Photo: Enerparc

For testing purposes, EPC Enerparc installed 7 MW out of 20 MW in a solar farm using the X-Modul design. The installation also solved problems related to a blinding assessment for parts of the plant located near a highway.

Cornering the market

Module mounting: A new mounting technique could change the appearance of solar farms and rooftop systems over the long term. Tilting solar panels by 10 to 45 degrees is said to greatly improve their self-cleaning properties and enable completely new array designs. Two major project engineering companies are already testing the concept and have confirmed its numerous benefits.

As an inventor of new PV technologies, Mirko Dudas has one overriding concern: reducing the production cost of electricity. He expects one of his latest ideas – an alternative method of mounting solar panels – to make this possible. At the same time, it may bring lasting changes to how solar farms and large rooftop systems look.

The concept: Instead of installing framed solar panels vertically or horizontally, they are mounted at an angle of 10 - 45 degrees from the vertical. Dudas says that this significantly improves module self-cleaning. Because rainwater flows down two sloping module edges, it is nearly impossible for dust and grit to build up. Unlike conventional installations where water and dirt accumulate on the lower edge of the frame, on the tilted panels there are no dirty edges, which can increase over time and cause the output of the panels to drop, says the inventor.

Dudas is convinced that his idea is a good one and the first products to implement the concept are already on the market. "This makes possible new system designs capable of optimizing efficiency," says Dudas. "For example, plant engineers can choose a lower angle of inclination for the panels to reduce shading losses and the distance between module rows to fit more capacity into a given area." In a case study for a solar farm on 2.5 hectares (25,000 m^2) of land near Leipzig, Dudas reckons that with his X-Modul ground mounting system, some 25% more peak capacity can fit into an area. This corresponds to approximately an 18% increase in annual solar power yield compared with the conventional design.

A partner to market maturity

Dudas has secured international patent protection for the concept with his company Solid Energy. Part of his business model involves developing new ideas together with partner companies and then granting them licensing rights for a fee. From the downward-pointing-corner idea, two new products have emerged. In addition to the X-Modul mounting frame for ground-mounted systems, there is also a system called Diamond Roof, which is suitable for both ground-mounted and flat-roof systems. Dudas

brought the X-Modul system to market in partnership with mounting system manufacturer Zimmermann PV-Stahlbau. Zimmermann is currently the sole license holder and sells the system under the name ZM X-Modul. Improved self-cleaning has also been demonstrated in practice, says Zimmermann General Director Holger Krug. "We have a sample rack, for instance, with modules that were previously mounted in the conventional way and had a distinct dirty edge. After we installed the modules with the X-Modul method, the dirty edge disappeared within a few weeks. The fact that rain water always flows along the edge of the module frame, means no dirt builds up." This effect occurs at very shallow angles of inclination of the mounting rack, starting at about eight degrees. As for inclination and module alignment, the ZM X-Modul system is available in a broad range of configurations.

Initial field experience

Edgar Gimbel is convinced of the self-cleaning effect. He is the head of design at the system provider and project developer Baywa r.e. In March 2016, he built an X-Modul test rack in an otherwise conventional solar farm. The improved self-cleaning he observed encouraged him to go even further. At the beginning of 2017, he finished the first complete solar farm with 5 MW of capacity and X-Modul construction in England. But he did not change the inclination angle of the modules in the farm. "We expect higher yields by reducing the amount of dirt build-up alone. And also due to the fact that with the X-Modul, much more snow slides off the panels at the same module angle. " This makes Gimbel optimistic about the future of the tilted mounting system. "If you go further north than our farm in England, we would have to take a careful second look. But I think that X-Modul makes sense for most of the projects we are building."

Another engineer convinced by the concept of tilted mounting, is Armin Scherl of the EPC Enerparc. "For us, the concept is attractive because today we are concerned with getting more capacity than we used to within the same area. The reason is that the cost for solar keeps going down but the cost of land remains the same. That is why Enerparc has been reducing module inclination and row spacing. As far as the module angle, 20° has been the magic number up to now."

Blinding assessment benefits

For test purposes, Enerparc has installed around 7 of a total of 20 MW using the X-Modul design in a solar farm in the town of Parsberg, Germany. "Originally, we wanted a smaller test area," says Scherl. But the plant is located near a highway, and several sections of the farm north of the highway could have blinded drivers had they been installed at an inclination of 20°, according to an assessment. "We then redesigned those parts of the array with an inclination angle of 12°. After that, there were no more problems with the blinding assessment. That is why we ultimately opted for a larger test field."

What is being tested in Parsberg is only how the lower inclination angle of just 12° will impact overall yield. Enerparc has not yet reduced row spacing to increase the use of the available area in this project. "We need a certain row spacing to build and maintain the farm, enough to drive a front-end loader between the rows. That's why we usually plan a 2.2 meter distance from module edge to module edge. That gives us our calculated optimum yield at an inclination of 12°. At a row spacing of 1.5 meters, the optimal calculated angle is 8°," says Scherl. However, he makes sure to add, that is not currently possible.

Efficiency factors

To weigh the advantages and disadvantages of X-Modul on annual yield, planners have to take a number of factors into account. On the one hand, the difficulty involved in installation and maintenance comes into play. Edgar Gimbel of Baywa r.e. sees no particular difficulty in installation. Armin Scherl of Enerparc believes that there are both advantages and disadvantages that balance each other out. "The diagonal installation is a bit more complicated, because it requires a different handling technique. But the lower angle of inclination makes the rack flatter overall." The result, he says, is that no mobile work platform is needed for the installation and wiring of the uppermost of the six module rows. "With X-Modul we managed to reach the top row with a simple ladder and sometimes even just standing." The flatter rack, however, results in a larger area of grass under the rows of modules that has to be mowed regularly by hand.

Changing the module rack's angle of inclination the way Enerparc did in its Parsberg solar farm raises a further question. Does the increase in yield from lower shading losses outweigh the loss to yield due to the less-optimal irradiation angle? Armin Scherl thinks so. With an identical surface utilization Enerparc expects a total of around 3% increase in yield based on its calculations. Scherl explains his estimate: "If we reduce the shading by 6%, for example, and yield lost to the lower inclination angle is only 3%, we still have a gain of 3%."

Other drawbacks can be compensated for similarly, such as lower yields resulting from the fact that, despite the X-Modul design, snow clings to modules at a 12° angle longer than it does when a 20° angle is used. Thus, the detailed planning is a balancing act to find the optimum. But both Enerparc and Baywa r.e.

Photo: Zimmermann PV-Stahlbau

A downward-pointing corner prevents dirt collecting along the frame, and the residue at the bottom corner is reported to be significantly less.

Photo: Zimmermann PV-Stahlbau

Even snow slides noticeably better off of modules tilted to one side without the need to change the inclination angle.

think that ultimately they can reap benefits from the system. "We won't know for sure until they have been in operation for a year, but even before that it might be possible to draw some conclusions," says Scherl. A detailed analysis is scheduled to start in May or June 2017. "If the expectations are confirmed, we can then potentially decide to build more projects."

Three-dimensional version for ground-mounted and flat roofs coming soon

While X-Modul is already in use in the first PV plants, another of Dudas's systems is still waiting to be put to real-world use. The so-called Diamond Roof is also based on a tilted panel-mounting system with one corner of the module pointing downwards and suitable for flat roofs as well as for ground-mounted installation. But the modules are laid out differently than those in the X-Modul system – more like an east-west system, but a bit different. Four modules are connected to form a unit, in which each module is aligned with one corner pointing downwards (see figure p. 37). Again, for the inventor Dudas, the key consideration is making sure the often expensive and scarce roof or ground space is utilized as well as possible.

The characteristics of the system are similar to the X-Modul, that is, better self-cleaning, minimal shading, and potentially better use of space.

But the arrangement of the modules has other benefits as well, says Dudas. First, he says, the system can be "installed without a compass." That means that no matter which way you rotate such a quad unit, it always produces the same annual yield. He says that this orientation also results in a flatter yield curve than a direct southern exposure. This makes particularly good sense for systems generating power for on-site use and, like east-west systems, lower-capacity inverters can be used. In addition, says Dudas, wind tunnel testing has demonstrated particularly good aerodynamics with reduced wind-suction coefficients. In ground-mounted systems, the values are 50 - 70% better than with conventional south-facing panels.

On the same site near Leipzig, where Dudas calculated around 18% more energy yield with the X-Modul installation, he calculates that the Diamond Roof system would result in an approximately 83% increase in yield. To achieve that, modules with slightly more than twice the peak capacity of a conventional 20° south-facing installation would have to be installed on the same site. But this approach, too, raises the question of whether there is a positive cost-benefit ratio. "That depends on where the plant is built," says Dudas. In the Gobi Desert PV plants will certainly continue to be built with steeply-inclined modules and large distances between the module rows, he says. "But where land is expensive and labor costs are high, cost calculations quickly show improved electricity generation costs on sites that are properly packed with modules."

Doubling up on land use

The company MKG Montagebau Karl Göbel is supporting Dudas in the development of the Diamond Roof system and is a licensee of the ground-mounted variant of Diamond Roof. For MKG the potential for higher land use is not the only reason to opt for Diamond Roof, says Marco Göbel, the Technical Director at MKG. "For us, there is a particular focus on a potential double use of the land. Globally, there has been a sharp decline in available land. It can thus make ecological and economic sense to make use of the area under the PV system as well."

With Diamond Roof, MKG wants to increase the overall height of the array to two meters or more. At that height, it would be easy to use the land underneath the power plant to raise livestock or crops.

The array could also be used as a form of hail protection. "Some farmers spend

a lot of money for extra anti-hail installations. Diamond Roof could act as a self-amortizing hail protection system."

However, Göbel also sees some challenges with the system. "The frame and installation costs are higher than for conventional project racks." Exactly how much higher is still unclear. But assembly at a height of about two meters on inclined surfaces tilted in four different directions is not quite as easy as installing panels on a standard mounting rack. "You have to expect to spend a few percent more on installation costs." But if the mounting technique can be continuously refined, the extra costs could be brought back into check.

Even on hilly terrain, the three-dimensionality of the system is a challenge, says Göbel. "If you make one angle steeper, another one is automatically shallower." That, he says, would have to be taken into account in sloping terrain. Solutions for this could be building either stairs or terraces, or adjusting all of the angles according to the terrain. Ultimately, the best approach will depend on the individual case.

Photo: Solidenergie

The Diamond Roof solution features modules with one corner pointing downwards. It can be used to fill scarce space at a very high density.

The PV system of tomorrow

Mirko Dudas's ideas for tilted panel mounting could result in major changes to the way PV systems look. He believes that the land-utilization efficiency for PV systems will approach 100%. As such, the inclination angle of mounted panels will become increasingly shallow. "With X-Modul and Diamond Roof we have two suggestions on how to achieve this." He has already registered three more patents in 2016, all of which deal with the subject of geometry. "We will try to create a new impetus with these as well." ◆ Mirco Sieg