Data Bulletin

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Proper Application of Panelboards in Solar Arrays

Retain for future use.

Introduction

Panelboards are designed, tested, and certified to meet the requirements of Underwriters Laboratories (UL) 67 Standard for Panelboards, while molded case circuit breakers are required to meet UL 489 Standard for Molded Case Circuit Breakers. These governing standards define the maximum ambient design temperature of the equipment to be 40°C (104°F). Equipment that is certified under these standards must operate properly when tested under laboratory conditions at the ambient temperature ranges defined in them.

Schneider Electric recognizes that in certain applications, such as solar (PV or photo voltaic) fields, the equipment is applied in environmental conditions that are typically more severe than the governing standards that they were designed under. It is the responsibility of the engineer of record to properly select and apply equipment in the field. The purpose of this document is to define the proper considerations to be taken into account for reliable equipment operation.

Background

Panelboards selected for solar applications are typically used as combiner panels versus traditional distribution panelboards. Under worst case environmental conditions, solar applications can create performance requirements near or above the upper limit of the test parameters defined for UL certification. Panelboards used for solar applications are typically installed outdoors in an open field, in direct sunlight. During peak daylight, the panelboard is subject to peak solar incident radiation, while at the same time receiving peak electrical generation coming from the solar field. This can cause circuit breakers to see environmental conditions that exceed their design limits, resulting in unwanted tripping events.

Application Recommendations

Circuit Breaker Current Carrying Capacity for Environmental Conditions Such as Outdoor Temperature and Altitude

In alignment with normal installation conditions, UL Standard 489 requires that molded case circuit breakers are designed, built, and calibrated for use on 60 Hz AC systems in a 40°C (104°F) ambient temperature. Time/current characteristic trip curves are drawn from actual test data that meets UL 489 testing requirements.

Circuit breakers can be applied in ambient temperatures up to a maximum 60°C. When applied at ambient temperatures above 40°C (104°F) and less than 60°C (140°F), at frequencies other than 60 Hz, on DC systems, or in other extreme conditions, the performance characteristics of the circuit breaker may be affected. In these cases, the current carrying capacity and/or trip characteristics of the circuit breaker may vary. Please review Schneider Electric Data Bulletin 0100DB0101 to learn how to correctly apply circuit breakers under these special conditions.

When considering the total ambient temperature that a circuit breaker in a panelboard is exposed to, the consulting engineer should consider the worst case outside ambient temperature expected in the region, during peak times in summer months. Additionally, all panelboards will have heat generated inside from the internal components. While the internal ambient temperature rise will vary from configuration to configuration, a good rule of thumb is to assume an internal ambient temperature rise of 15°C (27°F) above outdoor ambient in the areas surrounding the circuit breakers, due to internal heat generation alone.

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Enclosure Color

The temperature rise above the outdoor ambient on the inside of an outdoor electrical enclosure is caused by heat dissipation of the internal components, as well as absorption of solar incident radiation. There are design recommendations that can be employed to minimize the effect of solar radiation. One of the simplest approaches is the external color selection of the enclosure.

IEEE standard C37.24 (IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear) highlights the importance of proper color selection, and how it can be beneficial to equipment performance.

Table B.1: IEEE C37.24

Paint Color	Approximate Solar Radiation Absorption Coefficient
White	0.14
Cream	0.25
Yellow	0.30
Light gray, blue, green	0.50
Medium gray, blue, green	0.75
Dark gray, blue green	0.95
Black	0.97

Table B.1 of IEEE C37.24 lists the approximate solar radiation absorption coefficient of typical paint colors. Enclosures painted black were tested to show they can experience a temperature rise of 15°C (27°F) due to solar radiation alone. Using the absorption coefficients in table B.1, we can estimate the impact of various colors on the internal temperature rise. The standard exterior color for Schneider Electric NEMA 3R panelboards is ANSI #49 gray. This has been tested to have an absorption coefficient of 0.87. Therefore, by using the data provided in IEEE C37.24, we can calculate the effect of changing a panelboard enclosure from gray to white to be:

Equation 1:

$$\frac{(0.14 - 0.87)}{0.97} \times 15°C = -11.3°C$$

Recommended color for Solar Field Installations is white.

Equation 1 tells us that a white enclosure will have an internal ambient temperature rise of up to 11.3°C less than a gray enclosure, under the same worst case conditions, due to solar absorption alone.

Schneider Electric recommends that all panelboards installed for use in solar field applications be ordered with white paint, and all above ground conduit also be painted white. In the case where there is an existing installation with standard gray exterior paint, often the quickest and simplest improvement is to simply paint the exterior of the enclosure a flat white color.

Typical Lighting Panelboard Construction

The National Electrical Code® (NEC®) 2008 edition no longer distinguishes between lighting and appliance panelboards and power panelboards. In prior NEC editions, panelboards were required to have no more than 42 overcurrent protective devices (OCPDs) when used for lighting and appliance branch circuits (as defined in the 2008 NEC edition). Please review Schneider Electric Data Bulletin 1600DS0701 for more information on the definition of a lighting and appliance panelboard.

For the purposes of this document, a lighting and appliance panelboard is one that utilizes a "bus" and "stab" construction. These connections are often optimized for the installation of numerous lighting loads (which are typically lower amperage). This typical construction is shown in Figure 1. In this type of construction, circuit breakers can be mounted on either side of the panelboard. The circuit breakers attach to stab connectors (shown in red) which are bolted to the panelboard bus bars (shown in orange). Each stab connector has 2 circuit breakers attached to it, so it carries the load of both circuit breakers.

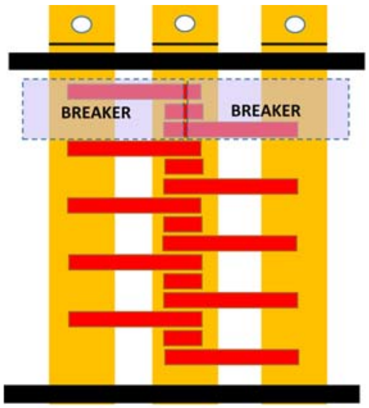

Figure 1:
Typical construction for a 30 circuit lighting and appliance panelboard.

Most panelboards utilizing this type of construction will have limitations on the maximum combined rating of 2 circuit breakers that can be installed across from one another on the same set of stab connectors. This limitation is documented on a wiring label that is affixed to the panelboard (usually behind the deadfront). When installing circuit breakers into a panelboard, the installer must review the limitations documented on the wiring label so they are not exceeded. These limitations are defined during testing when a panelboard is certified to UL Standard 67.

Figure 2a: Main Lugs

Max Breaker	Max Breaker
Min Breaker	Min Breaker
Min Breaker	Min Breaker
Min Breaker	Min Breaker
Min Breaker	Min Breaker

Typical UL67 breaker layout for certification testing of a panelboard.

UL Standard 67 defines the certification requirements for all panelboards. In UL67, it states that for temperature rise certification, a panelboard is to be certified by testing the largest branch breaker pair combination in the highest position in the panelboard, with the remaining spaces to be fully filled with breakers of the minimum handle rating required to load the rest of the panelboard to full load. See Figure 2a for a layout of a typical panelboard certification test.

Figure 2b: Main Lugs

Max Breaker	Max Breaker
Max Breaker	Max Breaker
Blank	Max Breaker
Blank	Blank
Blank	Blank

Not Recommended breaker layout for solar array applications.

In typical solar applications, where a panelboard is used as a combiner panel, often a panelboard only has the largest possible branch breakers installed, which often leads to a more severe loading condition than that under which the panelboard was tested. This is further exacerbated when all of the largest amperage breakers are grouped together on the top or one side of a panelboard. See Figure 2b and 2c for **not** recommended breaker layouts.

Figure 2c: Main Lugs

Max Breaker	Blank
Max Breaker	Blank
Max Breaker	Blank
Max Breaker	Blank
Max Breaker	Blank

Not Recommended breaker layout for solar array applications.

In order to reduce the ambient temperature surrounding each breaker, Schneider Electric recommends spacing out the circuit breaker placement throughout the panelboard with blank spaces between circuit breakers. Depending on the circuit breakers required, this may drive the panelboard to a larger circuit count, which may require a taller enclosure, which all helps to reduce the ambient temperature around each circuit breaker.

For lighting and appliance panelboards utilizing the construction depicted in Figure 1, where two circuit breakers may share stab connectors, this configuration is the most beneficial. See Figure 3 for a recommended typical circuit breaker placement scheme for a panelboard of this type, used in a solar array.

Figure 3: Main Lugs

Breaker	Blank
Blank	Breaker
Breaker	Blank
Blank	Breaker
Breaker	Blank

Recommended breaker layout for solar array applications for panelboards with bolted stab connectors.

Remote Main Electronic Trip Circuit Breakers or Remote Switches

When a panelboard is installed with an integral main circuit breaker, that circuit breaker adds to the overall heat generation inside of the enclosure, which results in an elevated ambient temperature around the smaller circuit breakers. This contributing heat generation can be removed with a remote mounted main circuit breaker that is in a separate enclosure next to the panelboard. Additionally, the trip units on Square D electronic trip circuit breakers are ambient insensitive from 14°F to 140°F (-10°C to 60°C).

Schneider Electric recommends that outdoor solar array panelboard installations be configured with remote mounted main circuit breakers with electronic trip units, or remote mounted switches, when needed.

NEC Article 690

Article 690 of the National Electric Code (NEC 2017) provides the minimum acceptable requirements for solar photovoltaic (PV) systems.

Article 690 requires that the maximum current in a circuit be rated at 125% of the rating of the PV modules connected to it. The 125-percent factor is required because PV modules can deliver output currents higher than the rated full load currents for more than 3 hours near solar noon. This coincides with UL's continuous rating of circuit breakers to be that of 80% of its handle rating when used in equipment. For example, an 80A load would require protection by a 100A circuit breaker. 80A x 125% = 100A.

For panelboards with bolted stab connectors, Schneider Electric recommends the same 125% correction factor be applied when selecting the mains rating of a panelboard installed in a solar array system.

For example, for a panelboard with (4) 100A circuit breakers installed, the typical mains rating selected would be 400A. When used as a combiner panel in a solar array, Schneider Electric would recommend a panelboard rated at 500A or larger be selected (400A x 125% = 500A).

While panelboards are tested and rated for continuous operation at 100% of their mains rating, it should be noted that certification is done in laboratory conditions, without the additional effects of solar absorption taken into account. By upsizing the panelboard in this manner, this will provide additional margin so that the installed panelboard is well capable of providing proper operation in all climate conditions during times of peak load.

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