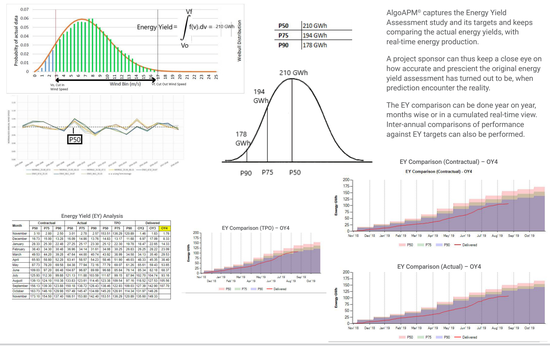
ALGO ASSET PERFORMANCE MONITORING (APM) RELEASE P-4

> PERFORMANCE AGAINST ENERGY YIELD (EY) STUDIES



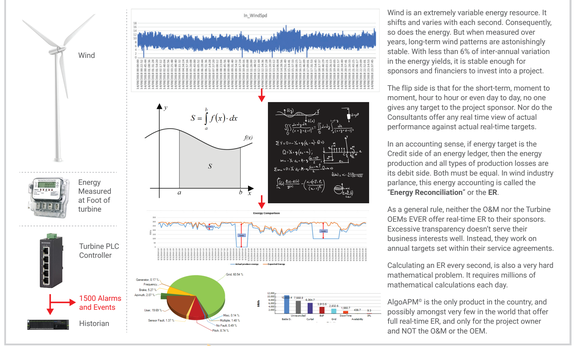
P50	210 GWh
P75	194 GWh
P90	178 GWh

AlgoAPM© captures the Energy Yield Assessment study and its targets and keeps comparing the actual energy yields, with real-time energy production.

A project sponsor can thus keep a close eye on how accurate and prescient the original energy yield assessment has turned out to be, when prediction encounter the reality.

The EY comparison can be done year on year, months wise or in a cumulated real-time view. Inter-annual comparisons of performance against EY targets can also be performed.

> ENERGY RECONCILIATION [ER]



Wind is an extremely variable energy resource. It shifts and varies with each second. Consequently, so does the energy. But when measured over years, long-term wind patterns are astonishingly stable. With less than 6% of inter-annual variation in the energy yields, it is stable enough for sponsors and financiers to invest into a project.

The flip side is that for the short-term, moment to moment, hour to hour or even day to day, no one gives any target to the project sponsor. Nor do the Consultants offer any real time view of actual performance against actual real-time targets.

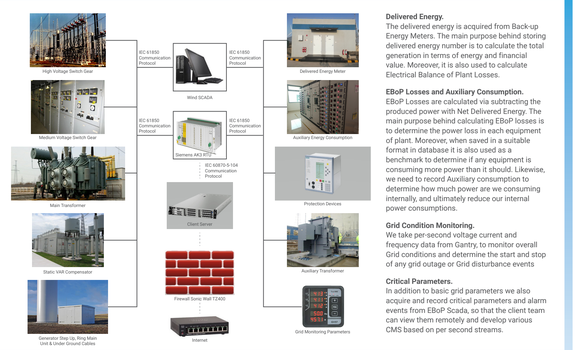
In an accounting sense, if energy target is the Credit side of an energy ledger, then the energy production and all types of production losses are its debit side. Both must be equal. In wind industry parlance, this energy accounting is called the "**Energy Reconciliation**" or the **ER**.

As a general rule, neither the O&M nor the Turbine OEMs EVER offer real-time ER to their sponsors. Excessive transparency doesn't serve their business interests well. Instead, they work on annual targets set within their service agreements.

Calculating an ER every second, is also a very hard mathematical problem. It requires millions of mathematical calculations each day.

AlgoAPM© is the only product in the country, and possibly amongst very few in the world that offer full real-time ER, and only for the project owner and NOT the O&M or the OEM.

> ELECTRICAL BALANCE OF PLANT (EBOP) STACK



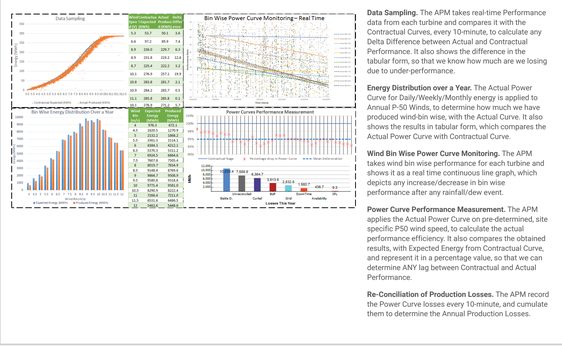
Delivered Energy.
The delivered energy is acquired from Back-up Energy Meters. The main purpose behind storing delivered energy number is to calculate the total generation in terms of energy and financial value. Moreover, it is also used to calculate Electrical Balance of Plant Losses.

EBoP Losses and Auxiliary Consumption.
EBoP Losses are calculated via subtracting the produced power with Net Delivered Energy. The main purpose behind calculating EBoP losses is to determine the power loss in each equipment of plant. Moreover, when saved in a suitable format in database it is also used as a benchmark to determine if any equipment is consuming more power than it should. Likewise, we need to record Auxiliary consumption to determine how much power are we consuming internally, and ultimately reduce our internal power consumptions.

Grid Condition Monitoring.
We take per-second voltage current and frequency data from Gantry, to monitor overall Grid conditions and determine the start and stop of any grid outage or Grid disturbance events

Critical Parameters.
In addition to basic grid parameters we also acquire and record critical parameters and alarm events from EBoP Scada, so that the client team can view them remotely and develop various CMS based on per second streams.

> REAL TIME MEASUREMENTS OF POWER CURVE PERFORMANCE



Data Sampling. The APM takes real-time Performance data from each turbine and compares it with the Contractual Curves, every 10-minute, to calculate any Delta Difference between Actual and Contractual Performance. It also shows the difference in the tabular form, so that we know how much are we losing due to under-performance.

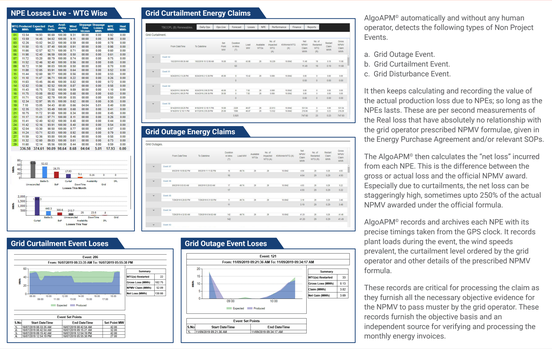
Energy Distribution over a Year. The Actual Power Curve for Daily/Weekly/Monthly energy is applied to Annual P-50 Winds, to determine how much we have produced wind-bin wise, with the Actual Curve. It also shows the results in tabular form, which compares the Actual Power Curve with Contractual Curve.

Wind Bin Wise Power Curve Monitoring. The APM takes wind bin wise performance for each turbine and shows it as a real time continuous line graph, which depicts any increase/decrease in bin wise performance after any rainfall/dew event.

Power Curve Performance Measurement. The APM applies the Actual Power Curve on pre-determined, site specific P50 wind speed, to calculate the actual performance efficiency. It also compares the obtained results, with Expected Energy from Contractual Curve, and represent it in a percentage value, so that we can determine ANY lag between Contractual and Actual Performance.

Re-Conciliation of Production Losses. The APM record the Power Curve losses every 10-minute, and cumulate them to determine the Annual Production Losses.

> NON PROJECT EVENT (NPE)



AlgoAPM© automatically and without any human operator, detects the following types of Non Project Events.

a. Grid Outage Event.
b. Grid Curtailment Event.
c. Grid Disturbance Event.

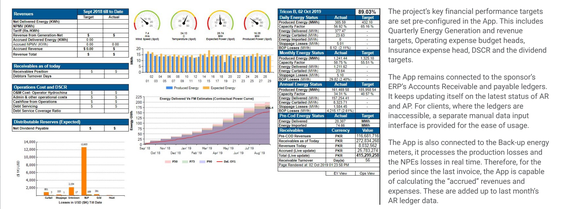
It then keeps calculating and recording the value of the actual production loss due to NPEs; so long as the NPEs lasts. These are per second measurements of the Real loss that have absolutely no relationship with the grid operator prescribed NPMV formulae, given in the Energy Purchase Agreement and/or relevant SOPs.

The AlgoAPM© then calculates the "net loss" incurred from each NPE. This is the difference between the gross or actual loss and the official NPMV award. Especially due to curtailments, the net loss can be staggeringly high, sometimes upto 250% of the actual NPMV awarded under the official formula.

AlgoAPM© records and archives each NPE with its precise timings taken from the GPS clock. It records plant loads during the event, the wind speeds prevalent, the curtailment level ordered by the grid operator and other details of the prescribed NPMV formula.

These records are critical for processing the claim as they furnish all the necessary objective evidence for the NPMV to pass muster by the grid operator. These records furnish the objective basis and an independent source for verifying and processing the monthly energy invoices.

> FINANCIAL PERFORMANCE [FP]



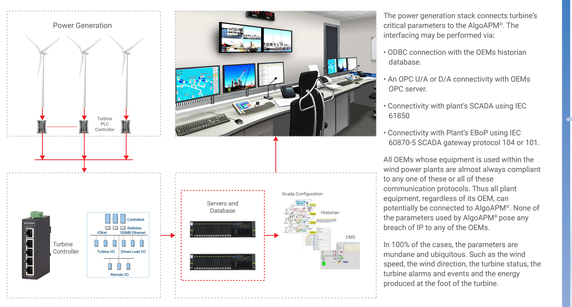
The project's key financial performance targets are set pre-configured in the App. This includes Quarterly Energy Generation and revenue targets, Operating expense budget heads, Insurance expense head, DSCR and the dividend targets.

The App remains connected to the sponsor's ERP's Accounts Receivable and payable ledgers. It keeps updating itself on the latest status of AR and AP. For clients, where the ledgers are inaccessible, a separate manual data input interface is provided for the ease of usage.

The App is also connected to the Back-up energy meters, it processes the production losses and the NPEs losses in real time. Therefore, for the period since the last invoice, the App is capable of calculating the "accrued" revenues and expenses. These are added up to last month's AR ledger data.

Thus the App creates a real time view of the financial performance that keeps updating itself, every 10 minutes. Unlike the G/L view, which only updates itself at the end of each month, when an energy invoice is raised and AR's are booked.

> POWER GENERATION STACK



The power generation stack connects turbine's critical parameters to the AlgoAPM©. The interfacing may be performed via:

- ODBC connection with the OEMs historian database.
- An OPC U/A or D/A connectivity with OEMs OPC server.
- Connectivity with plant's SCADA using IEC 61850
- Connectivity with Plant's EBoP using IEC 60870-5 SCADA gateway protocol 104 or 101.

All OEMs whose equipment is used within the wind power plants are almost always compliant to any one of these or all of these communication protocols. Thus all plant equipment, regardless of its OEM, can potentially be connected to AlgoAPM©. None of the parameters used by AlgoAPM© pose any breach of IP to any of the OEMs.

In 100% of the cases, the parameters are mundane and ubiquitous. Such as the wind speed, the wind direction, the turbine status, the turbine alarms and events and the energy produced at the foot of the turbine.

> ENERGY FORECASTING

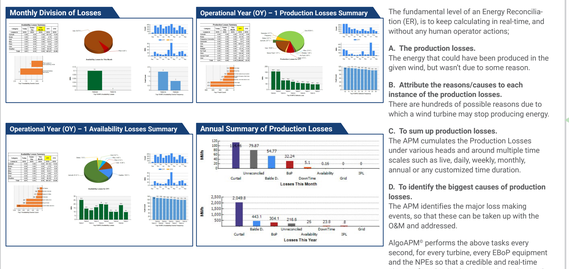
AlgoAPM© through its strategic alliances and dedicated data exchange interfaces with its European weather forecasting service providers, provides an hourly energy forecast. The energy forecast is fully and seamlessly embedded within the AlgoAPM© . Its accuracy remains within 10% threshold of Annual Absolute Error.

The best use case and the most powerful feature of AlgoAPM© forecast is the optimum scheduling of maintenance activities. In our experience, the annual production losses due to maintenance activities, reduce by a whopping 50%. On a 200 GWh annual energy yield plant, this could mean a net saving of at least 2.0 GWh per annum.

AlgoAPM© also automatically and without any human operator involvement, compiles various forecasting reports for the grid operator. It emails them automatically, at the prescribed time intervals to the grid operator.

AlgoAPM© keeps calculating and maintaining a scorecard of the "absolute error" to help assess any financial risk to the sponsor posed by grid operator imposed penalties.

> PRODUCTION LOSSES (EBOP, WTG, TECH AVAILABILITY)



The fundamental level of an Energy Reconciliation (ER), is to keep calculating in real-time, and without any human operator actions;

A. The production losses.
The energy that could have been produced in the given wind, but wasn't due to some reason.

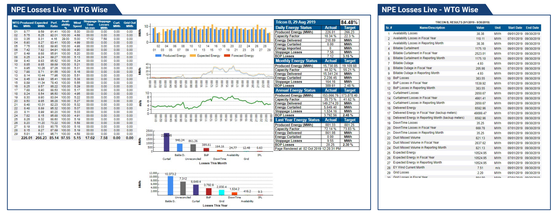
B. Attribute the reasons/causes to each instance of the production losses.
There are hundreds of possible reasons due to which a wind turbine may stop producing energy.

C. To sum up production losses.
The APM cumulates the Production Losses under various heads and around multiple time scales such as live, daily, weekly, monthly, annual or any customized time duration.

D. To identify the biggest causes of production losses.
The APM identifies the major loss making events, so that these can be taken up with the O&M and addressed.

AlgoAPM© performs the above tasks every second, for every turbine, every EBoP equipment and the NPEs so that a credible and real-time picture of production losses can be maintained.

> PERFORMANCE REPORTS



In Terms of Performance Reports, AlgoAPM© has several Operations Report on Daily, Weekly, Monthly and Annual Basis. Algorithm is committed to create On-demand customized reports as per the wishes of its customer.

Typical performance Reports covers following aspects:
a. WTG Key Parameters (Produced Energy, Expected Energy, Wind Speed, Stoppage Losses, Stoppage Time, Details of Grid Events)
b. Comparison of Produced, Expected and Forecasted Energy
c. Summary of monthly and annual production losses in Graphical format
d. Summary of Key Parameters and Production Losses in Tabular format

These reports furnish the objective evidence for the owners to draw assurance on the state of their assets. These reports also form the basis of holding O&M or the OEM accountable. Other aspect of Operations Report is to keep track of Production losses and control production loss and downtime of WTGs. Summary of Production losses indicate the tripping events which hurts us the most. All of this insight in the plant performance could help any Owner in taking relevant actions for rectification of these faults.

> WEATHER FORECASTING STACK

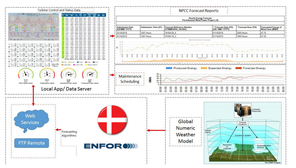
There are very few Global Weather forecasting services in the world right now. Almost all of these are publically owned and operated. Such as the National Weather Service of the US, The UK's Met Office or the Weather Europe. The resources they command such as weather satellites, hundreds of weather stations, thousands of weather balloons, oceanographic vessels etc. are simply too expensive to operate by any commercial concern.

These global weather services take the data inputs from thousands of resources, deployed globally. They use super computers to run partial differential equations on complex weather that predict the weather over up to six days of time window. Since last 30 years, and with the exponential advances in computing power, these global numeric weather models have become extremely accurate. Especially, the very short-term prediction, upto next 12 hours.

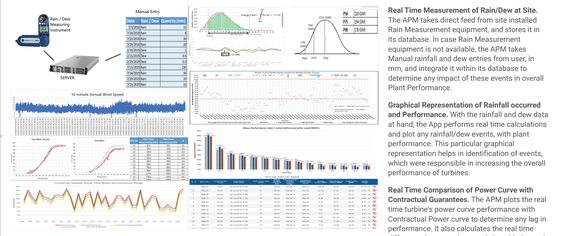
Commercial organizations such as aviation, oil and gas industry, merchant marine, television channels, farmers and now increasingly the wind industry subscribes to the services of these global weather service providers. Thus periodically, typically every hour, the wind forecasts for any place on the planet can be subscribed and regularly received over the Internet.

An accurate wind forecast is still not enough to create an accurate energy forecast with less than 10% errors. The plant needs to take several operational factors into account. The nuances involved are the total number of turbines, turbines' power curves, plant's BoP losses under various load conditions, turbine status weather on line or not, the NPEs, the turbine wake losses that are themselves, dependent on the wind direction.

AlgoAPM© weather forecast stack, through its strategic alliances with European wind industry's leading energy forecast suppliers, seamlessly integrates plant's operational data with the service provider's deep learning algorithms. Thus delivering an actionable and accurate energy forecast, every hour to its customers.



> REAL TIME MEASUREMENT OF DUST LOSSES



Real Time Measurement of Rain/Dew at Site. The APM takes direct feed from site installed Rain Measurement equipment, and stores it in its database. In case Rain Measurement equipment is not available, the APM takes Manual rainfall and dew entries from user, in mm, and integrate it within its database to determine any impact of these events in overall Plant Performance.

Graphical Representation of Rainfall occurred and Performance. With the rainfall and dew data at hand, the App performs real time calculations and plot any rainfall/dew events, with plant performance. This particular graphical representation helps in identification of events, which were responsible in increasing the overall performance of turbines.

Real Time Comparison of Power Curve with Contractual Guarantees. The APM plots the real time turbine's power curve performance with Contractual Power curve to determine any lag in performance. It also calculates the real time difference, between dusty and clean blades and calculate real-time difference.

Real Time Comparison of Various Performance Benchmarks.

The APM performs real time comparison between;

a. Expected Energy as per Contractual Power Curve.
b. Actual Produced Energy.
c. Expected Energy Produced with Clean Blades.

The comparison gives us critical benchmarks of how far are we lagging from our Contractual Performance and how much we could gain, if we clean the accumulated dust from our blades.

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