pv magazine

PHOTOVOLTAIC MARKETS & TECHNOLOGY

In Conversation

Thought Leaders from across the industry share their views on the latest developments and where solar is headed.

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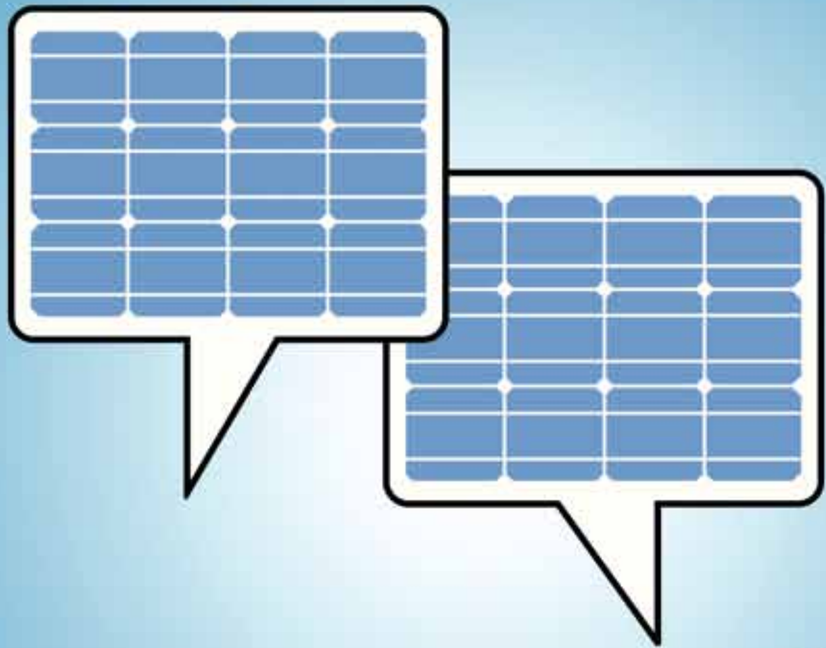

Strings to the bow

Next generation string inverter concepts add firepower.

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The caterpillar

The solar industry is still debating the extent to which this problem, whereby temperature-related expansions and contractions cause an installed system to move gradually across a rooftop, actually occurs in flat-roof PV systems, and what a practical remedy might look like.

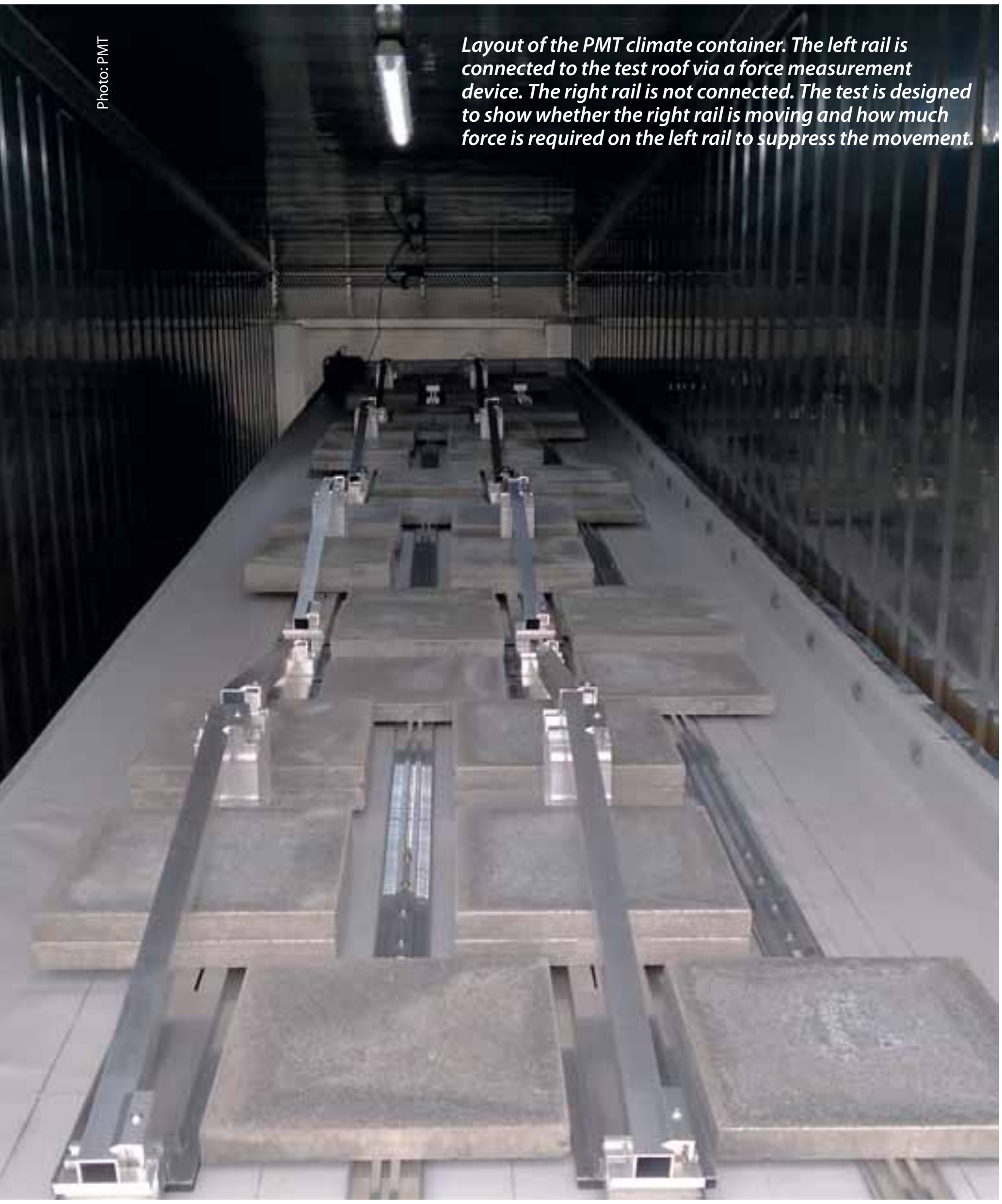

Photo: PMT

Layout of the PMT climate container. The left rail is connected to the test roof via a force measurement device. The right rail is not connected. The test is designed to show whether the right rail is moving and how much force is required on the left rail to suppress the movement.

For half the days in April, Peter Grass had to dress warmly. Every morning and evening for four weeks, the Managing Director of Premium Mounting Technologies (PMT) walked into the new 40 foot container he had set up on the company grounds. He took readings, and switched the climate in the container from summer to winter and back again. “We set the container to -30, 0, and +30°C every 12 hours,” he says. He did this to measure how his PMT Evolution flat-roof mounting system and the PMT Flat Direct roof-parallel system behave when subjected to alternating hot and cold temperatures, just as they are in real-world conditions but on a somewhat accelerated cycle, so that the effects become visible more quickly.

The industry has been aware of the problem for a year and a half, but that it’s largely talk over action, Grass believes. He wanted to finally get some clarity about how his system behaved on a slightly inclined roof, as the mountings expand and contract with fluctuations in temperature. In theory, each fluctuation causes the system to inch its way, like a caterpillar, a few millimeters closer to the abyss.

His reason for taking action was an inquiry from a large corporate group with numerous locations throughout Europe. It had already installed PV plants with systems from another manufacturer and, after some installations had shifted, it feared for its rooftops.

The caterpillar effect is also an issue in the construction division of the German trade association BSW Solar. Its members, BayWa r.e. Solar Energy Systems (SES),

effect

Goldbeck Solar, IBC Solar, Mounting Systems, PMT, and Schletter are discussing solutions for fixing arrays in position, says Martin Schäfer, Deputy Working Group Leader at BSW and Product Manager for mounting systems at Baywa r.e. SES: "We are working on an information sheet."

When rules were introduced in Europe stipulating a minimum pitch of two degrees for flat roofs, it became clear that this issue was not going away. This means that all new roofs will have some degree of pitch.

Like a hanging car?

"We've never seen a problem with the caterpillar effect," says Peter Grass, "but now the customer has asked us to officially certify a large number of roofs with a 3.5 degree pitch." In theory, you could keep the system in place by simply attaching it to a fixing point in the roof, but the customer did not want more than ten connection points. If you work out the effective forces based on the theory, these connections would have to be designed so that each of them could withstand seven kilonewtons – meaning you could hang a small car from it. Such strong anchors are extremely complex, since such a force can usually not be directed into the roof. "I have seen designs in which pipes the size of an arm pass down to the supporting structure" says Grass. The PV system then has to be designed around possible anchor points in the roof. He could not believe that this was the solution, "despite the fact that we have never seen any movement in an array!"

That is why Grass started measuring. He had the test setup monitored and evaluated by Knörnschild Engineering Office. In the container he had a 1.73 meter wide test roof built with a 7.5 degree pitch. He then installed the PMT Evolution mounting system with two parallel rails. In the direction of the roof pitch, the system was 8.6 meters long. He fixed one of the two rails, while the other remained free, in order to measure its movement, and installed a newton meter at the anchor to measure the force at that point.

If an 8.6 meter long aluminum rail is heated from -30 to +30°C, its length theoretically changes by 6.5 mm, due to thermal expansion. Based on this consideration, it follows that in this case a compressive force of four kilonewtons would be necessary to compress the rail by the same 6.5 millimeters. In theory, this compressive force is applied by the static friction of the rail against the building protection mat and on the roof. Only when the compressive force exceeds the force with which the system adheres to the roof by friction does the system start to move and the caterpillar effect occur. If the array is secured by a fixing system, the theory says that the force must be counteracted by the fixing device.

Actual forces

Measurements quickly refuted this theory. The first surprise was that the rail only expanded by 1.5 millimeters. The second surprise was that a force of only 0.4 kilonewtons, or one tenth of the force initially calculated, occurred where the test system

"The industry has been aware of the problem for a year and a half, but is mainly just discussing it"

was anchored in the climate container. Since there are many influencing factors, Grass ran tests on numerous setups during the four week experiment: with heavy ballast, with little ballast, with low friction Teflon-coated base rails, and with systems in east-west and north-south orientations. Consistently, the results demonstrated that the actual force on the connection was about a factor of 10 less than calculated according to the theoretical assumptions. Even the right rail, which was not anchored to the roof, never moved.

Grass explains the result by pointing out that the system is flexible. The rails are constructed from several 1.88 meter long segments with click connections. Due to the spring effect of the connections, the expansion is a factor of five less than predicted. In addition, the 11 mm thick polyethylene protective mat, which is glued to the system prior to delivery, can absorb part of the movement. “This protective mat has a higher elasticity than the conventional stiff building protection mat,” he says. He introduced it about two and a half years ago. “It stays in the same position even if the rail on top of it moves 1.5 millimeters.”

This, Grass believes, should put minds at ease and eliminate the need for fixing the array to the roof. But the situation is not quite that simple. “The wind load itself, blowing effects of the roof membrane, or strong vibrations in the building can accelerate the caterpillar effect,” notes Grass. These effects are difficult to measure, so he recommends anchor points under certain conditions. Systems can be installed on roofs with pitches of up to 2.5 degrees without the need for any fixing system.

For roofs with a pitch of 2.5 to 5 degrees, he recommends fixing hardware which he designed based on sample static loads representing the worst case. Since the test showed that actual incident forces are lower than previously feared, the connection to the roof can be made using a standardized component without the complicated step of opening up the roof. This is done by sinking self-tapping screws from above through the insulation into the corrugated sheet metal roof below and then sealing it with generously overlapping layers. “Like the PMT mounting system, the anchor point itself is approved by building authorities,” says Grass. He is pleased to have found a solution that enables a skilled installer to fix the array to the roof and can be used flexibly on a variety of roofs without extensive static testing. For pitch angles of five degrees or more, he would conduct a detailed analysis of both the mounting system and the roof. In any case, customers are satisfied with his conclusions and he now has several dozen orders.


Photo: Baywa r.e.

Such connections can protect against the caterpillar effect. However, the question is how they should be dimensioned. The product in the picture can withstand up to six kilonewtons, but it undergoes deformation at 0.5 kilonewtons.

Trials at Baywa r.e.

Martin Schäfer of Baywa r.e. SES also initiated a field test at an actual plant this winter. Via four anchor points in the roof, he connected a 100 kW system on a roof with a pitch of 3.5 degrees.

To determine the dimensions of the fixing elements, Schäfer now primarily wants to determine the force acting on the fixing points in response to temperature fluctuations.

To do this, he connected eight cables via force gauges to the four connection points, and pre-tensioned them at different forces, from 5 to 15 kilograms. At the end of May, after seven and a half months of testing, the force values were read again, in addition to the minimum and maximum forces occurring during the period. The maximum force was insignificant at all of the connections, regardless of the degree of pre-tensioning – perhaps just a few kilograms higher than the preset tension.

Martin Schäfer inferred from this that no significant additional forces were involved. This is not the only reason that Schäfer doubts the accuracy of the theoretical calculation, which is based on the tensile force of thermal expansion. He has his own theory: As long as the static friction is greater than the compressive force resulting from temperature effects, no additional force is applied to the fixing point. If the static friction is exceeded, the system can move if not held down, according to his estimation. In that case, the only forces that occur are those which the system has on the inclined roof plane due to its weight, as if the array were on rollers. Only at the transition – the exact point at which the static friction is overcome – could maximum forces at the level of the compressive force occur. "These were compensated for by the springs of the tension gauges used to connect the systems," he says. With this in mind, it may well be a sensible solution in the future to connect systems with springs. Systems can also be left to "float" if the temperature-induced expansion in the direction of the roof ridge becomes too great. It is therefore also essential to pay attention to the length of the continuous rails in that direction.

Always anchor points

Calculated in this way, Schäfer arrives at similar dimensions for the fixing system as Peter Grass. Despite the positive test results, Schäfer recommends that all systems be connected to the roof. "In my view, based on the theoretical model, the roof pitch is not decisive for whether the system will move, but only how fast it will move," he says. At the same time, he is aware that the extra effort of fixing arrays to the roof is one that nobody is keen to make.

It is also important to be aware that a shifting array is not immediately noticeable, as the effects can also be small. "They are often only discovered when leaks occur in the roof seal," says Schäfer. The mounting rails rub against the roof projections, the skylight, or ventilation pipes.

The important thing, says Schäfer, is that the fixing system for the PV array is not

"The extra effort of fixing arrays to the roof is one that nobody is keen to make"