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Rail Span Considerations

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Residential PV Rail Spans:

How to ensure long-term performance and structural integrity from roof to array

- **Roof load concentrations and module deflection are important considerations for determining maximum rail spans between attachment points.**

- **PV installers are liable for roof structure failure or module issues caused by mounting system design decisions, even when designing within mounting system manufacturer guidelines.**

- **The optimum PV mounting system rail span for residential rooftop applications is one which minimizes the number of attachment points, but still safeguards the modules and the roof to which the array is mounted.**

For many PV system designers, maximum achievable rail span is an important performance criterion for a rooftop PV mounting system. They prefer longer spans between attachment points, as this reduces installation labor and the number of roof penetrations required. However, rail spans are limited by multiple design considerations, the most obvious of which are rail and roof attachment strength. Less obvious but **equally important considerations include rail deflection, module deformation, and load concentration.** All of these factors must be analyzed to ensure a structurally sound mounting system and PV array.

Rail deflection and module deformation

Rail deflection in PV mounting systems is the distance a rail is displaced when a load is applied. In Figure 1, the upper diagram represents an idealized rail suspended between two supports. In the lower diagram of Figure 1, a uniform distributed load is applied to the rail along its unsupported length, resulting in a vertical displacement or deflection of the rail at the midpoint of the span.

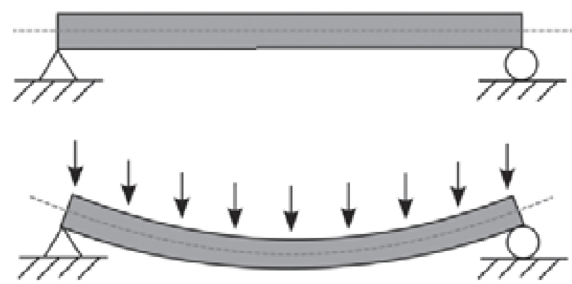

Figure 1

For a given site and rail type, the magnitude of the deflection is proportional to the rail span between supports – longer rail spans result in greater deflection. Typically, mounting systems are designed such that deflection does not compromise the integrity of the rail itself.

The more serious consequence of rail deflection is the potential deformation of PV modules that are attached to the rail. Because the PV modules are fixed solidly to the rail, deflection of the rail itself introduces stress into the modules. This is due to modules being more rigid than the rail, but not necessarily stronger – when the relatively flexible rail deflects, the relatively rigid modules cannot. ***If enough rail span and deflection is allowed, the resulting stresses transferred to the attached modules can result in module damage.*** The types of damage incurred can include micro or macro cracking of cells, bent frames, compromised environmental seals, broken glass, etc. Any such damage is obviously detrimental

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Load concentration and roof structure limitations

Load concentration is another important but often overlooked consideration in PV mounting system design. This concept can be illustrated by analyzing the loads transferred to roof rafters with and without a PV array mounted to the roof.

Figure 2 represents the plan view of a 20-ft by 40-ft rooftop supported by rafters spaced on 2-ft centers. A retrofitted PV array measuring 5.4-ft by 32.7-ft (a single row of 10 60-cell modules in portrait) is also shown mounted to the roof. The PV array is mounted on rails (not shown) supported by roof attachments fixed to rafters every 8-feet.

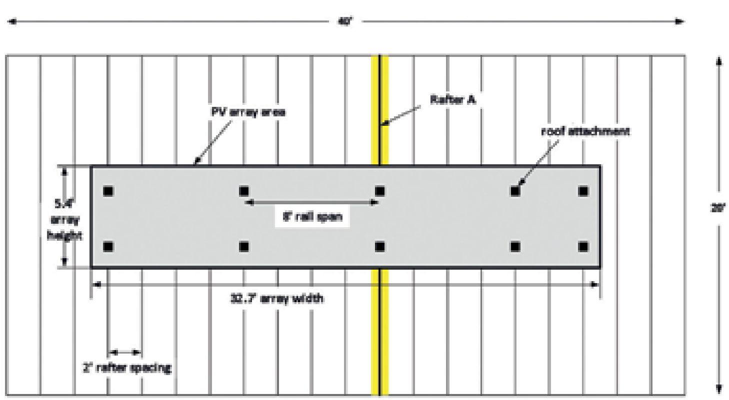

Figure 2

Table 1 presents a simplified analysis of loads transferred to the highlighted Rafter A both with and without the PV array – the loaded area considered is limited to the array area so an equivalent comparison can be made.

Row	Description	Roof Specifications	Roof + Array 8' Span	Roof + Array 16' Span
a	Design roof load (psf)	20	20	20
b	Loaded area height = array height (ft)	5.4	5.4	5.4
c	Loaded area width = rafter or roof attachment spacing (ft)	2	8	16
d	Loaded area (sf) (b x c)	10.8	43.2	86.4
e	Total load transferred to Rafter A (lbs) (a x d)	216	864	1,728
f	Distributed load transferred to Rafter A (lbs/ft) (e ÷ b)	40	160	320

Table 1

In the "Roof Specifications" scenario, the loaded area supported by Rafter A is 2-ft wide (1-ft on either side of the rafter) and 5.4-ft high. As Table 1 shows, if a 20 pound per square foot (psf) design load is assumed for this roof and applied to the array area, the total load transferred to Rafter A is 216 pounds (lbs) or a distributed load of 40-lbs per ft (lbs/ft) of rafter length. This load is effectively the design load that is transferred to Rafter A.

In the "Roof + Array, 8′ Span" scenario, the loaded area is much wider because the design load of 20-psf is now acting on the PV array instead of the roof. In turn, this load is transferred through the rail and concentrated at the roof attachments, which are fixed to the rafters every 8-ft (loaded width of 4-ft on either side of the rafter). Given the same height then, the loaded area increases to 43.2-sf, and the total load transferred to Rafter A is now 864-lbs or 160-lbs/ft. This is 400% more than the original design load transferred to Rafter A. Note that in our example, load transferred to the rafter is linearly related to the loaded width. Taken to an extreme as in the "Roof + Array 16′ Span" (not illustrated in Figure 2) scenario, a rail span of 16-ft would result in loads on the rafter 800% more than the original design load, while eliminating the need for only two roof attachments.

Note that actual site conditions, rafter dimensions, rafter materials, code-driven safety factors and other considerations not included in this simplified example mean that some load concentration due to retrofitted PV mounting systems is allowable without risk of damage to rafters. However, it should be clear that longer rail spans increase the risk of overloading roof rafters, and consideration of load concentration vs. roof structure must be made, especially if long rail spans are desired.

Mounting System Rail Span and Installer Liability

PV system integrators who rely on mounting system manufacturer guidelines to determine maximum allowable rail spans may be putting themselves at financial risk for future structural or module failures. Mounting system manufacturer warranties do not cover potential building structure or module damage resulting from their rail span guidelines. Therefore it is the installer's responsibility to ensure that their mounting system designs do not introduce excessive loads into mounted modules or underlying building structures.

The optimum PV mounting system rail span for residential rooftop applications is one which minimizes the number of attachment points, but still safeguards the modules and the roof to which the array is mounted. Maximum achievable rail span should not be the sole factor in mounting system selection and design. Rather, achievable rail spans should be balanced against rail deflection and its effect on modules, as well as possible structural issues resulting from load concentration.

The Mounting Systems Alpha+ system has been designed to provide a highly cost-effective balance of rail strength and span capability. Foremost in Mounting Systems' approach to system design are module protection and structural safety.

The Mounting Systems Quick Configurator design tool incorporates calculations that maximize the safe spanning distance for both long-term module reliability and the structural integrity of the roof.

Installers can be assured that the combination of the Alpha+ rails and the Mounting Systems Quick Configurator will be safe, secure, durable and risk-free.

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