PIMS Workshop on Math and Clean Energy

Hot Topics in the renewable industry

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Agenda

- Introduction
- Wind Power Forecasting
- Component Failure Prediction
- Conclusion

UTOPUS INSIGHTS

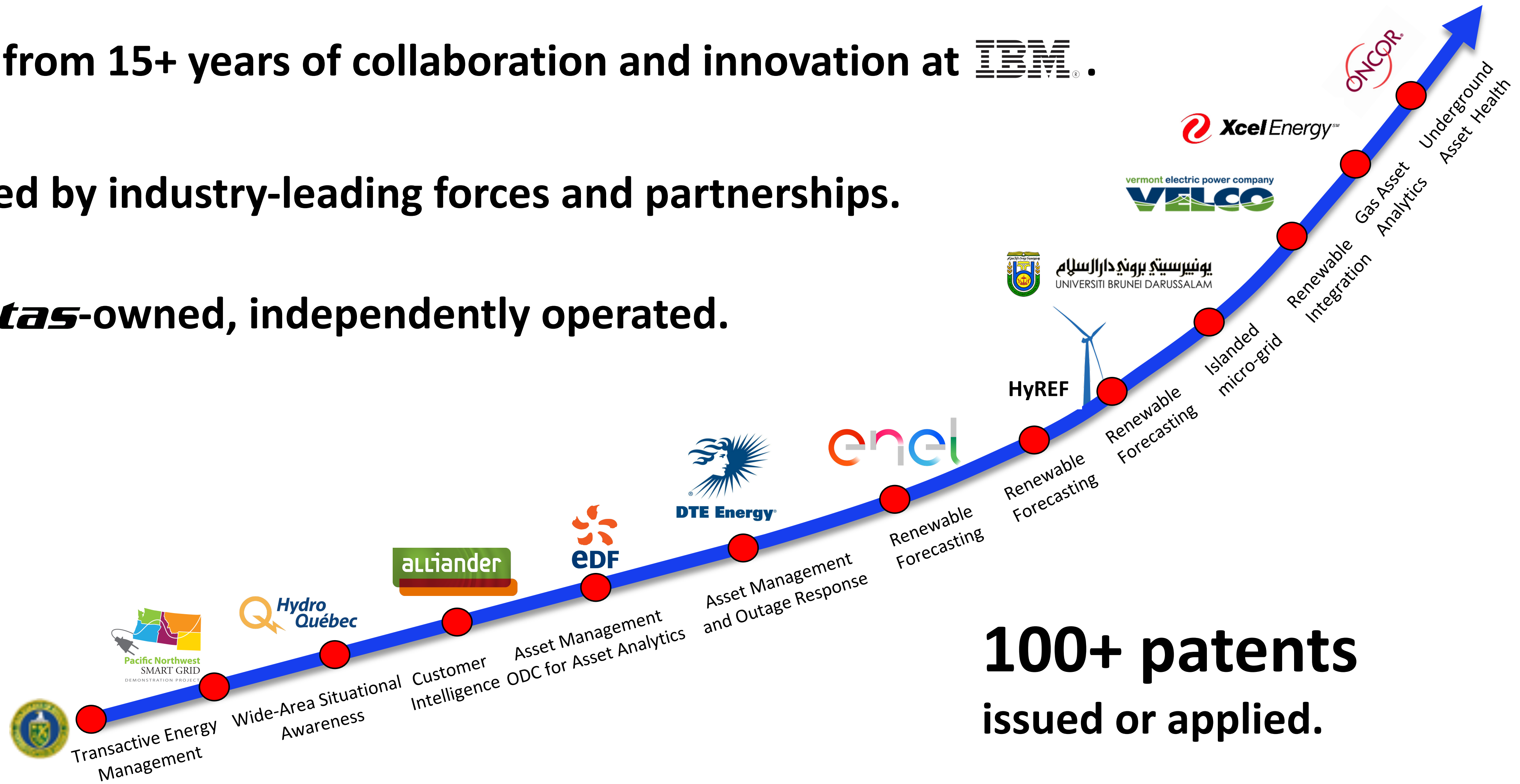
Our Vision

"Be the leading analytics solution provider for a sustainable, reliable and cost-effective energy future"

UTOPUS INSIGHTS

Our lineage

- **Built from 15+ years of collaboration and innovation at IBM.**
- **Backed by industry-leading forces and partnerships.**
- ***Vestas*-owned, independently operated.**



100+ patents

issued or applied.

Our Products

SEE → PREDICT → MANAGE → ORCHESTRATE

Scipher Vx

Intuitive and customizable visualization of time-series data; KPIs and alerts

Descriptive analytics

Scipher Fx

Accurate hyperlocal renewable energy and weather forecasting, powered by Wx

Predictive analytics

Scipher Rx

Leverage data patterns to predict failures and optimize asset maintenance

Prescriptive analytics

Scipher Ox

New intelligence to orchestrate the electric grid

Orchestration analytics

Scipher

Extensible hybrid SaaS/On-Premise/IoT energy analytics platform

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Utopus Insights with Big Data in Renewables

65 GW
capacity in Scipher

32,000+
wind turbine generators

8 years
historical failure data

26
countries

2.4 TB
daily data processing

55 billion
signals processed daily

102
active customers

100 TB
in data lake

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Trend in the renewable industry

Renewable assets are commodity

- O&M is the biggest cost
- Vintage year goes beyond 30 years

Failure Prediction/Cost Optimization

Favorable regulation is phasing out

- Traditional subsidy phase out
- Various penalty rules being introduced (e.g. India – deviation charge)

Reliable Power Forecasting

https://mercomindia.com/gujarat-regulations-solar-wind-deviation/

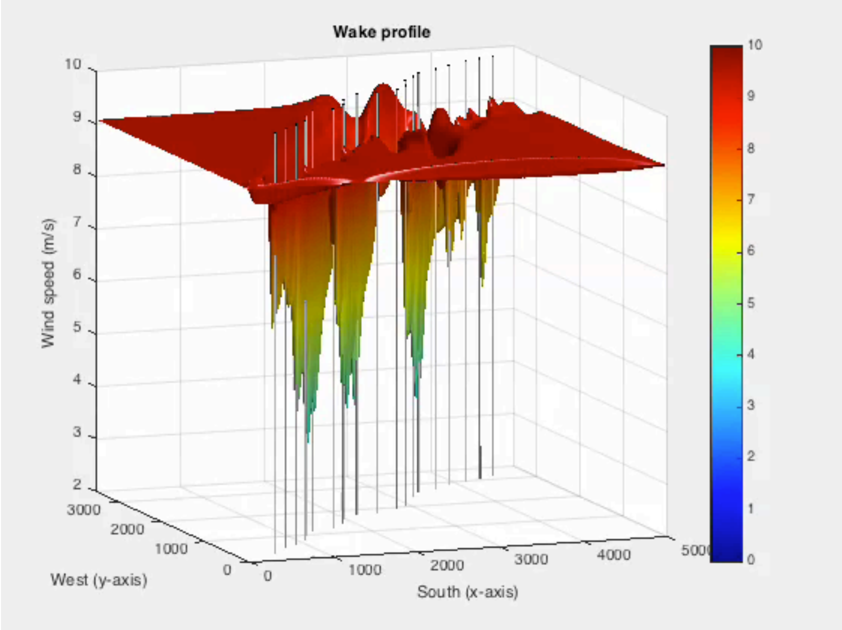
Complexity of Wind Power Forecasting

Weather data ingestion → Multi-dimensional data assimilation → Weather-energy correlation → Energy curve modeling → Spatio-temporal energy forecasting

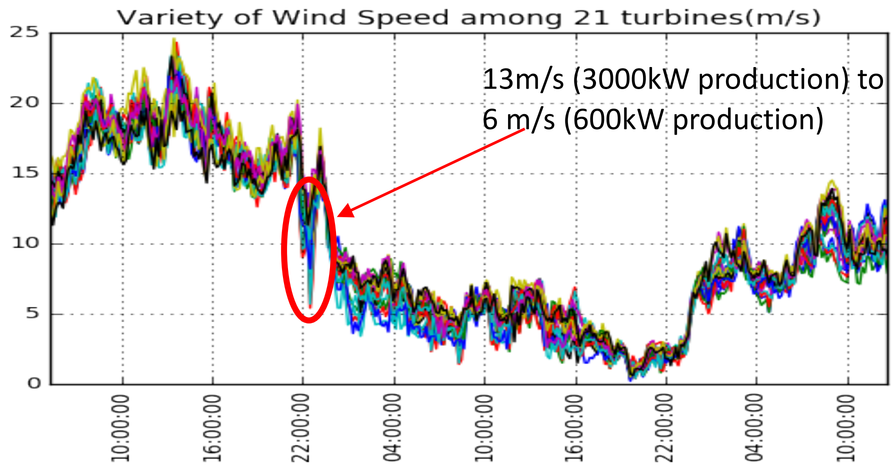
Weather data ingestion	Multi-dimensional data assimilation	Weather-energy correlation	Energy curve modeling	Spatio-temporal energy forecasting
Sources	Domain selection	Non-linear modeling	Design vs. actual	**Turbine level**
Wind specific insights	Wind customization	Seasonality modeling	**Wake effect**	Spatial aggregation
Quality	Wind ramp	Shoulder season modeling	Wind direction and speed	Temporal granularity
Granularity	Temporal granularity	Farm topology modeling	Loss modeling	Curtailment modeling
Geography	Forecast window		Turbine failures	Bidding optimization

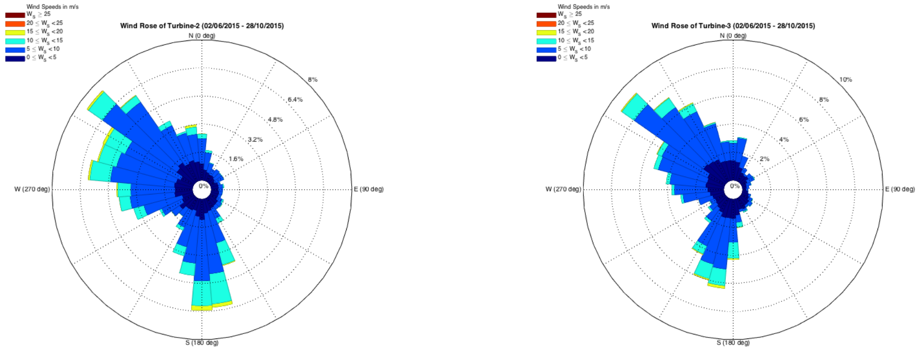
Role of Big Data in Wind Power Forecasting

Wake modeling using CFD



Wind speed variability



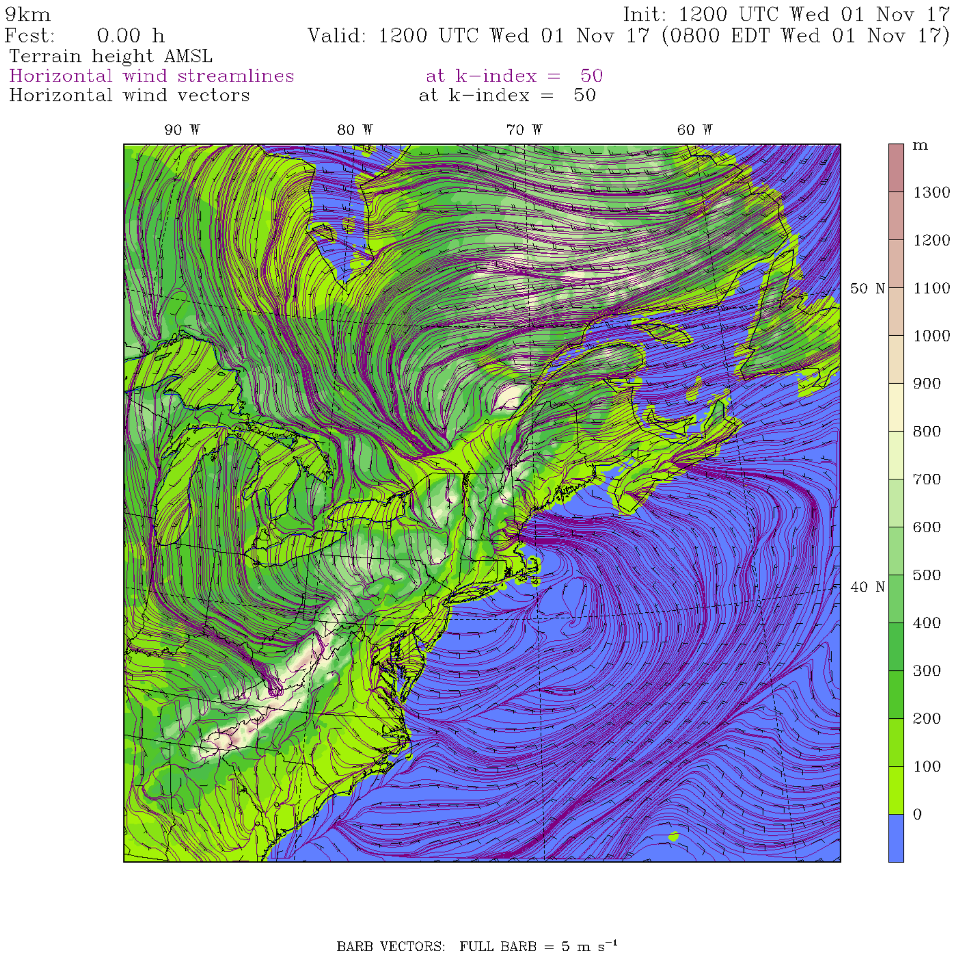


Yaw Control Variability between two nearby turbines

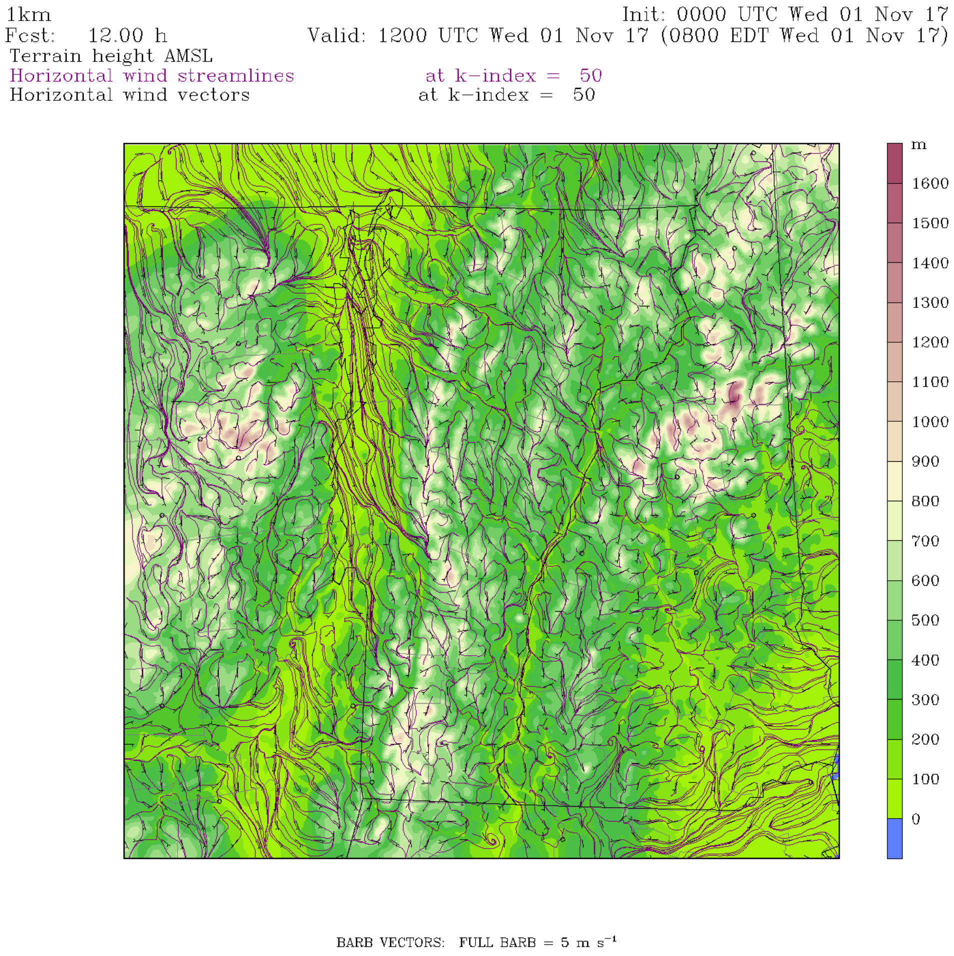
- **Computational methodology to pick a subset from various modeling**

Weather forecasting: impact of high resolution

NOAA/NCEP GFS



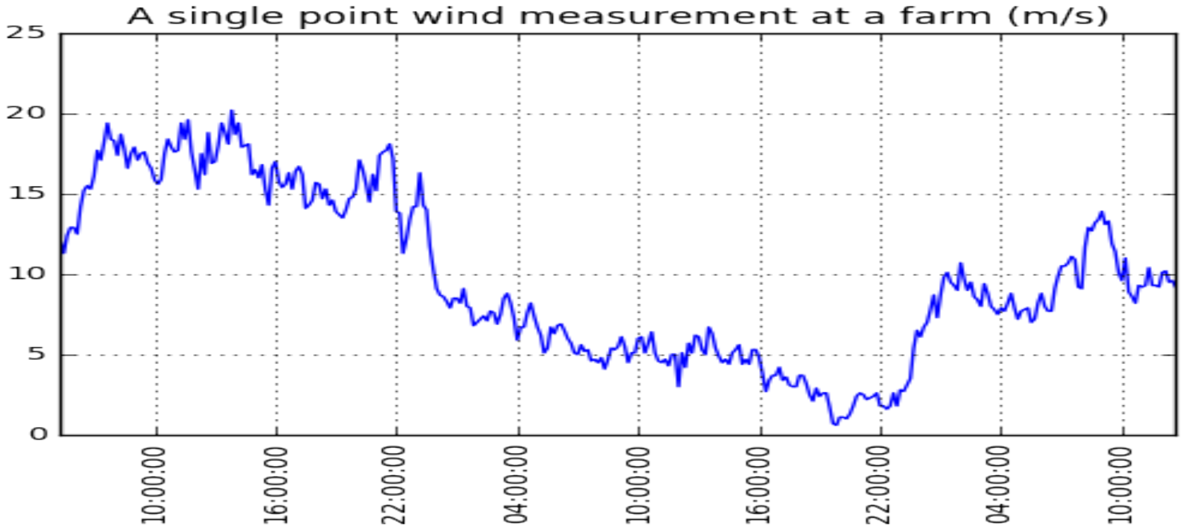
Wx 1-km Resolution

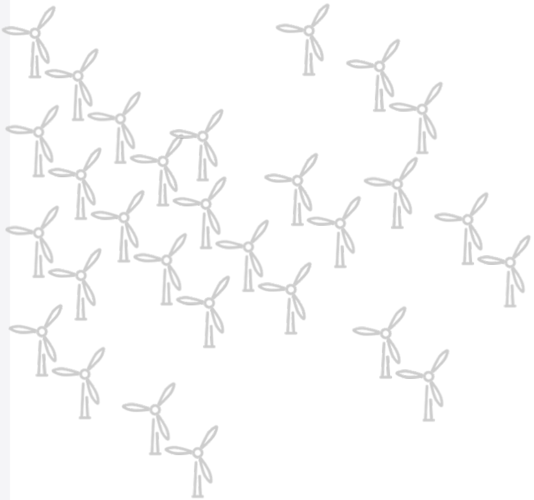


High resolution grids more accurately resolve the topology/landuse and delivers more accurate forecasts, especially for winds.

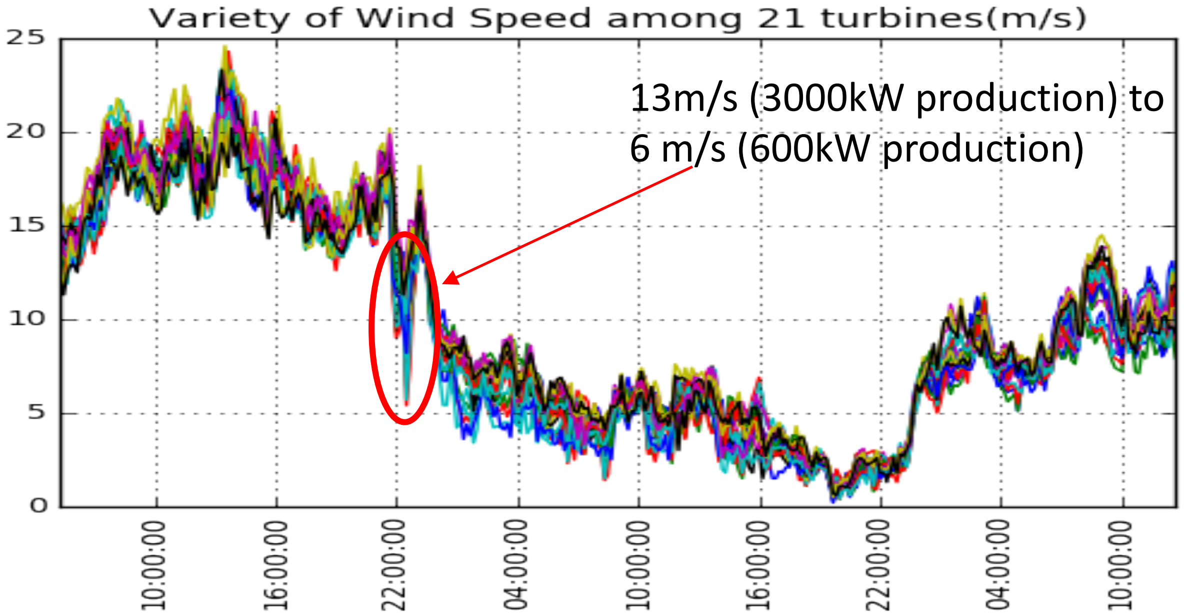
Hyper local wind forecasting is a must

A wind farm





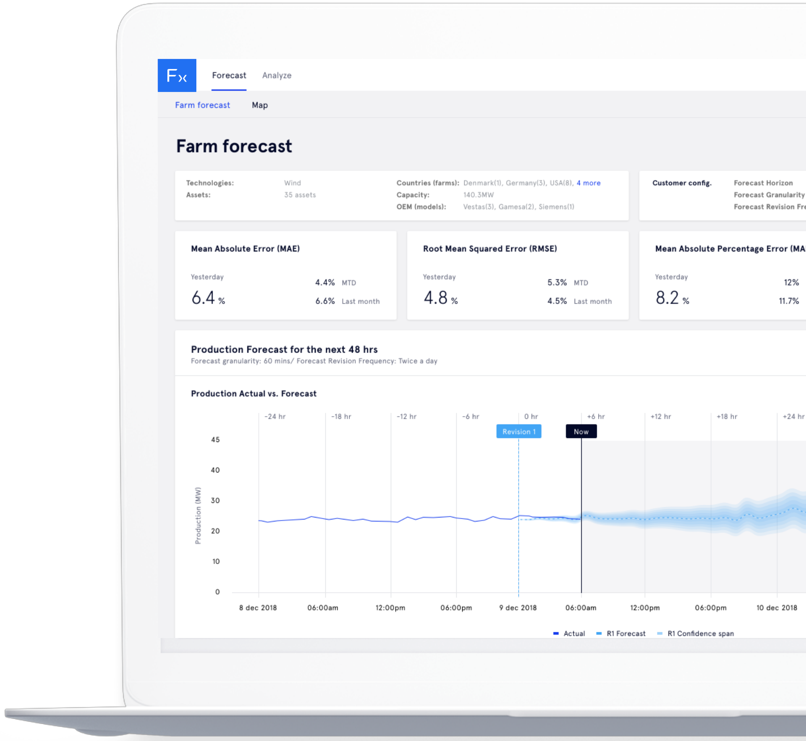
A farm of many turbines



- Wind speeds among turbines vary significantly
- For example, during the ramp events, the range spans between 13 to 6 m/s which result in the production 600kW to 3000kW (5x difference)

FORECASTING

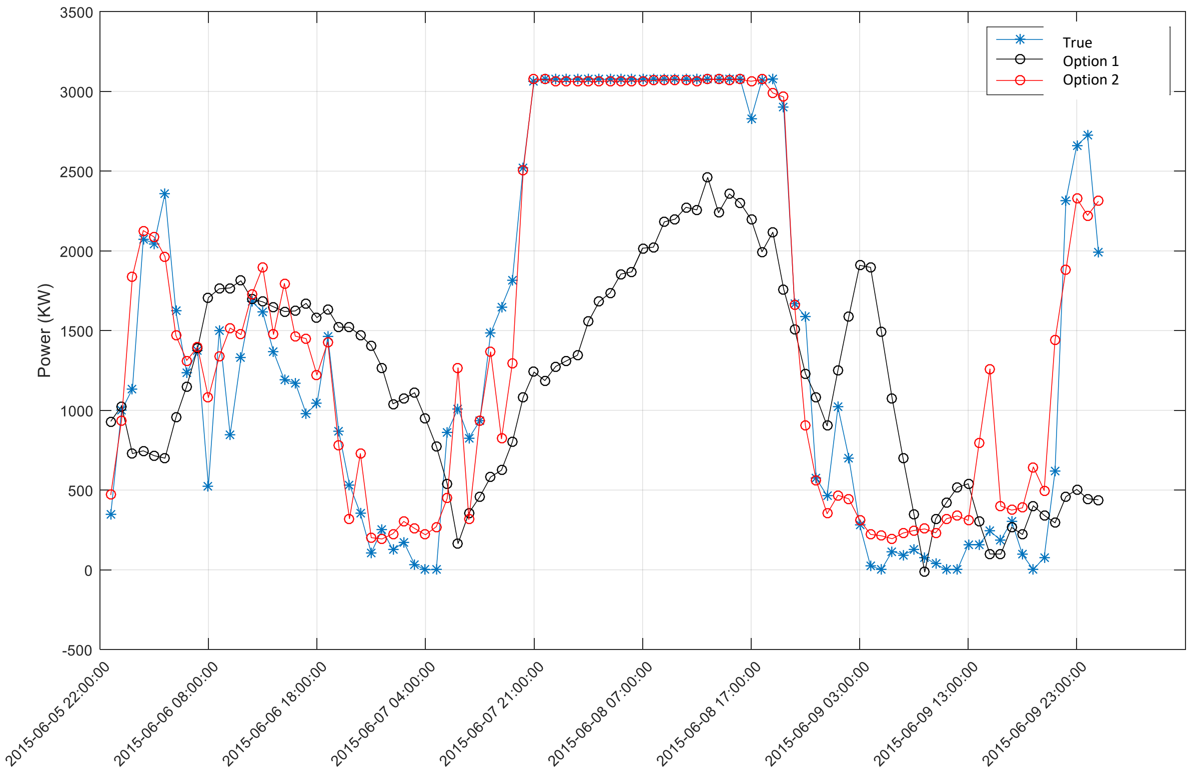
- Uses **hyperlocal weather forecasts** together with historical data from assets to precisely predict power from **wind and solar assets**.
- **Predicts available power production** at both farm and asset level within an hour-ahead to 48-hour forecast time horizon.
- Compares actual production with predicted production to calculate the **accuracy of the forecast**.
- Powerful tool to **optimize power bidding strategies**, with the addition of an advanced user interface to visualize forecast data.
- Forecast data delivered via sFTP, FTP and email with granularity of 5, 10, 15, or 60 minutes at **user-defined schedule**.



Problem 1: Minimize Regulation Imposed Penalty

- Power Forecasting is an Accuracy Game
- If we are to choose a forecasting, which one do we want to choose?
  - Option 1 or Option 2?

Day ahead wind power forecasting



Wind Power Forecasting

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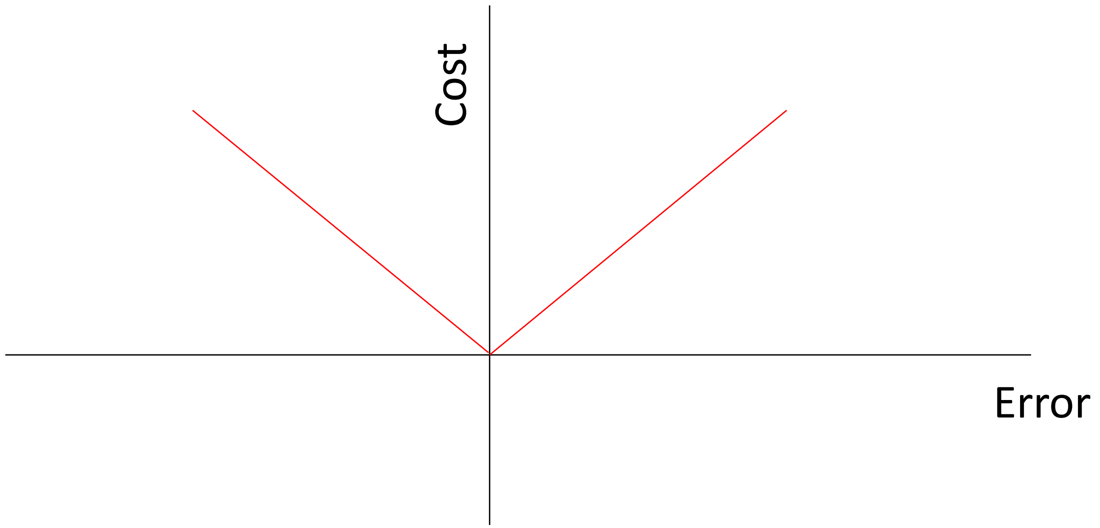
Problem 1: Minimize Regulation Imposed Penalty

Minimize (Mean Absolute Error)

s.t. physical constraints



Cost Function

Minimize (Cost)

s.t. physical constraints

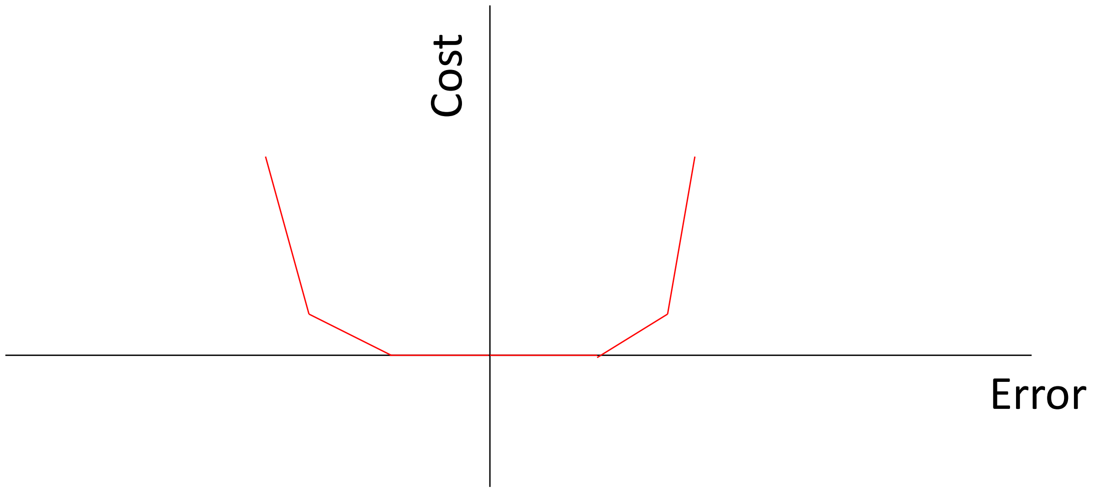
where

Cost = 0 if error is <=12%

Cost = error*tier1 if error is >12% & <=24%

Cost = error*tier2 if error >24%

** https://mercomindia.com/gujarat-regulations-solar-wind-deviation/



Cost Function

Wind Power Forecasting

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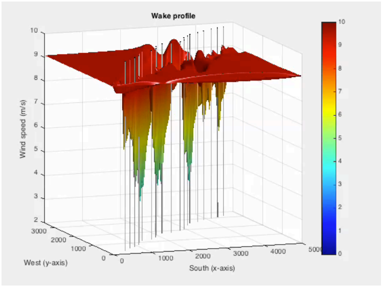
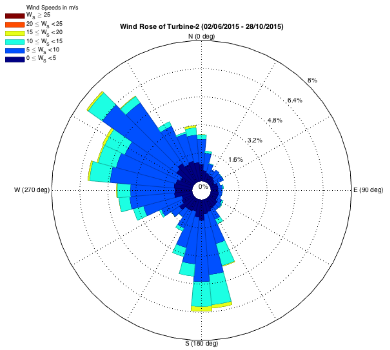
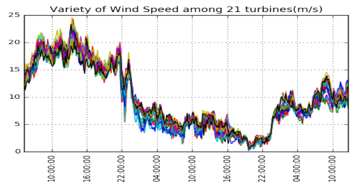
Problem 2: Exploring 100s of variables with the potential to overfit

- When p >> n, tuning the lasso method or other feature selection method is difficult
- As a starting point, we tend to sub-select features that are relevant to the forecasting (e.g. wind speed)
- But, in this data rich situation, every feature seems to be relevant with minor difference
- Robust numerical methods (possibly dense) going beyond a Lasso regression is needed







1000s variables

100s variables

1000s variables

$$\sum_{i=1}^{n}(y_i - \sum_{j} x_{ij}\beta_j)^2 + \lambda \sum_{j=1}^{p} |\beta_j|$$

Power

Input Variables

Regularization tuning parameter

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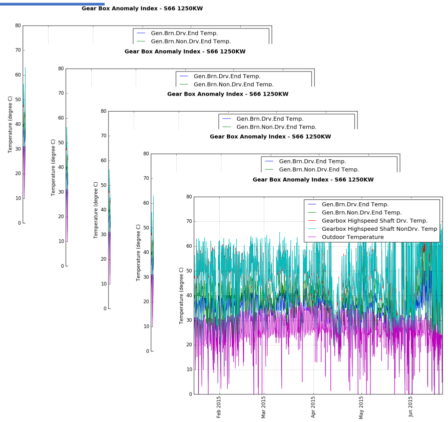
Scipher Rx

Why Predictive Analytics? – Distilling insights from big data

Component Failure Prediction

Traditional approach



Dump of Timeseries Data →

Overwhelming Amount of Data

Analytics driven approach

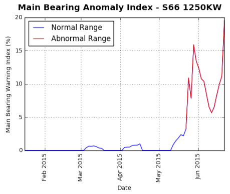
Multivariate Timeseries

Historical Major Breakdown Data → Data Curation → Machine Readable Breakdown Records → Labels for Machine Learning →

Machine Learning:

- Supervised Learning
- Multi-variate time-series analysis
- …

Insights →



Component Failure indicator

Effective Response to upcoming failures with enough lead time

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Traditional Failure Prediction Approach and Challenges

- Mechanical system model
- Nominal operating modes

- Observability
- Sensor dynamic range

- Model specific parameters
- Site specific parameters

Gearbox failure model

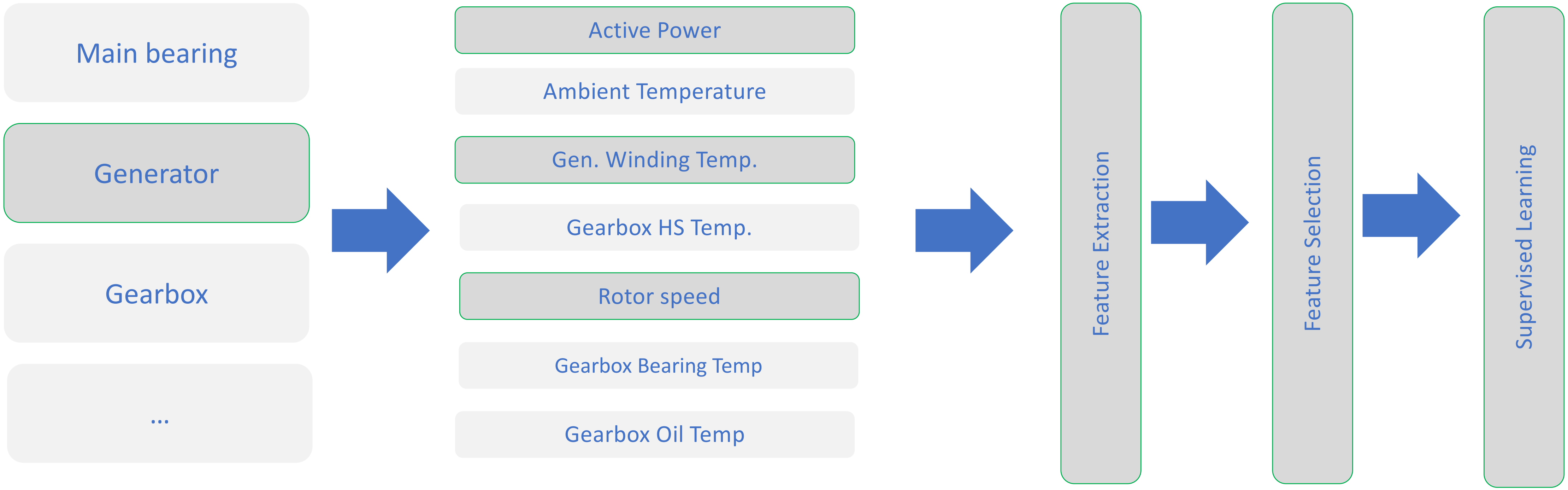
Temperature → High temperature warning

Noise → Resonant frequency analysis

Vibration → Excessive vibration alerts

- Expensive model tuning
- Early indication of failure can be easily overlooked if its nominal operating mode is loosely defined

Our solution: domain knowledge meets machine learning



Business case

Domain expertise

Machine learning expertise

102
active customers

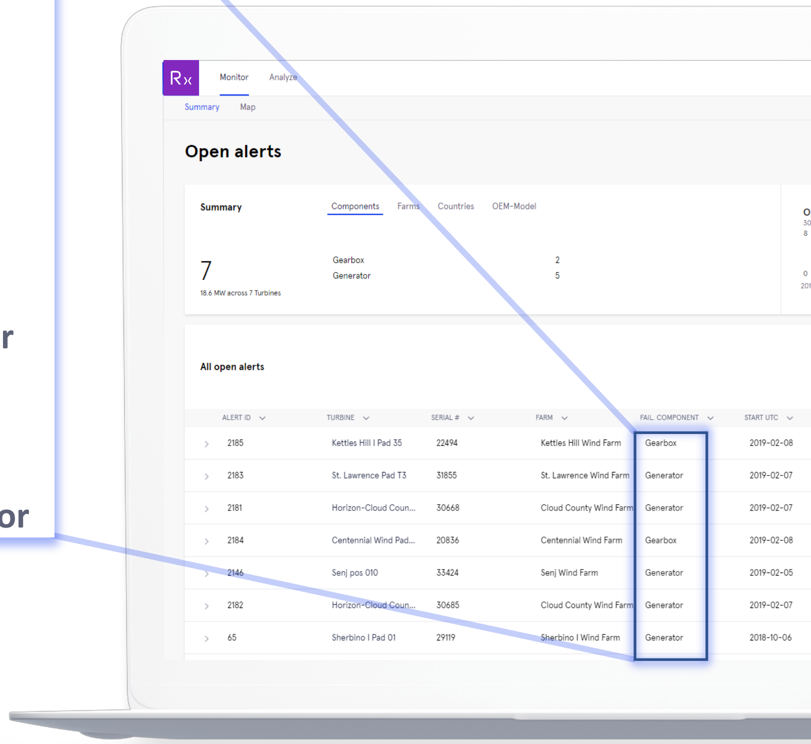
100 TB
in data lake

8 years
historical failure data

ASSET HEALTH

- Advanced predictive maintenance tool for wind assets with an **ability to predict failures at the component level**
- Powerful predictions in an intuitive user interface **reduces time employees use on manual analytics and unnecessary inspections**
- Plan (instead of react) to **save time and resources**

Gearbox
Generator
HSS
IMS
Bearing
Slip ring
Blades
Blade bearing
Pitch accumulator
Pitch cylinder
Proportional valve
Hydraulic unit motor
Main bearing
Yaw motor
Yaw gear
Cooling system motor



Component Failure Prediction

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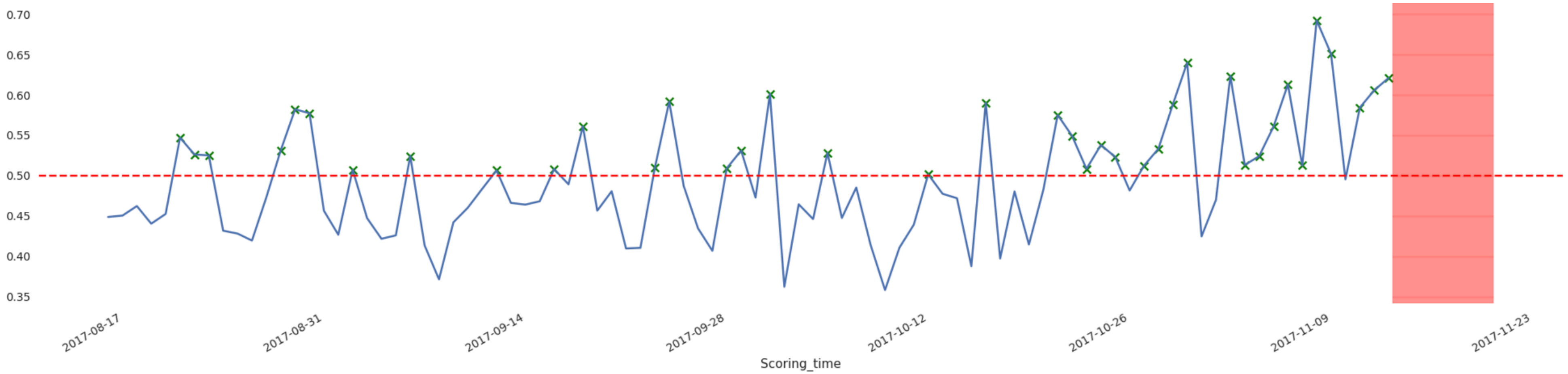
Problem 3: Fix it or wait?

1. Should we minimize the cost associated with the up-keep of the system?
2. What is the definition of optimality?

- Failure forecasting is good
- 'God knows when'
- Extremely uncomfortable to make a call to fix it



Component Failure Prediction

Concluding Remarks

Fx

FORECASTING

- On fine-resolution weather forecasting
- On fine-resolution measurement
- Scalability in model training and scoring

Rx

ASSET HEALTH

- Application of domain knowledge
- Rich historical failure records
- Exploiting computational efficiency and scalable framework for multi-OEMs (~ 200 high performance compute cluster)

Exploiting Big Data Means

- Rapid exploration of multiple data sources for accurate model building
- Canonical procedure to evaluate vast number of models (1 million models evaluated)
- Changes from an engineering driven approach to a data driven approach

Thank you

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