Building and running the smartest solar farm in the world

With its operational digital twin via a smart digital reality

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Earlier this year Hexagon announced the creation of a new subsidiary, R-evolution, to double down on our commitment to sustainability by using our extensive software and hardware technology portfolio to accelerate the world's transition to a sustainable global economy. We believe in putting our virtual software and real sensor data to work for real sustainability outcomes. R-evolution stands for 'Our Evolution' and it is the starting point of a journey where Hexagon aims to accelerate the advancement of green technology solutions to our world's many sustainability challenges.

It has been clear to both politicians and citizens alike for some time that we, as the dominant species on our planet, have failed to scale sustainably over the last 50 years as we've doubled in global population. Indeed, humans have only been in existence a very short time in geological terms, and yet we have already consumed 30% of all available natural resources on Planet Earth. At current rates we will need 2 to 3 planet earths to sustain our resource consumption trends. Something has to give, and a new approach is clearly needed urgently. However, the COVID-19 Pandemic of 2020 has also shown us that big changes can be achieved with enough willpower, shared resources and awareness of risk.

R-evolution has been tasked to utilise the incredible range of technology resources and talent from across Hexagon to help 'save our planet' with a business approach focused on three investment waves: current, next and rising. Within the first investment

sustainability wave our focus is on solar and wind power, alongside ecological monitoring. We also want to 'walk the talk' as it were and put our money and technology into these initiatives, so we have 'skin in the game'. Our goals are therefore threefold:

- Gain firsthand experience to build, own and operate renewable energy plants,
- Use these facilities as innovation platforms for our complete Hexagon portfolio, and
- Generate a renewable energy cashflow and run our facilities as a P&L business with the goal of reaching profitability as early as possible. We believe we can save the planet and be profitable.

We chose to start building R-evolution's renewable energy project in April 2021 with the acquisition of a 40-hectare PV solar farm site in Archidona, South West Spain near Malaga, and to use the facility to gain valuable first-hand solar energy experience in this innovation hub for leveraging our Hexagon and partner technologies. Our first farm, Archidona 1, is a8.24 MWp and it was connected to the Spanish Grid in September and it spans 60 football pitches. It has 20,592 bifacial panels that have single axis trackers that can rotate on one axis as the sun moves across the sky during the day. We are currently extending it to a neighbouring Archidona 2 facility which we are constructing that will take our overall capacity to 16.44 MWp; enough to power a village of 6,000 people annually. Our PV panel cells convert the sun's energy into electricity and we then supply green energy to the Spanish national grid.

Our target is quite simple – to make the smartest Solar project portfolio in the world with an ambition to deliver electricity at 30% higher efficiency than equivalent farms not using Hexagon's technologies. Hexagon's target efficiency improvements will cover everything from Solar Farm planning, design, manufacture, build, operation, and optimisation.

We have currently installed (see Figure 1) or are utilising in Archidona these technologies from the Hexagon portfolio - with others to be added over time:

- Planning – **HXDR** content program 3D planning
- Digital twin / reality capture – **BLK2GO & RT 360** scanners
- Facility IoT monitoring and forecasting – **AI Hub & Xalt**
- Facility construction monitoring – **Oxblue** camera
- Facility security surveillance – **BLK247** camera
- Design & Engineering Simulation and AR – **Cradle CFD, Adams MBD & Xalt**.

Mechanical performance challenges of solar plants

There are no moving parts in solar panels - the major source of reliability issues in other types of electrical generating systems. A PV module's operating life is therefore largely determined by the stability and resistance to corrosion of the materials from which it is constructed. Nevertheless, there are several failure modes and degradation mechanisms which may reduce the power output from a solar farm or cause the modules and tracks to fail. Nearly all of these mechanisms are related to weather effects or temperature-based stresses on panels or supporting structures:

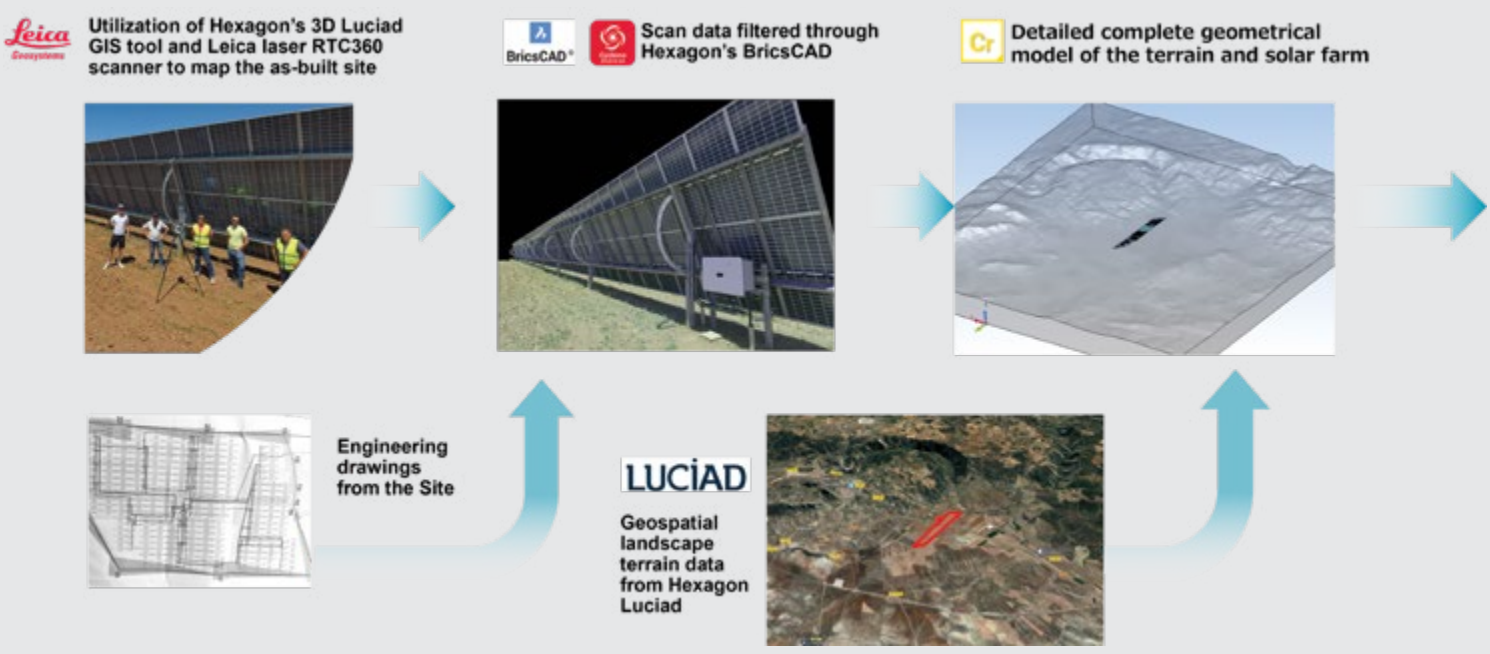
1. Mechanical damage due to wind gusts and storms – this typically accounts for around 15% of solar farm failures in the US due to storms and hurricanes
2. Thermo-mechanical stresses and cracking in the supporting structures due to solar thermal effects
3. Ground erosion around the solar panel supports, potential vegetation overgrowth and shade effects from neighbouring structures
4. Dust, snow and debris buildup on solar panels plus occasionally hailstone damage
5. Electric circuit degradation and short circuiting in the electrical circuits
6. Power inverter/transformer overheating and PV fire related risks
7. Erosion and corrosion of the panels and trackers from water ingress, and
8. PV Panel damage and soiling by wildlife (animals, birds and even water creatures).

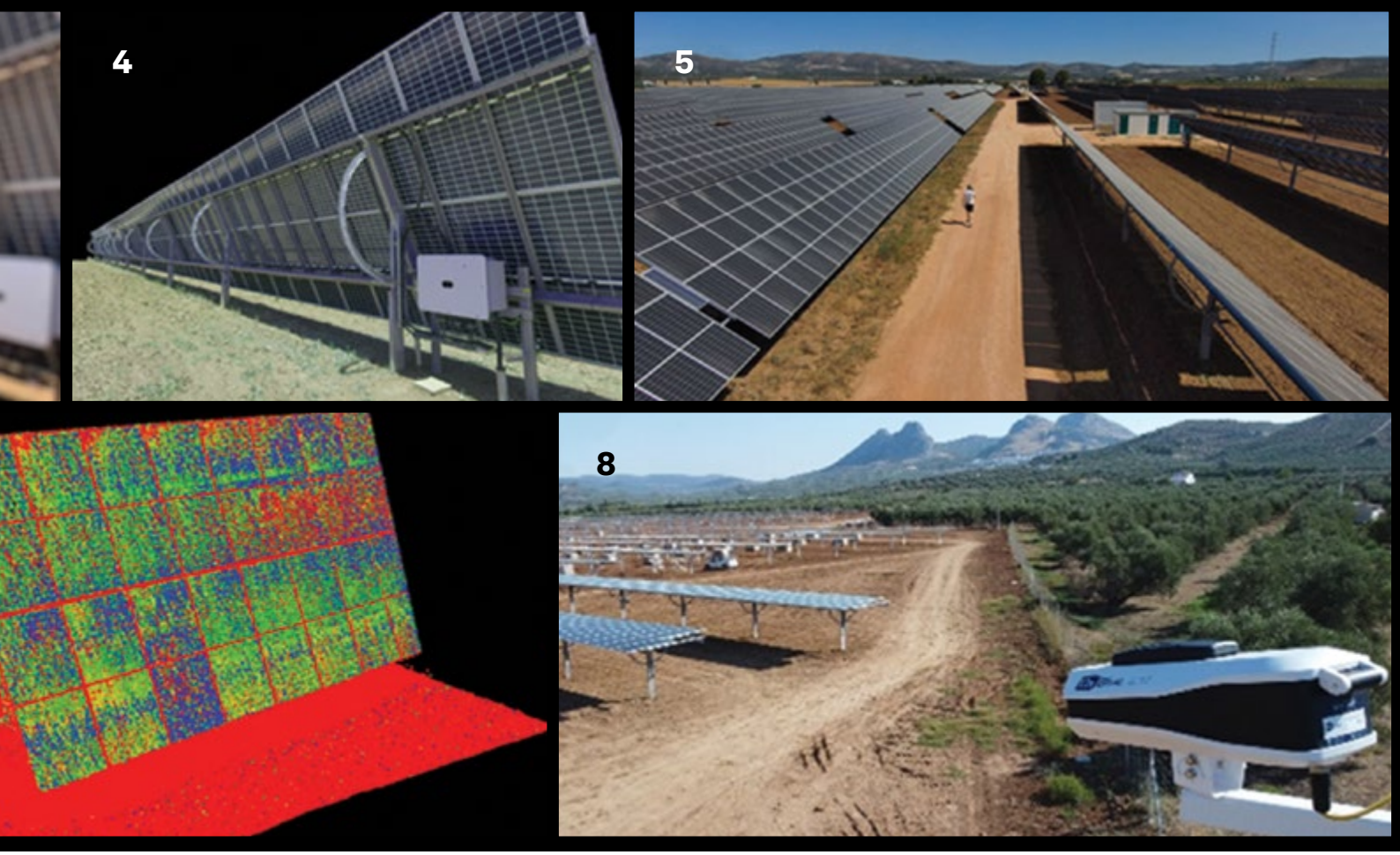
All of these factors can result in maintenance, downtime and electricity generation shortages.

Figure 1: Several Hexagon Technologies used in the creation and monitoring of the Archidona facility

CFD based digital twin of the Archidona solar farm

Cradle CFD from Hexagon is the world's most modern general purpose CFD software that is Multiphysics focused and coupled with accuracy leading computer-aided engineering software such as MSC Nastran, Marc, Adams and Actran for structures, multibody dynamics and acoustic predictions. We wanted to apply it in realtime to the solar farm so that an Operational Digital Twin of the facility could be produced for operators to use onsite. To this

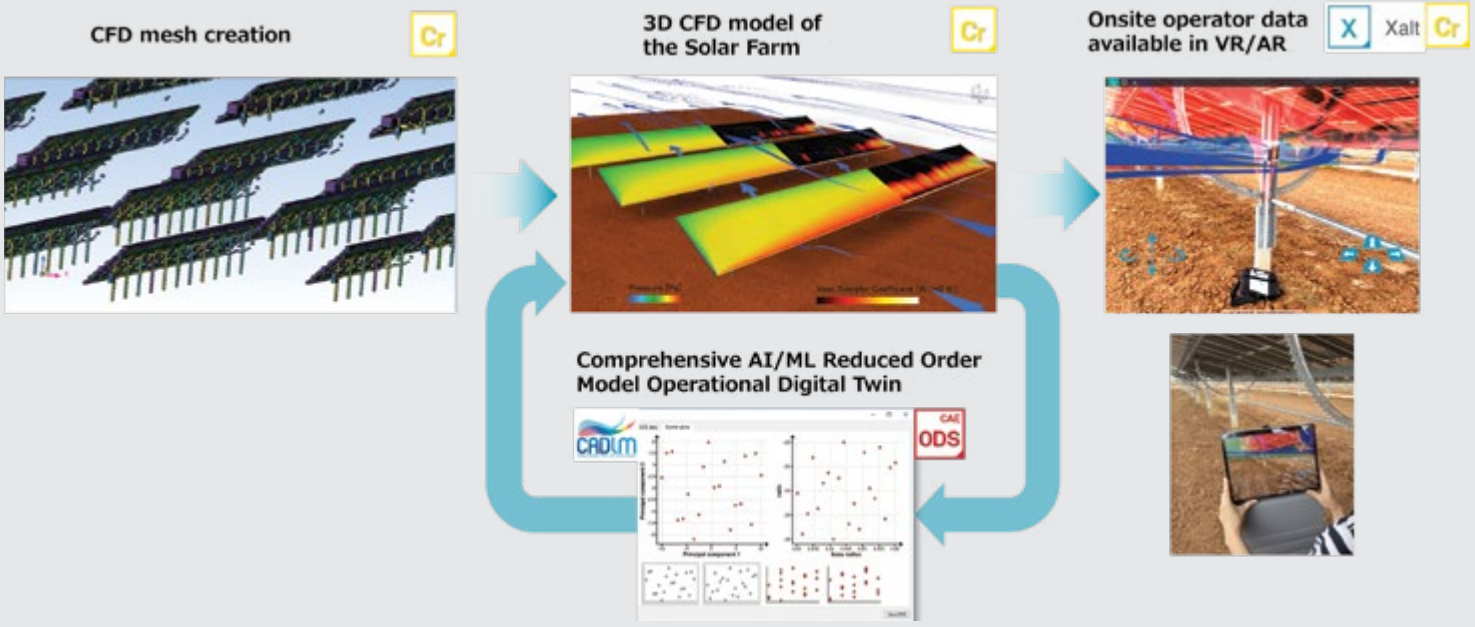




end we created a complete model of the landscape around the Archidona facility and the neighbouring hills using Hexagon geospatial and geosystems scanned data (see Figure 2). This allowed us to take real world as-installed data (as well as engineering drawings) and Leica scanned data from the actual solar tracks to create a very accurate model of the terrain and PV equipment.

From meteorological data we know that the predominant wind directions in Archidona are NW-SE for most of the year. We also know the trajectory of the panels through the sky following the sun on a single axis for any day of the year. We were then able to train Hexagon's

Figure 2: Scanning, geospatial and CFD model creation of a Solar Farm Operational Digital Twin



ODYSSEE CAE AI/ML software with a range of accurate 3D CFD simulations for conditions such as wind speed, wind direction, panel orientation to the vertical and create a powerful 0d Reduced Order Model. We were able to establish that the only wind direction of concern was an easterly wind (Figure 3) that showed complex recirculation patterns near the SE section of the solar farm, and it could predict precise fluid-structure effects on the panels such that any mitigating actions can be taken. Similarly, we were able to use CFD to assess the impact on solar panel structures of sloping ground sites (Archidona 2 is on a 3 degree inclination) and it was shown to have a minimal mechanical effect.

Solar panels are like giant sails these days as they get bigger and taller. However, strong winds can catch and twist them, causing massive damage to the panels themselves. It was reported in August of this year by Sandia National Laboratories and the DOE in America that an estimated 15% of damage incidents to panels over the last 6 years is caused by hurricanes, which is expected to rise as climate change increases the intensity of hurricanes (1).

It is also a little surprising to learn that approximately 25% of all incoming solar radiation hitting a solar panel gets converted into electricity on average; the rest just heats the panel, or it gets reflected to atmosphere. Indeed, solar panels can overheat and as they get hotter their electricity generating ability starts to tail off. Hence, the possibility of using local wind cooling effects to augment electricity generation is of interest to operators on solar farms. Again, Cradle CFD has allowed for lots of 'what if' analyses of this type on the site. Indeed, CFD can even help to

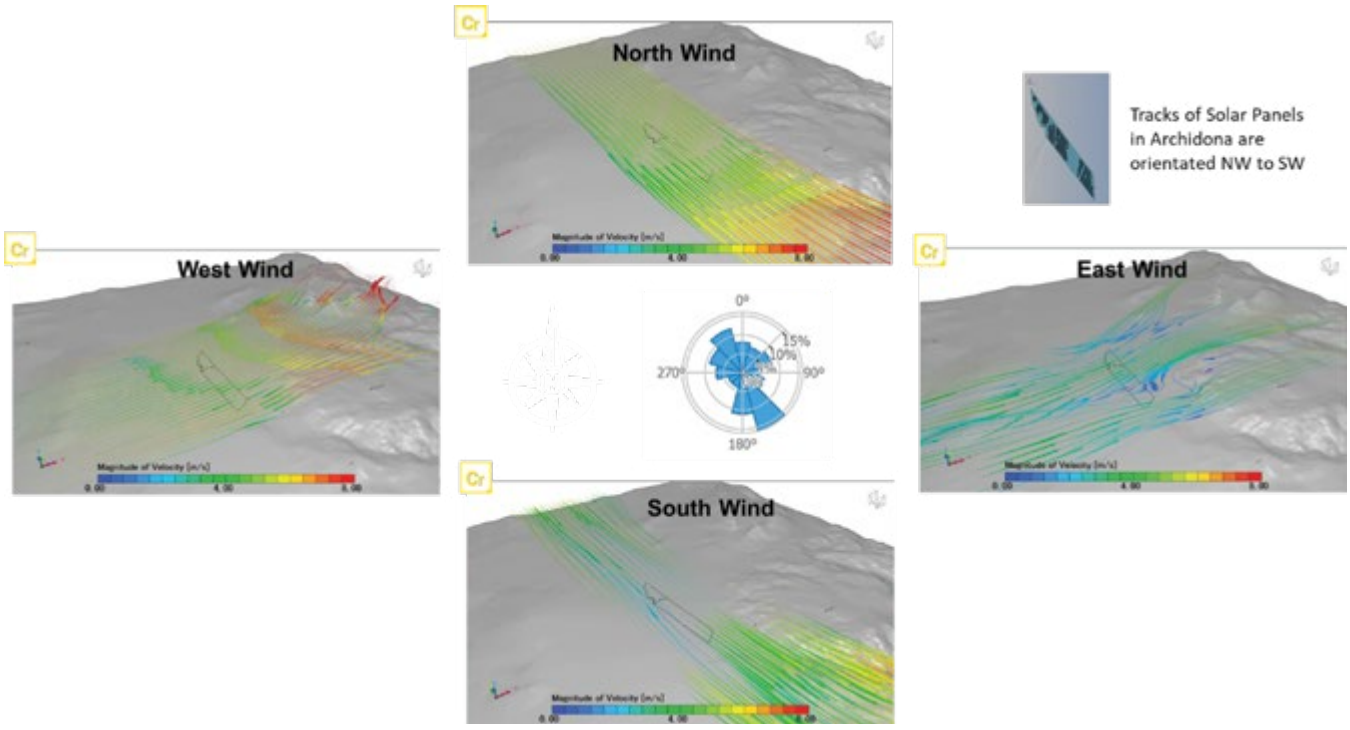


Figure 3: Cradle CFD simulation predictions of the local cardinal wind direction and patterns on the Archidona site

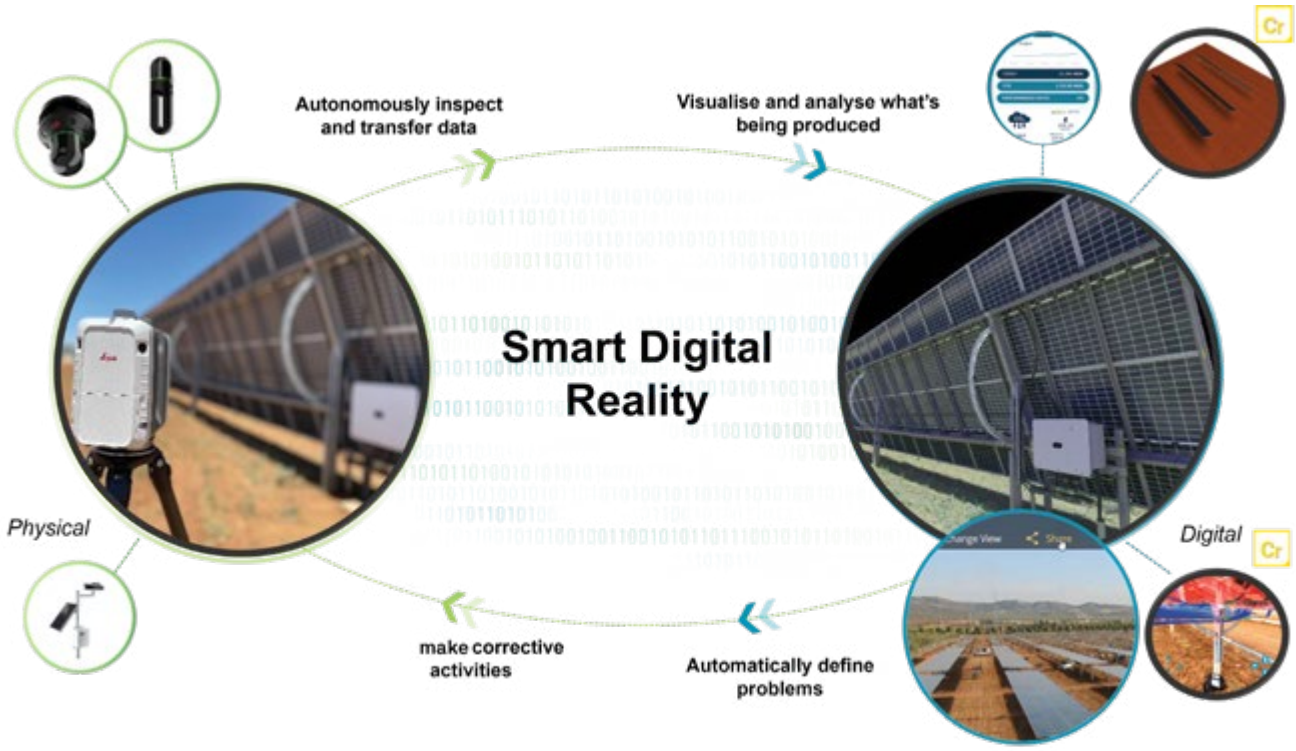


Figure 4: Hexagon's Operational Digital Twin schematic of the Solar Farm Smart Digital Reality

assess the optimal angle for solar panels to be tilted to on rainy days to wash the cells on the 6 days on average it rains every year in this part of southwest Spain! A schematic of the Operation Digital Twin Hexagon has created in Spain is shown in Figure 4 with the workflows around the sensing – simulating – acting of the plant's operator outlined relative to a local weather forecast event.

We were able to do multiphysics fluid-structure-multibody simulations via Cradle CFD and Adams to show that beyond 40° of inclination of the solar panels, the wind pressure levels applied to them could be problematic for their structural safety. Finally, what has proven to be one of the most useful outcomes from this project is the connection of Cradle CFD to our Hexagon Xalt technology to produce an augmented reality visualisation of the facility onsite for operators to look at fluid flow effects and thermal temperatures as they hold their iPads or iPhones up and view what is in front of them on a given day. As well as a powerful tool for operating insights it can also be used in training scenarios (Figure 5).

Each 3D Cradle CFD model scenario typically took about 1 hour to calculate on a multicore PC but once enough simulations were in ODYSSEE for it to interpolate between the many permutations of weather and operating conditions, a complete operating Reduced Order Model (0d) CFD Digital Twin of the facility could be obtained to run on a laptop. It can allow operators to run in seconds a wide range of scenarios that might apply to that particular day due to the prevailing weather conditions (Figure 6). This is one of the most powerful outcomes from our Hexagon Archidona solar farm project in terms of augmenting the performance of the facility and taking countermeasures as necessary on a given day.

Figure 5: Cradle CFD's Digital Twin flow prediction at Hexagon's Archidona Solar Farm in Xalt Augmented Reality iPad viewer

Summary

Hexagon's R-evolution subsidiary has created, commissioned and started to operate it's first solar farm in Archidona, Spain, in just over four months. We intend to expand the park's efficiency by putting data to work using Hexagon's hardware and software monitoring solutions, including visualisation platforms and sensors. We have employed Hexagon's Cradle CFD and Adams MBD predictive engineering tools to simulate, thermal, fluid and structural effects on the solar farm in order to create a Smart Digital Reality of the entire solar park that can be remotely and autonomously monitored to detect solar panel anomalies, improve maintenance, aid inspections and deal with day-to-day meteorological conditions. Our aim is for Archidona to be the world's smartest, most efficient solar farm that can anticipate potential damaging influences, such as wind and overheating, and can protect against them. By combining an operational 'Digital Twin' model of the farm with realtime surveillance and weather forecasting, the farm's operators can predict how it will react to environmental conditions and instruct exactly when and how to make the right operational adjustments to prevent any damage while maintaining maximum electricity generating operations.

Hexagon is uniquely positioned to deliver digital and sensor solutions across a broad array of sustainability applications. In Archidona we have been able to operationalise simulation with AI-based reduced order modelling and combine it with IoT data to produce operational digital twins that can be used to inform and optimise the facility's operation. This usage of all available simulation and sensor data to inform better solar farm business decision making around supply and demand and asset management is crucial for performance improvements. The PV site is largely autonomous today and we believe that Hexagon technologies accelerate this move towards facility autonomy, using data-driven systems to control more functions of the solar farm. Our Hexagon sustainability mission is entirely focused on putting virtual and real data to work to increase efficiency, productivity, and quality wisely in renewable energy facilities, and in a way that mitigates the urgent risks of natural resource depletion and waste.

Reference:

1. "Hidden factors that affect solar farms during severe weather", Science Daily, August 31st 2021: https://www.sciencedaily.com/releases/2021/08/210831131359.htm
2. "R" Projects https://r-evolution.com/r-projects

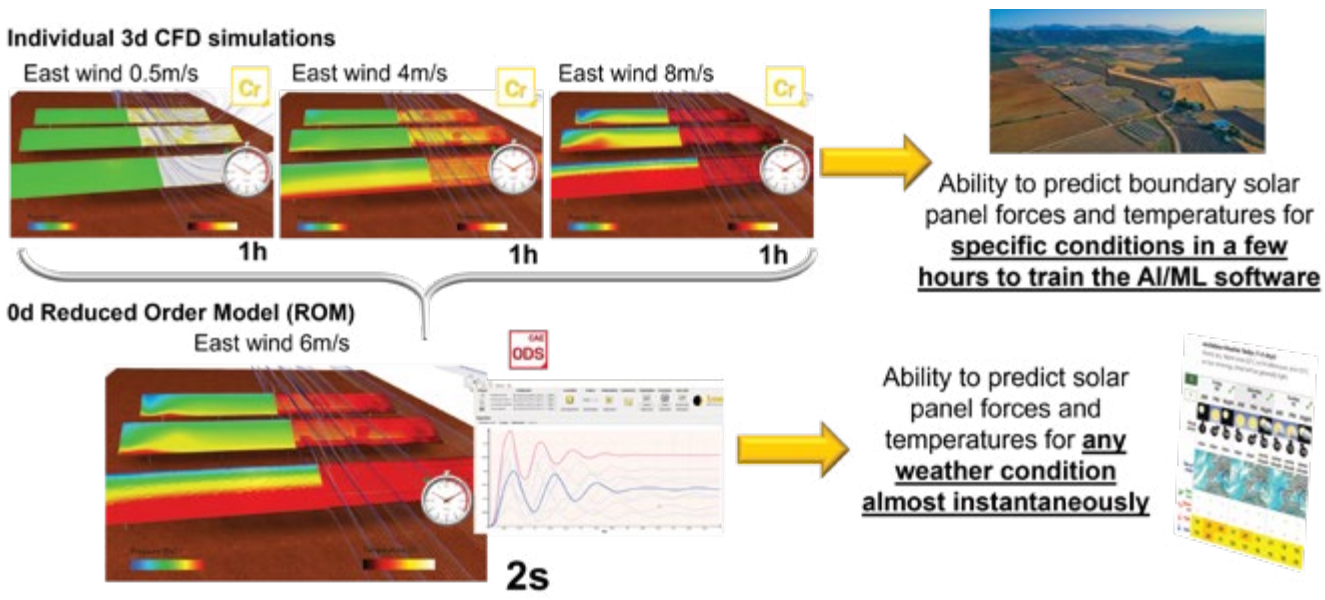


Figure 6: CFD Digital Twin of Hexagon's Archidona Solar Farm - 3D Cradle CFD Simulations feeding 0d AI/ML ROM to get realtime weather predictions