

Plant Audit with Digital Twin AI

For a Solar developer, operating a growing portfolio of solar assets brings new complexities every season, every day and every hour. All those issues would be eventually dealt with, but until then they leak money. This is where Quadrical Ai comes in.

Based on data from October 2, 2020 – December 23, 2020, (3 months) we performed a Digital Twin AI Audit for our customer. Through this we identified Energy Generated, PR, and Losses at generation (String) level as well as transmission (Inverter and other) levels. We were able to pinpoint losses and catch faults, failures and degradations with substantially higher accuracy than traditional approaches.

Additionally, the Quadrical engine identified a **severity-based list of Plant Modules (Strings) with data inconsistencies, current and long-term underperformers, various generation issue trends such as long-term degradations, slackers (late starters / early finishers), and strings with energy generation uncorrelated with the Digital Twin benchmark for the Audit window.**

We also detected Strings with most recent issues (last 7 days) of the Audit window and offered recommendations.

Our solution for our customer used stacked Digital Twins built on peer Comparison, Environmental Context and Time, and provided recommendations with maximum accuracy, minimum noise and clear reporting for their O&M team

Portfolio Studied

Capacity	9.26MW
Total Area	22 Acres
# of Strings	920
# of Panels	33877
# of Inverters	13
Sensor Level	String
Audit Period	2 Oct – 23 Dec 2020

Being a weather and module corrected benchmark, our Digital Twin based Machine Learning is even **reliable at tracking Needle-in-Haystack issues down to string level (or the lowest sensed level).**

Using SCADA, tracker, weather, calibration and manufacturer data, plus 3-month plant operating data, we at Quadrical Ai went to work.

Performance & Benchmarks

Standard Performance Ratio (PR)	0.88
Digital Twin Benchmark based PR	0.98
Contracted Energy Benchmark	4005 MWh
Digital Twin Energy Benchmark	4625 MWh
Total Actual Energy Exported (ABT Output)	3936 MWh

Immediately, we discovered the plant was capable of producing significantly more energy than estimated by PVSyst. **620 MWh = \$126, 078 extra energy yield in 3 months.**

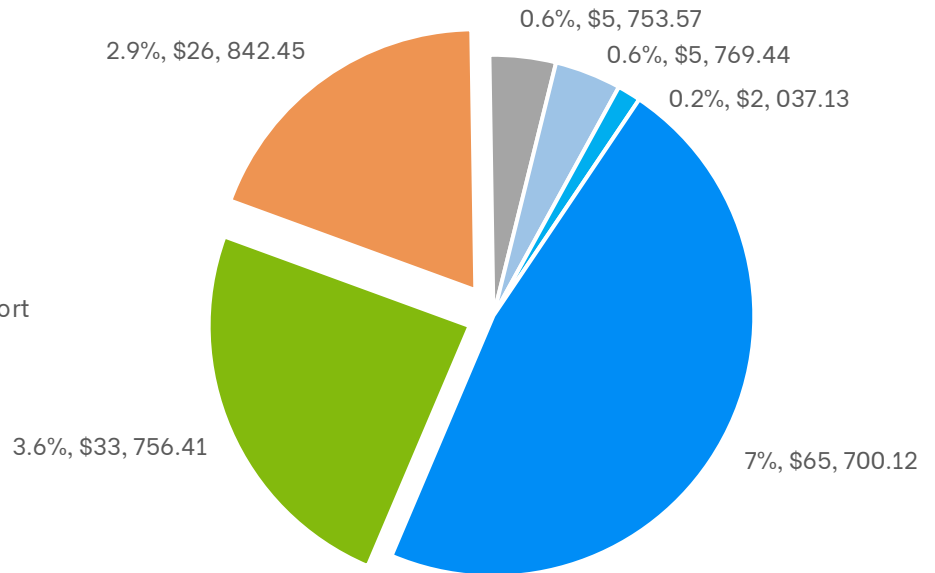
Our benchmark was personalized exactly to the plant, and calculated using string and weather data, peer behavior and full complement of custom digital twins. Running these stacked

twins simultaneously, we could see exactly how the plant would behave under ideal conditions, and then derive tickets to be issued to bring it up to those ideal conditions.

Thus, our Digital Twin Benchmark was much more highly correlated to actual value as opposed to standard PVSyst based Contracted Energy Benchmark.

Loss categorization

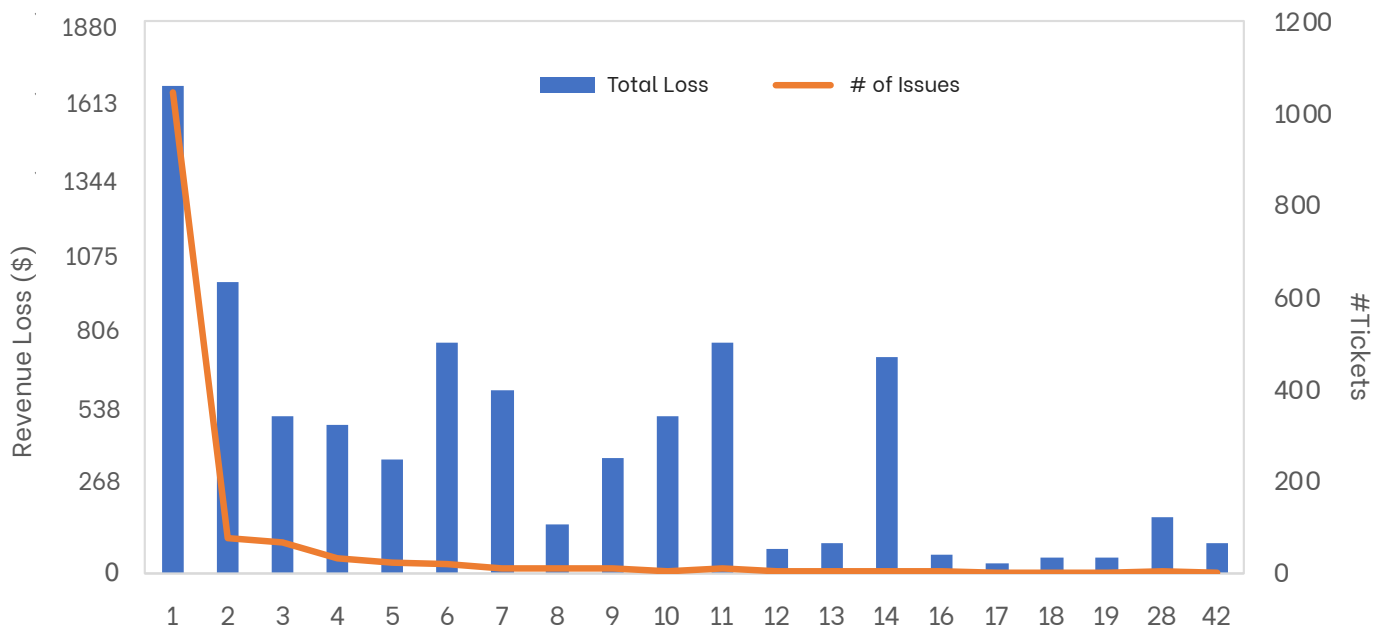
- Transmission - Inverter (DC to AC)
- DT Generation-Long Term Issues
- DT Generation-Uncorrelated with DT
- Transmission - Inverter Output to Export
- DT Generation-Slackers
- DT Generation-Unlisted



Leaky losses – Detection and Revenue Impact

With ticket aging analysis, we were able to detect hidden leakages capable of undermining even the best execution of typical monitoring and maintenance. Digital Twin technology yields the most accurate loss detection and anomaly prediction capability.

This means our plant-specific Audit can actually predict and arrest more significant revenue losses, by capturing each leaky loss well ahead of time.



Needle-in-Haystack / Temporal Issue Examples

- Detected Inverter Level Losses of 3.6% (\$33,756.41)
- Pinpointed 4 inverters of 13, that contributed 1.38% of total loss
- Identified 93 Strings (10%) of 920, that contributed 1.4% of total loss, and 17% of total generation loss
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We recommended investigation of strings which were:

- Slackers (Late Starters/Early Finishers) Uncorrelated to Digital Twin
- Most Degraded
- Causing Recent Issues

Missing Data

We DO often work with low fidelity data (this plant had significant missing data) – but missing (and unreliable) data affects Digital Twin Benchmark accuracy. Thus we needed to further fine-tune the model by removing unreliable strings Model by removing unreliable strings from training, to deliver even more accurate outcomes.

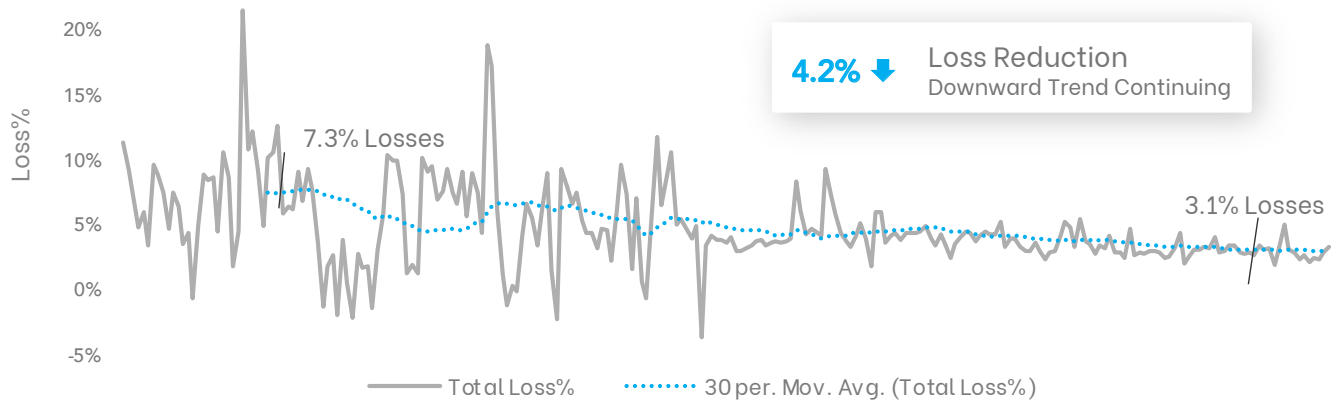
Strings with Missing Data Days = 278
 Total Missing String Data Days = 4975
 Total # of Strings = 920

Needle-in-Haystack / Temporal Issue Examples

Our benchmark ensures the most precise loss tracking and remediation to increase yield via O&M schedules. With our Audit - Remediation cycles, we've helped customers achieve >4% yield improvement. Loss percentages continue to improve further as timely actions are taken on O&M guidance. With on-site O&M feedback, the Quadrical Ai

Platform is also trained to become more intelligent with time.

Our RealTime Monitoring/Reporting solution ensures complete and efficient implementation of Audit recommendations, supporting your team through constant, RealTime monitoring of portfolio through a Remote Operations Center (RoC).



The Quadrical Ai Advantage

- Our Plant Audit uses RealTime and historical data to create a reference model customized to every plant for an exhaustive and in-depth analysis.
- As we accurately pinpoint underperforming modules by detecting signal change in comparison with predicted parameter, issues are fixed much earlier, avoiding leaky losses.
- Prescriptive O&M recommendations close the loop with actionable insights. This means increased up-time due to anomaly and outage predictions we provide on asset health.
- Accurate loss tracking, and loss bucket estimation allows for optimized yield and ability to reach optimum O&M targets earlier.
- O&M costs automatically reduced as emergency maintenance avoided and cleaning plans optimized.
- Identification of Needle-in-Haystack/ Temporal issues (granularity and accuracy for catching leakage losses).
- The Digital Twin Benchmark being Pyranometer agnostic, makes it highly correlated to actual energy - a much more reliable benchmark to detect String Level Degradation.
- Digital Twin powered behavior expectation is personalized at scale for all instrumented strings, SCB, and inverters. Thus, it can make error-free, quantified, and actionable recommendations and tickets.
- Advanced ML replaces complex calculations to automate analysis - which means your staff can focus time on mining deeper insights and discovering revenue opportunities more efficiently.
- State-of-art cloud storage and data archiving solutions provide unlimited scale, 99.99% data availability, 99.5% or more system uptime performance, highest standards of data security and secure encryption in-flight and at-rest.
- Protect sensitive data by restricting access using Role-based and Network-based access controls, and specific controls like SQL /other database encryption so data in transit stays protected throughout.

Digital Twin 3-Dimensional Benchmark

Pyranometer agnostic

Context - Satellite Weather Data, Weather Station (Pyranometer), and Plant Yield

Peer and Proximity Data for better gauge of granular conditions

Meter specific using Time Series performance of individual meters



Sharat Singh
Quadrical Ai
CEO

Our state-of-art Digital Twin Plant Audit guarantees RealTime impact on plant yield, loss identification and revenue leakage plugging. Plug-&-Play SaaS delivers accurate recommendations with minimum noise. Your team can focus on Yield improvement and O&M best practices.



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Deployed on 3064 MW Solar + 667 MW / 2433 MWh Storage + 200 MW Wind