Simulating aeroelastic instability in solar panels

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The COVID pandemic had a severe economic jolt worldwide in 2020, but despite the impact on the global economy installed solar energy capacity grew by 18% compared to 2019, reaching 138.2 GW (see Figure 1) and beating another global annual installation record for the solar photovoltaic sector. This brings the global cumulative solar capacity to 773.2 GW, a 22% increase, and marks a new milestone for the solar sector by exceeding three quarters of a terawatt.

This surprisingly strong renewable energy growth helped solar maintain its dominance among all newly installed power generating technologies, reaching a 39% global share, which translates into the impressive fact that more than one in every third power plant unit installed in 2020 came from solar. At the same time, solar's total power generation share increased by 0.5 percentage points to around 3.1%, with nearly 70% still coming from fossil fuel and nuclear, highlighting the need to rapidly accelerate solar deployments.

The good news is that solar's cost competitiveness progressed further in 2020, resulting in an even wider spread versus conventional generation technologies as the cost of gas, coal, and nuclear increased. Solar's cost improved across the board for all segments with utility-scale solar now superior to fossil fuels in all unsubsidised investment cases, which also applies to solar + storage used to meet peak demand compared to gas peakers, according to investment bank Lazard.

Design & engineering simulation challenges for the solar sector

The current development of the solar photovoltaic (PV) energy sector has resulted in a number of new structural typologies that are the physical support of the solar panel energy production systems. Photovoltaic energy is a very mature power generation source, and it is obtained using rows of panels implemented in a longitudinal grillage. Many studies have been carried out in the past with the aim to improve solar capacity to obtain electrical power, but another important mechanical issue is the need to guarantee the performance of these industrial facilities under meteorological phenomena such as that induced by turbulent wind flows which are especially important taking into account the fact that they are usually built in wide open outdoor spaces.

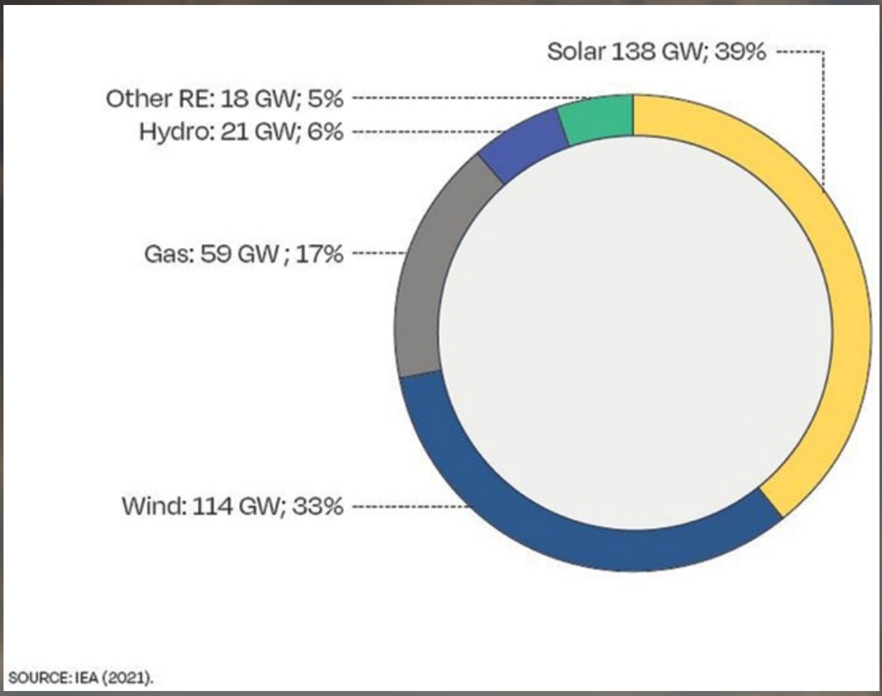

Figure 1: Net global power generating capacity added in 2020 by technology type

Nowadays, wind gusts and storm damage has been shown to be one of the biggest challenges for photovoltaic electricity production, since it damages many solar trackers; wind computational fluid dynamics (CFD) analysis is essential, therefore, not only to comply with standards but also to simulate the actual environment that these solar panels will experience on site. In reality, current Design Standards applied to solar trackers define very conservative Drag Coefficients for equivalent static wind pressures and tend to oversize the structure. Conventional wind tunnels use rigid solar panel models that do not consider fluid-structure interaction effects such as the aeroelastic response of the structure and have been shown to be insufficient to prevent aeroelastic instability. Hence, fluid-structure interaction analysis with realistic drag coefficients, and taking into consideration flexible structures allows us to optimise the solar panel structures thus reducing cost and ensuring panel safety and 100% panel availability with lower maintenance costs.

Precision and efficiency in consulting solar farm operators is possible with a variety of software that is suitable for combining dynamic fluid flow analysis and structural analysis using finite element calculations. This is exactly where the co-simulation tools of Hexagon come in, such as MSC CoSim, which can play an important role in assessing aeroelastic instabilities thus providing engineers with a unique, more complete, and holistic performance insight by coupling multiple computer-aided engineering simulation disciplines. We have done CFD simulations using Cradle CFD (Figure 2) and coupled them with our CivilFEM structural analysis solutions (Figure 3) via MSC CoSim using the easy-to-use MSCOne token system.

From our considerable CAE simulation experience at Ingeciber, co-simulation between CivilFEM and Cradle has allowed us to deeply analyse fluid-structure interaction and instability problems of solar panel wind effects, such as wind flow vortex shedding, panel galloping and battering to help us to design good global behaviour of the solar tracker system for all weather conditions. Moreover, CivilFEM's capabilities for the design of the supporting steel structures allows for a unique tool for this co-simulation problem. We can therefore design in detail solar tracker columns, the beam axis, purlins to support panels, connections and foundation so that they avoid undesirable wind related damage at a solar farm.

In addition to the above-mentioned aeroelastic instability problem, Cradle CFD simulations can go further than only studying the dynamic effects of wind. CFD models can also be used to analyse how wind-breaking obstacles, such as fences, trees or panels, help to reduce the impact of wind at Solar Farms, and how wind actually behaves in the topography where the solar plant is located. This is done via the integration of data displayed by anemometers, with three-dimensional geometric models of the terrain, to provide engineers with the exact wind behaviour over and above the standards and regulations of each region for any given solar farm.

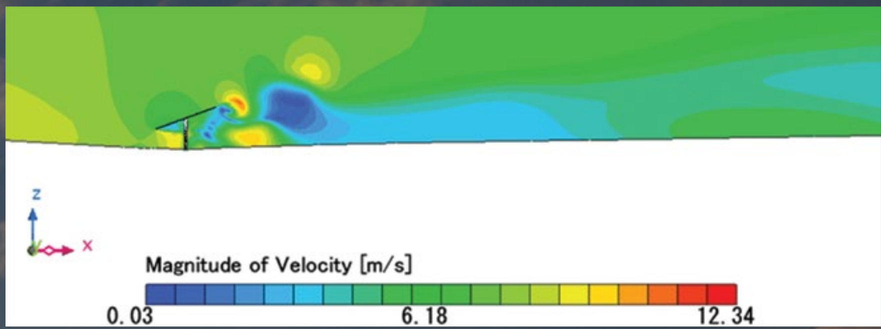

Figure 2: Cradle prediction of wind velocity magnitudes around a solar panel and tracker array (wind from left to right)

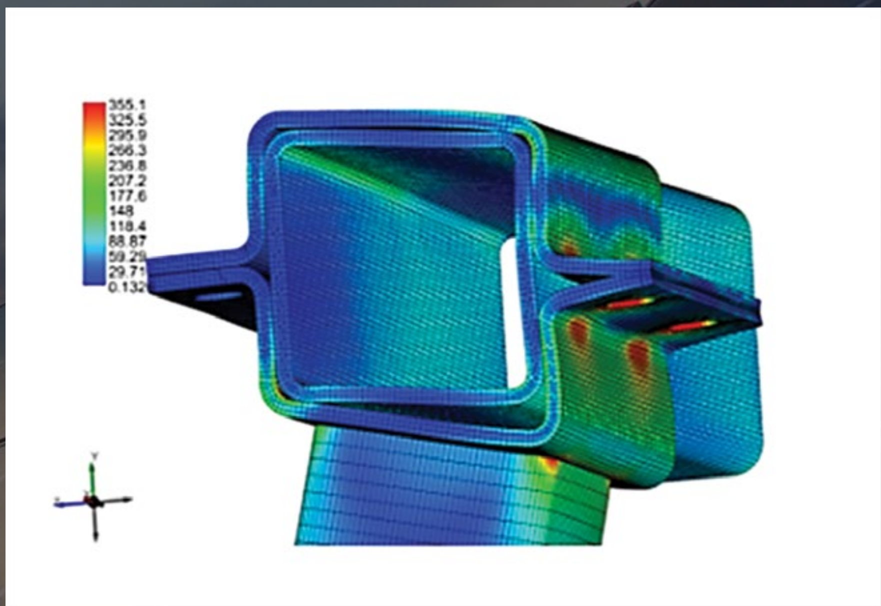

Figure 3: CivilFEM Structural Model of a Tracker Column connection