VIEW POINT

DIGITAL TWIN OF A SOLAR PLANT

A paradigm shift in streamlining operation and maintenance

Abstract

While the Internet of Things (IoT) has made huge quantities of data available, digital twin technology has enabled the analysis of this data. A digital twin can positively impact the performance, ROI, and output of a solar power plant. It can create auto-generated alarms and performance benchmarks which help minimize energy losses and improve output at the same time. Digitalization of a solar plant makes it possible and easier to synchronize production with weather forecasts, better balance the power demand/consumption curve, avoid sudden failures with predictive maintenance and reduce overall maintenance costs as well.

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Digital twin – A catalyst bridging the digital and physical

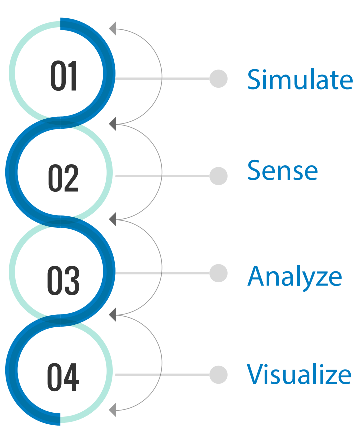
Until recently, industries relied heavily on a human workforce to run optimal operations. Automation accelerated business processes and production. But what if industries can go further? What if they can build extreme reliability on software and hardware simulations and depend on these to monitor performance. Digital Twin technology can deliver this and more.

A digital twin refers to a digital replica of a physical asset, process, and system. It can be used, to represent the myriad of components in a plant's equipment and monitor their behavior from an operational view. A digital twin can be conceptualized and designed in any form, but its sole benefit lies in capturing and analyzing data and predicting failure or maintenance of an asset in the physical world

Conceptualization of the digital twin

A digital twin is powered by emerging technologies such as IoT, Cloud, artificial intelligence, advanced analytics, simulation software, and tools for immersive visualization.

Enabling a digital twin typically involves 4 steps:



- **Simulate** – Virtually duplicating a physical asset on a digital platform with the help of simulation software and tools
- **Sense** – Gathering real-time operational and health information through sensors and mapping this against historical data from various sources
- **Analyze** – Transforming data to derive intelligence and predictions
- **Visualize** – Integrating data into a virtual digital model which is then visualized on a device to deliver an immersive experience

In the paradigm of digital technology, data acquisition, and its in-depth analysis is useful for predictive and preventive analysis. A digital twin prevents downtime of a plant and increases visibility into performance. Importantly, it allows for accurate future planning with the help of simulations and defers unwanted investments.

Digital twin powering solar farm

The adoption of a digital twin allows for humongous quantities of data to be collected from across a solar farm. This data could include models as well as historical data from associated assets, and environmental and climatic conditions. The data itself may not prevent the failure of an asset but can certainly guide plant operators to design efficient plant monitoring programs. If a problem is reported or forecasted by a digital twin, plant operators can make proactive decisions that are backed by insights or engage in preventive maintenance. Some of the other benefits of a digital twin on a solar farm are as below:

- **Continuous health assessment:** Data collection can be undertaken by drones that are mounted with telescopic cameras and through thousands of sensors that are deployed on the farm. Statistical or predictive machine learning models can analyze this data that is continuously collected. Insights related to health and performance can be derived and these can predict potential chances of failure or degradation in the performance of solar panels or associated functional equipment such as inverters, transformers, and others.
- **Insights and predictions at the fingertip:** Insights into the loss or decline in energy production can be accessed easily and these insights can be compared to expected outputs from previous months or years. Predictive maintenance models can indicate the need to clean the solar panels and this can be more efficient and economical than traditional periodic cleaning schedules. Insights on asset performance or malfunctioning ahead of time can help the farm to plan up-gradation or replacement seamlessly.
- **Visualization and immersive experience:** Real-time data and insights can be presented in an immersive digital way. This data can be consumed hands-free, via smart glasses or augmented reality while a technician points his camera of the phone to the equipment. Smart videos can be automatically compiled and pushed to a plant head to demonstrate insights or forecast situations of concern such as a dip in energy production in a better manner.
- **Notifications and actions in real-time:** Real-time alerts, or notifications on any asset needing urgent attention can be pushed to the hand-held device of a field operator or supervisor who can take action or assign the task to skilled personnel. There can be policies built into the system to automatically shut down an inverter or disconnect a solar panel as a reactive or preventive measure by the digital twin ecosystem.

Adoption of emerging technologies across solar farms

Emerging technologies are enabling energy companies to build smart energy plants and grids, and optimize energy generation, distribution, and consumption. Breakthroughs in remote monitoring, reduction in sensor costs, and a boost in network coverage and bandwidth are helping energy companies adopt smarter IoT ecosystems and economically manage solar generation. Plant managers can collect and analyze data on critical parameters of the solar farm. They can view this information on a centralized command dashboard and improve the efficiency and reliability of the solar energy system.

- **Data collected by sensors:** Monitoring of solar radiation, temperature, wind speed, dust levels, and energy outputs of individual panels can uncover low-performing units and the cause. This can optimize repairs and maintenance planning to enhance asset performance.
- **Image capture with mounted cameras on drones:** Analysis of high-resolution RGB or thermal images can help model the type of dust or damage of a solar panel (e.g. soiling, birds dropping, or cracks). The intensity of the anomaly can be associated with the reduction in power generation by the respective panel.
- **Machine learning and artificial Intelligence:** Time series data collected from sensors on the solar farm when subjected or trained with machine learning models can be useful to predict energy generation, the impact of dust or damage of panels, and the reciprocal decline in energy output. This can also help to schedule maintenance like cleaning of panels, repairs, replacement of cables, and maintenance of associated equipment like inverters, transformers, the alternating current distribution box (ACDB), and more. AI can play a key role in the modeling, analysis, and prediction of both the weather and the performance of renewable energy assets. AI systems can learn key information patterns, obviating the need for complex rules and mathematical routines.
- **Immersive experience via AR/VR:** Advanced high-resolution images captured via drones or mounted cameras, along with augmented reality, are being used for collaborative design, planning, and analysis of solar panels and data feeds from such panels across a solar farm. Virtual reality-based applications are gaining popularity for training apprentices or building real-world simulations for planning meetings, expansions, and alternations of solar farm design to enhance productivity.

Creating a digital twin of a solar farm – End-to-end lifecycle management

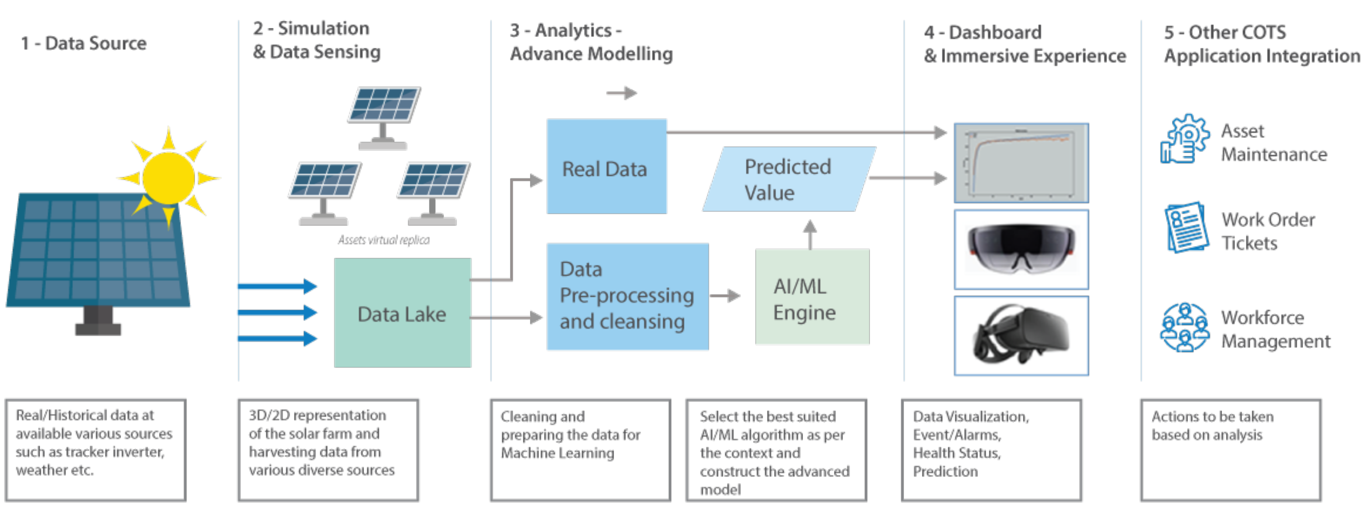
As depicted in the graph below, real-time data is collected from solar panels and associated equipment like trackers, string inverters, and ACDBs (AC Distribution box), solar voltage and current measuring sensors, temperature sensors, tracker movement analyzers, and others. Mounted cameras or drones are used to capture periodic images of solar panels to infer the level of dust accumulation and associate it with the loss or depletion in power generation by photovoltaic (PV) cells. The data that is collected undergoes cleaning and preprocessing to detect and repair errors through extrapolation of missing sensory readings, elimination of outliers, and other corrections. The cleaned data is subjected to predictive modeling via machine learning and AI algorithms. This data modeling can predict equipment performance, power generation loss or gain in the future, and the impact of dust or damage that may require proactive maintenance or a change in the panel cleaning schedule to improve overall power generation efficiency.

These observations can be viewed by administrators or infield operators either on their desktop, on a web app, or as an immersive augmented experience on their smartphone. The information helps field operators to act immediately. A digital twin ecosystem also enables the integration of data with external or plant monitoring systems. The analytical insights into the efficiency of the workforce can help plant managers to better plan their workforce utilization.

The digital twin startup ecosystem in the solar industry

Many up-and-coming startups working on designing solutions for the energy industry. These leverage a subset of the many emerging technologies to address industry problems. Offerings from a few of these start-ups are highlighted below:

- Helios, the digital twin-based analytics engine developed by Pratiti Technologies can have a significant effect on the performance, ROI, and output of a solar power plant. Their solution is effective to closely analyze the performance of solar PV cells under various conditions. SCADA and remote monitoring systems are integrated to provide features of failure analysis, power prediction and forecast performances.
- Companies are leveraging drone-based technology to capture images of solar assets which is manually time consuming. US-based Raptor Maps have designed and developed software powered by AI for analyzing photo voltaic images and provide actionable reports.
- Most efficient solar PV cells can produce around 21% output. Oxford Photovoltaics has designed an efficiency enhancement solution for silicon cells. The design elevates performance of PV cells by applying high-efficiency thin-film perovskite solar cells on top of commercial silicon solar cells.
- Lithuanian WePower has built a decentralized marketplace that enables renewable energy prosumers to transact electricity among themselves without the need for third-party intervention.



Benefits of digital twin in the solar industry

Digital technologies have inspired transformation in the power generation industry. They have provided new insights into the planning, operations, and maintenance of energy plants. With the advent of sensors, gateways, data collection and interpretation methodologies, and predictive analytics capabilities—newer opportunities are being envisioned by energy companies to better understand their customers:

- Helios, the digital twin-based analytics engine developed by Pratiti Technologies can have a significant effect on the performance, ROI, and output of a solar power plant. Their solution is effective to closely analyze the performance of solar PV cells under various conditions. SCADA and remote monitoring systems are integrated to provide features of failure analysis, power prediction and forecast performances.
- With the aid of real-time simulation, energy operators can easily assess. information on the condition of each part of the solar farm
- The digital twin is effective for analyzing the performance of solar PV cells under various weather conditions and the soiling of the panels.
- Forecasting is one of the benefits of digital twin technology. Helios enables the mapping of the solar grid to a virtual program and guarantees better utilization of the whole system.
- Improved ROI is assured through operation insights. Auto-generated alarms and performance benchmarks help minimize losses and improve output at the same time.

Digital twin case studies from Infosys

Infosys has invested in digital twin technology that can be deployed in industries such as manufacturing, utilities, energy, healthcare, and others. We have end-to-end capabilities in sensor-driven data acquisition, industrial cloud platforms for data massaging, and building state-of-the-art predictive models to derive insights

Infosys is in an experimental phase to design a digital twin for condition monitoring of its 40 MWp solar farm at Sira, Karnataka, India. This condition monitoring solution aims at prioritizing cleaning and repair schedules of solar panels based on the intensity and type of soiling (dust, birds droppings, and snow) or accidental damages/cracks that may be caused to the solar panels over time. The solution being developed would help optimize the power generation capability of each panel. The reduced generation of power caused by high level of dust can be better handled with image processing and predictive analytics.

Images of panels captured by drones will be fed into a deep learning sequential image classifier which categorizes them into buckets as per predicted power loss. Our idea is to prioritize cleaning those panels which may potentially cause a steep decay in benchmark power production expected from that panel.

Summary

For renewable energy, digital transformation and digitalization are foundational. Economies across the globe are turning to renewable sources such as solar photovoltaic energy to meet their growing energy needs, eliminate greenhouse gas emissions, and shift clean energy production. Digital Twin technology can be applied to almost any renewable energy generation industry including solar and wind to achieve optimized performance of the plants.

Improved operations, reduced outages, and better management of variations in market conditions may seem idyllic, Digital Twin makes it possible. It certainly explains why this technology is well received in the energy sector, and why we are set to see more applicability of the digital twin in the near future.

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Authors

Dr. Arunkumar Ranganathan, Associate Vice President – Head Domain Consulting Group

Dr Arun heads the domain consulting group for Energy, Utilities & Services business. He has 27+ years of Consulting, Global Leadership & Software Delivery experience, primarily assisting clients in the Energy Utilities & Services industries.

Dr. Satish Balantrapu, Lead Consultant, Utilities Domain

Dr. Satish is a Lead Consultant within the Utilities division of Infosys Ltd. He has around 19+ years of experience in providing solutions and consultancy in the Utilities projects including Smart Grid, Work and Asset Management System and Mobile Workforce Management system. His PhD research work on 'Artificial Intelligence applications in Load Forecasting' is included in the syllabus of Columbia University. He published around 25 papers in International Journals & Conferences including IEEE & Elsevier.

Animikh Ghosh, Senior Technology Architect, Infosys Center for Emerging Technology Solutions

Animikh Ghosh is a Senior Technology Architect at Infosys Center for Emerging Technology Solutions with more than 12 years of consulting experience in the area of IoT and Cloud solutioning. He leads the IoT solutioning at ICETS and comes with a strong research background. He has presented several peer reviewed publications at various prestigious conferences and has multiple patents to his name.

Pankaj Negi, Principal Consultant, Infosys Center for Emerging Technology Solutions

Pankaj Negi is a Principal Consultant at Infosys Center for Emerging Technology Solutions. He has 14-plus years of experience and has worked across diverse consulting engagements on Internet of Things (IoT) technologies led innovation and business transformation programs for various industries. Pankaj holds a bachelor's degree in electronics engineering and an M.B.A. from SP Jain Institute of Management and Research, Mumbai.

Surya Srinivas Chavali, Industry Principal, Utilities Domain

Surya Chavali heads the Transmission and Distribution (T&D) Centre of Excellence (COE) at Infosys. His primary focus areas are Grid Modernization, GIS, DERMS, ADMS, and Work and Asset Management. As the T&D CoE lead , he is responsible for establishing strategic partnerships with niche industry vendors and deliver value added services to Infosys clients. He has over two decades of core Utility industry experience which includes defining and driving T&D solutions for Utilities across US, Europe, and Asia-Pacific.