red border around it and SMA is distinguished by black.

A randomized design of experiments was performed with two factors into the design consideration namely a) the size of the module b) load condition (short / open circuit or resistive load). The random sequence was generated using commercial software DesignExpert™ version 7.0. Each configuration of the module needed a full day of temperature measurement. This design gave rise to 12 configurations that were carried out over a period of 12 days at the PTL. If data from any of the configurations was not reliable or useful due to weather / technical disruptions, the measurement was continued for the following day(s) until the measurement was completed. A weather station recorded the wind speed, wind direction and the ambient temperature at the same frequency as that of the data acquisition system.



**Figure 1: LMA (red border) and SMA (black border) mounted on an open rack for NOCT testing**

NOCT is defined by the following equation:

$$T_{\text{NOCT}} = 20^{\circ} \text{C} + T_{\text{rise@ } 800\text{W/m}^2}$$

Using the above equation, the NOCT was determined for 12 days. The preliminary results are shown Table 1.

<b>Module</b>	<b>Mode</b>	<b>NOCT (avg) (°C)</b>
<b>70W</b>	70W-RL	41.4
<b>70W</b>	70W-OC	46.19
<b>70W</b>	70W-SC	52.6
<b>170W</b>	170W-RL	44.87
<b>170W</b>	170W-OC	47.48
<b>170W</b>	170W-SC	47.92

**Table 1: NOCT Summary for LMA and SMA (RL: Resistive Load; OC: Open Circuit; SC: Short Circuit)**

It is observed that the NOCT values for 70W module in RL (resistivity load) and OC (open circuit) configurations is less than that of the 170W module in similar configuration. However, it is noticed that the NOCT of 170W module in SC (short circuit) mode is lesser than 70W module in SC configuration. There could be many possible reasons for these observations. In addition, the SC configuration in both 170W and 70 W modules give the higher NOCT value than OC and RL.

This is a preliminary work for this study. This study is planned to be extended for next three months to get data with more number of modules and for over a larger window of time to get statistically balanced data with both pyronometer and reference cell based irradiance sensors.

The other part of this study is to evaluate the effect, if any, of low energy photons on the NOCT value of the modules. The solar spectrum contains photons with wide range of energies. Not all the photons contribute towards electrical energy generation. A large portion of high energy photons contribute to the cell heating through a thermalization process. To study the effect of near infrared on the cell temperature, a KG-3 optical filter was selected; which would cut off the photons above the wavelength of 850 nm. These optical filters were procured from Advanced Optics, Schott Technologies. To check the spectral transmittance of this filter, Analytical Spectral Radiometer was used. Figure 2 shows the spectra collected with and without this cut-off filter.

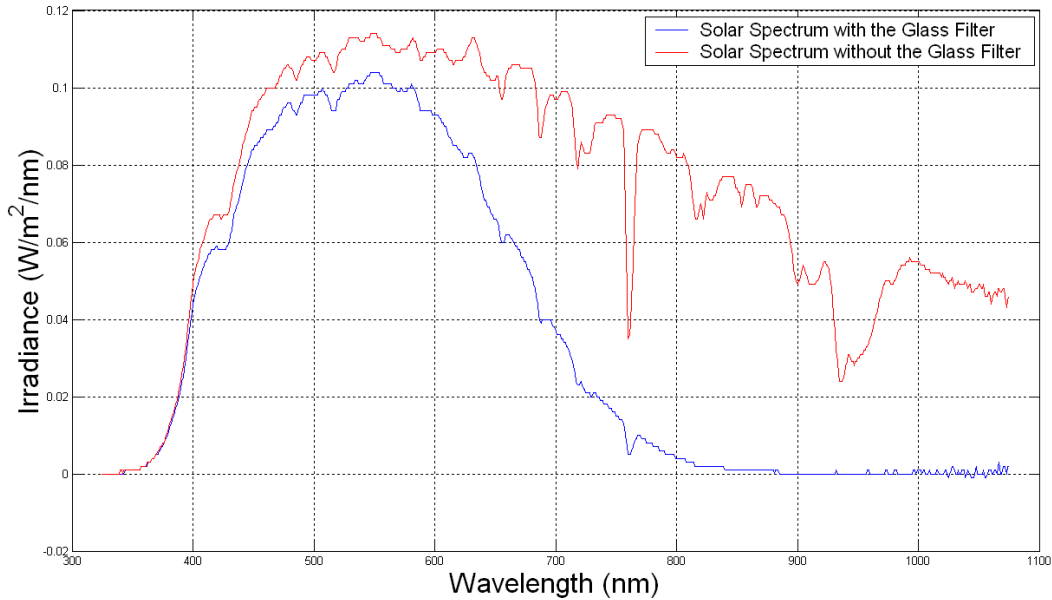


Figure 2: Solar spectrum with and without the KG-3 filter

The groundwork for this study is done. Following this, the filters will be stuck on small PV modules. These modules will be prepared for NOCT by cutting the backsheet and securely taping back two thermocouples. The modules, with and without filters, will then be mounted on the rack for data collection.

The collected data will then be processed to compare the NOCT value of the modules with and without the cut-off filters. The results will be evaluated to see if the low energy photons contribute in increased NOCT or not. If they don't, then the applicability of the use of pyronometer, instead of a reference cell, for the irradiance measurements during the NOCT testing will be investigated.