Installing solar on water opens up huge new possibilities for the technology

Credit: Seaflex

Unlocking solar's new terawatt opportunity

Floating PV | Floating solar has caught the industry's imagination in recent years, opening up potentially limitless new opportunities for PV installations in land-constrained parts of the world. Ben Willis reports on the work underway to address questions about the performance and reliability of water-based solar installations

From ground zero in 2007, the total capacity of floating solar installations worldwide had grown to around 1.3GW by the end of 2018, according to recent analysis by the Solar Energy Institute of Singapore (SERIS) for the World Bank. That's a solid start for an emerging market segment that many hope will become the 'third pillar' of the PV industry, alongside ground-mount and rooftop solar. Around the world, there are some 400,000 square kilometres of manmade reservoirs alone; if just a fraction of these bodies of water were to become home to floating PV arrays, all of a sudden a key constraint that has prevented many regions of the world from embracing solar – namely, land, or lack of it – would become irrelevant, cracking the technology and its many benefits wide open to a host of new users.

Unsurprisingly, interest in floating PV is strong and growing, observes SERIS director, Dr Thomas Reindl, but plenty of obstacles still stand in the way of its full potential being realised.

"What we have witnessed recently, is a strong interest from governments and private actors to develop floating solar projects across multiple regions. Such projects are no longer focused on Asia, but projects are being considered and constructed in Europe, America and to a lesser extent in Africa. The Middle East has also shown a recent interest in the technology, where water evaporation losses are significant. Another recent development is the announcement from various consortia or governments to start research and piloting projects in seawater," Reindl says.

"Many actors across the public and private sector, however, agree that there is a lack of data about the existing projects (confidentiality is often an issue). If solved, data could help to understand better the cooling effect in various climates, leading to improved modelling of the energy yield and thus cash flows."

Better data on the performance benefits of floating solar is certainly one key factor that would help it live up to its promise. Yet, as a still-nascent market segment, the reality is that floating PV faces numerous other challenges – technical, operational, financial – that it must overcome on the road to mass deployment. With the extensive experience and knowledge the solar industry has collectively amassed in becoming a plus-500GW global market, the good news is that none of these should be seen as insurmountable. This article explores some of the efforts underway to help floating solar live up to its considerable potential.

Hardware

Modules

According to SERIS' report for the World Bank, there are no particular standards for modules deployed in floating solar projects, and the most commonly used are framed glass-glass modules, which withstand moisture ingress comparatively well. Frameless modules have also been used in some projects to date, as these offer the best resistance to potential-induced degradation (PID) in high humidity situations.

PID, a problem that has afflicted ground-mount solar installations in particular, is something of an unknown where floating solar is concerned. Humidity is one factor that increases the likelihood of PID in land-based installs; the probability of humidity being higher around water implies it may be problematic for floating arrays. But the jury is out on this, says Reindl.

"PID is a known issue for several large PV farms, and could cause severe setback in terms of project profitability. Given the higher humidity on water, it could be a pitfall, but there are no reports on that happening yet. FPV systems in Singapore's Tengeh test-bed [operated by SERIS] are being closely monitored for PID issues. Theoretical calculations suggest that the PID stress is not much more severe than those specified in standards IEC 62804-1, so modules are expected to perform well if they are properly certified as PID-free," he explains.

Floats

Another critical area where more work is required concerns arguably the key components in a floating PV installation – the floating structures themselves. Currently, a number of companies are producing floats for solar arrays, following two main generic design types (see Table 1 and Figures 1&2) but as a comparatively new technology, without a long track record in the field, the SERIS report lists floats as a possible technology risk that must be addressed through more rigorous testing and certification to prove their durability.

"Standards create methods to measure a specific property that can be related to another difficult-to-measure property that is a quality or performance indicator," says Reindl. "For example, the thermal cycling stress test for modules will indicate that limited degradation of the performance of a module after a specific number of thermal cycles will probably indicate this module can last longer than 20 years under normal circumstances. Whoever does this test, the chances are high they get comparable results.

"This we also need for floats: standard reproducible measurements that can be related to a quality or performance parameter, so I can measure and say objectively float A is better for this measurement than float B. If these parameters are well selected it will create a trend in the industry to focus on these parameters and create better and better floats."

Mounting

A further consideration in the design of floating solar arrays concerns the tilt angle of modules. Typically, modules in a floating array are set at a limited tilt to reduce problems associated with wind loading. This can have implications for achieving the best energy yields from floating installations, particularly in high-latitude regions where a generally steeper tilt angle is optimal to maximise exposure to the sun.

Shankar G. Sridhara, CTO at REC Group,

Mounting type	Advantages	Disadvantages
Pure-float configurations These use specially designed buoyant bodies to support PV panels directly (Figure 1).	-Easy to assemble and install -Can be scaled without major changes in design -Few metal parts required, minimising corrosion -Adapts to wave motion and relieves stress	-Modules mounted very close to water, reducing air circulation and cooling effect from evaporation. It also generates a high-humidity environment for PV modules and cables -Not cost-effective to transport pure floats over long distances, so they may need to be made in nearby facilities -Constant movement may cause stress and fatigue to joints and connectors
Pontoons + metal frames These use metal structures (frames or trusses) to support PV panels as with land-based systems. The structures are attahed to pontoons, which provide buoyancy; special floats are not required (Figure 2).	-Simple concept -Floats are easy to make and can be easily sourced locally -Wave movement between PV modules is less variable, thus reducing wear and tear on module connection components and wires.	-With more rigid structures, waves cause stress to concentrate at certain points -Structures are more difficult to assemble -Access for maintenance can be difficult in certain designs

Table 1. The pros and cons of the two most common flotation designs used in FPV installations. Source: World Bank/SERIS

Credit: SERIS

Figure 1. Ciel et Terre's floating solar mount is an example of the pure-float design

Credit: SERIS

Figure 2. Takiron Engineering is one company producing the pontoon + metal frame variant of the floating solar mounting structure

which has been an early pioneer in developing floating solar technologies, explains: "The angle of module installation on the floating system is often predetermined in its design and may leave little room for adapting to the best angle for local conditions. Other systems may allow a degree of flexibility. This means that the complete project, including installation time, needs to be weighed up against the angle of installation and any associated impact this has on the expected yield and levelised cost of energy."

Performance and operation

According to the SERIS/World Bank study, operation and maintenance (O&M) costs for floating PV arrays should not be inherently higher than for their ground-mounted counterparts. Nevertheless, certain factors particular to floating arrays are likely to come into play where O&M is concerned, necessitating some new skill-sets, techniques and procedures, according to REC's Sridhara.

"O&M is certainly an important factor also when it comes to corrosion, especially in more aggressive coastal environments," he says. "Corrosion can affect combiner boxes, inverters, cables and any other metallic supporting structures. Bird droppings can additionally corrode the glass and frames of the panel, ultimately affecting the performance of the installation – and hence must be cleaned. Aquatic life, such as plants or barnacles, need to be removed from the floating understructure so that they do not weigh down the system."

Michalis Papageorgiou, senior solar engineer at international technical consultancy, DNV GL, takes up the theme on the potential problems caused by aquatic animal and plant life.

"Especially in water bodies with live ecosystems and biodiversity you can't prevent animals from considering the floating solar PV system as part of their aquatic environment, therefore creating shelters or just finding it interesting to walk on, causing minor to major issues," he says.

"Tropical reservoirs and dams may have water weeds growing out and also cause shading to the modules. Further to the shading issues, these can also cause mechanical stress on the floating solar PV structure and mooring systems due to increased weight."

Another potential issue highlighted by Papageorgiou concerns the constant moving of the floating PV structure. This causes problems such as mechanical stress at the joints of the rigid structures, on equipotential bonding tapes and DC/AC wires, and at the earthing tape connection for grounding, as well causing stretching or bending of cables, leading to accelerated degradation and cracking and increasing the risk of fire.

But Papageorgiou adds: "Like all PV projects installed in any surface, issues are not inevitable. [It] is well understood that with appropriate PV component specifications from the very beginning, proper system design, standard operation procedures in place and good O&M practices you minimise at least predicted issues for each floating solar PV component and for the floating solar PV system as a whole."

Finance and bankability

Another of the risk categories for floating solar concerns its bankability and attractiveness to financiers. In simple terms, as alluded to by Reindl at the start of this article, a lack of long-term operational data on the performance of floating solar projects means accessing suitable finance is still far from straightforward for the sector, with the consequence that most floating projects are still being financed "on balance sheets". Some exceptions to this appear to exist; for example, the report cites claims from the Chinese inverter manufacturer, Sungrow, which has also become active in floating solar, that despite the slightly lower return on investment from floating projects, banks are willing to support them because they don't "have a real-estate problem" as ground-mount projects do in some regions.

Nevertheless, finance and bankability are still considerable challenges for this nascent segment, and will require a collective effort across the industry to address, starting with ensuring the reliability and durability of the technologies being deployed.

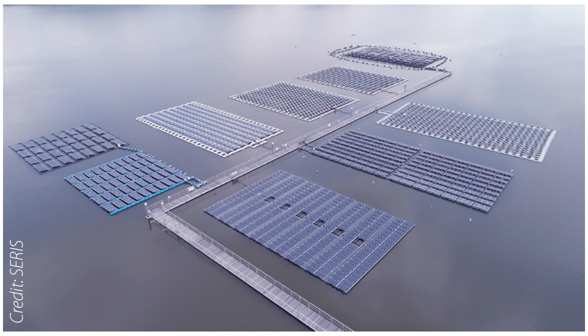
"Reliability equals bankability," says DNV GL's Papageorgiou. "Project financing is the required driver that helps projects to evolve. And project financing from private investors or international financial institutions (IFIs) to owners means that there is a demand from all sides to understand what is the unpredictable in terms of key technical risks.

"In practice we know of course that risks are identified, assessed and managed through key legal, financial and technical review points. Nonetheless, when assessing the investment-worthiness of a floating PV photovoltaic project, different PV stakeholders such as investors, IFIs, insurers and regulatory bodies will evaluate differently the impact and probability of investment risks, depending on their investment goals. Therefore, it is of utmost importance to reduce the risks associated with investments in PV projects. Why? To improve the financeability and attractiveness of these sustainable energy investments. How do we do this? By increasing the trust between the solar industry and investors, IFIs, insurance companies and regulatory bodies. The future of floating PV is still fragile if risks are not predicted and if there is no proven reliability and quality in place."

As with the example of floats explored earlier in this article, the key focus for the industry will be in developing the necessary testing to prove floating solar systems are able to withstand the most likely widely varying environmental conditions they will encounter.

"A site in the tropics may have high humidity and moderately high temperature conditions throughout the year as opposed to another site in Asia where there are sub-zero temperatures where the lake freezes over to minus 20 degrees C," says Papageorgiou. "I believe the floating systems undergoing these stresses will have to evolve to better handle these conditions on water. So there should be clear understanding and tests done to help address this if there is a growing market in these areas."

REC's Sridhara agrees: "I believe the industry plays a crucial role in fulfilling the potential and promise of this segment. Solar panel producers must additionally focus on developing seawater-compliant modules. At the same time, we need reliable and improved understructures to support the installation. In addition, official third-party approval is vital to ensure quality and sustainability: certification protocols and tests should be developed, which address the combination of water quality, module product and floatation understructure."



The testbed on the Tengeh reservoir in Singapore is helping prove the case for new floating solar technologies

Credit: SERIS

The outlook for floating PV

The market potential for floating solar is vast. According to the SERIS/World Bank study, if just 1% of the world's man-made reservoir surfaces were used, global floating solar installations could rapidly reach 400GW – equalling the total installed solar PV capacity worldwide at the end of 2017. Even covering just 10% of every third man-made reservoir in the world would represent potentially a terawatt-scale market opportunity, the report estimates.

The latest indicators certainly point towards rapid growth in the floating solar segment over the coming years, with analysts IHS Markit recently predicting that up to 13GW of new floating capacity will be built by 2023. Whether some of the grander long-term ambitions for floating solar come to fruition remains to be seen.

What is clear, though, is that the underlying drivers for this nascent market segment – rising demand for clean energy, pressures on land – are only going to get stronger as time passes. Floating solar is very much a work in progress, a relatively immature set of technologies that still has much to prove on cost, performance and reliability. But as the growth curve of solar generally over the past decade has demonstrated, this is an industry with an enormous capacity for innovation. Only a fool would bet against floating solar following a similarly rapid upward trajectory, driven by the same spirit of invention that helped propel total solar capacity beyond 500GW last year.

"The solar industry or FPV market does not need any specific help in growing as we have seen the rapid rise in the industry over the last 10 years," says Papageourgiou. "What will continue to drive growth is the competitive cost of solar, ease and simplicity to install generally and the growing need for clean accessible energy. Also where the usual spaces for traditional ground and roof areas become limited then there can be a focus and switch to looking at water bodies to install solar." ■