

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.

Capacity **9.26 MW**

Total Area **22 Acre**

of Strings **920**

of Panels **33877**

of Inverters **13**

Sensor Level **String**

Audit Period **2 Oct – 23 Dec 2020**

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

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



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.

The difference between Contracted Energy and Digital Twin Benchmark reflects pyranometer calibration issues.

Contracted (Budgeted) Energy is less accurate as it is overly dependent on:

- Simplistic PVSyst calculations of Irradiance
- Pyranometer accuracy

This makes it more unreliable as plants become larger.

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

0.88

Standard Performance Ratio (PR)

0.98

Digital Twin Benchmark based PR

4,005 MWh

Contracted Energy Benchmark

4,625 MWh

Digital Twin Energy Benchmark

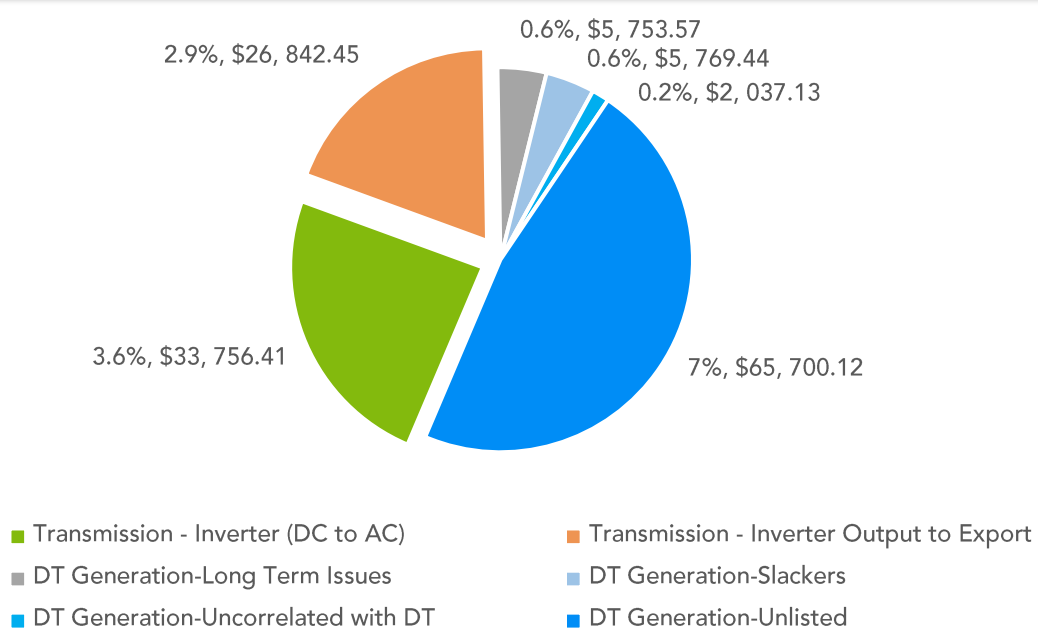
3,936 MWh

Total Actual Energy Exported

Running stacked twins simultaneously, we could see exactly how the plant should behave under ideal conditions, and then derive tickets 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



Note: All figures in \$ (USD). Per Unit (KWh) Price was \$0.20

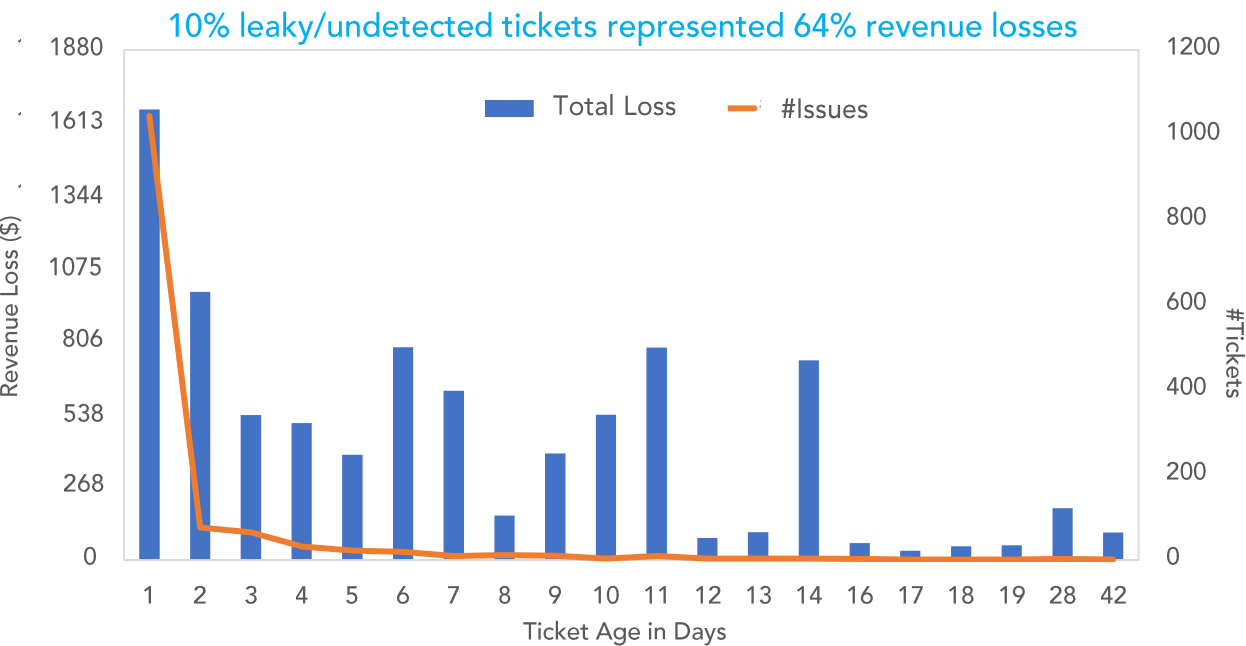
Leaky losses – Detection and Revenue Impact

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

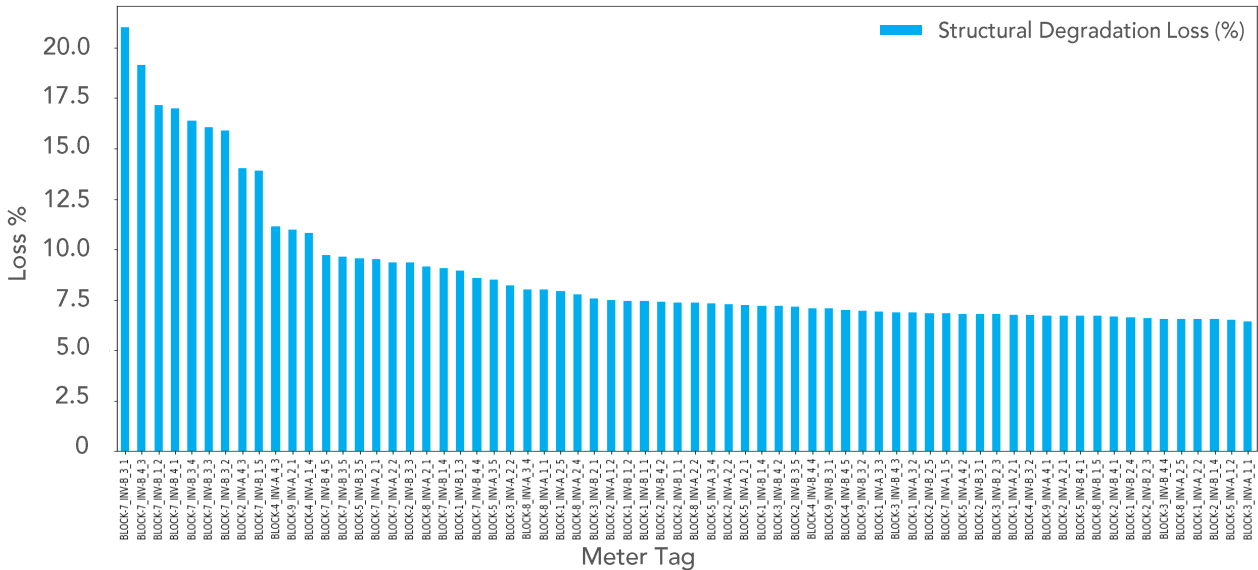
We found improperly calibrated systems with pyrano-calibration issues that might have easily affected the accuracy of audit results.

Below graph shows that meta data in terms of plant’s capacity at different nodes and different electrical measuring units was misrepresented, as confirmed by the consistent delta between Contracted Energy Benchmark and Digital Twin Energy Benchmark.

- 17% of total generation loss
- We recommended investigation of strings which were:
- Slackers (Late Starters/Early Finishers) Uncorrelated to Digital Twin
 - Most Degraded
 - Causing Recent Issues

However, our platform is intelligently designed to not blindly/completely? rely on label data. It creates plant layout/schema using raw data – and cross-checks the data validity and accuracy as well, before generating reports.

This means our customers can actually differentiate between data issues due to reading instrument error, and faulty plant parts.



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



Post Audit Remediation

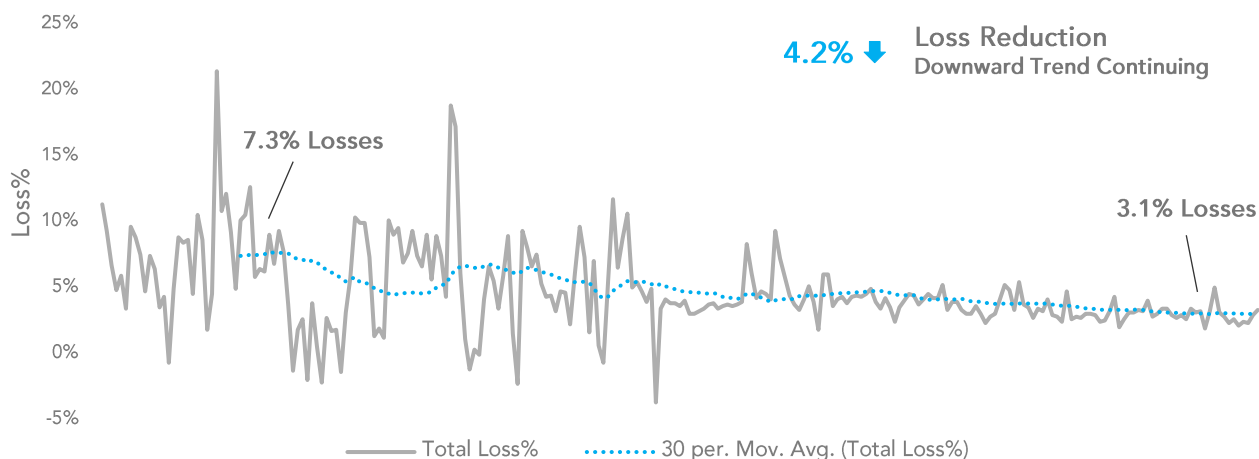
Our benchmark ensures the most precise loss tracking and remediation to increase yield via O&M schedules.

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.

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

- 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 quantified, and actionable recommendations and tickets.
- Advanced ML replaces complex calculations to automate analysis – 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.



Sharat Singh
CEO, Quadrical Ai

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.

About Quadrical Ai

Our Asset Management for Yield Improvement helps solar both Increase Generation and Reduce O&M costs.

- Plant Audit. Actionable guidance in 2 weeks with no time, impact to your existing systems.
- Fast Onboarding for immediate results.
- RealTime Monitoring & Reporting (Faults/Failures) across Plants and Portfolio
- Predictive Maintenance with AI. Actionable O&M Guidance, prioritized by revenue impact
- Digital Twin AI Based Data Platform
- Forecasting generation >98% Daily accuracy in Head-to-Head Tests

Combining Data Engineering and Deep Math, founders Sharat Singh and Dr. Hugh Hind have built this Solar Management platform with proprietary and patented AI. 'Future Proof,' and Extensible, these 'Digital Twins' of your plants learn how to optimize every aspect with a holistic 25-Year Plan.