



Industrial Intelligence: Artificial Intelligence in Action

Presented by **Stuart Gillen and Jason Cox**



Agenda

- Maintenance Costs in Wind Industry
- Invenergy Use Case
- Machine Learning/AI Basics
- AI Architecture

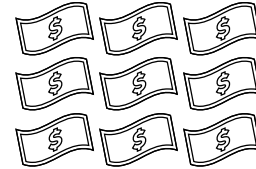
Growth of Maintenance Costs in Wind Power

“Global Data Power estimates the maintenance expenditure on wind turbines vital to productivity is expected to rise from \$9.25B in 2014 to \$17B in 2020.”



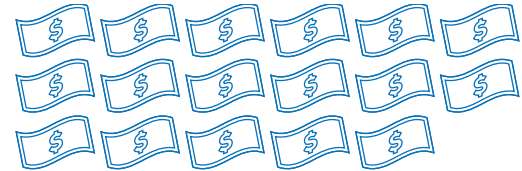
2014

\$9.25 billion



2020

\$17 billion



<http://www.edie.net/news/6/Win-turbine-maintenance-costs-to-nearly-doubl/>

Growth of Maintenance Costs in Wind Power

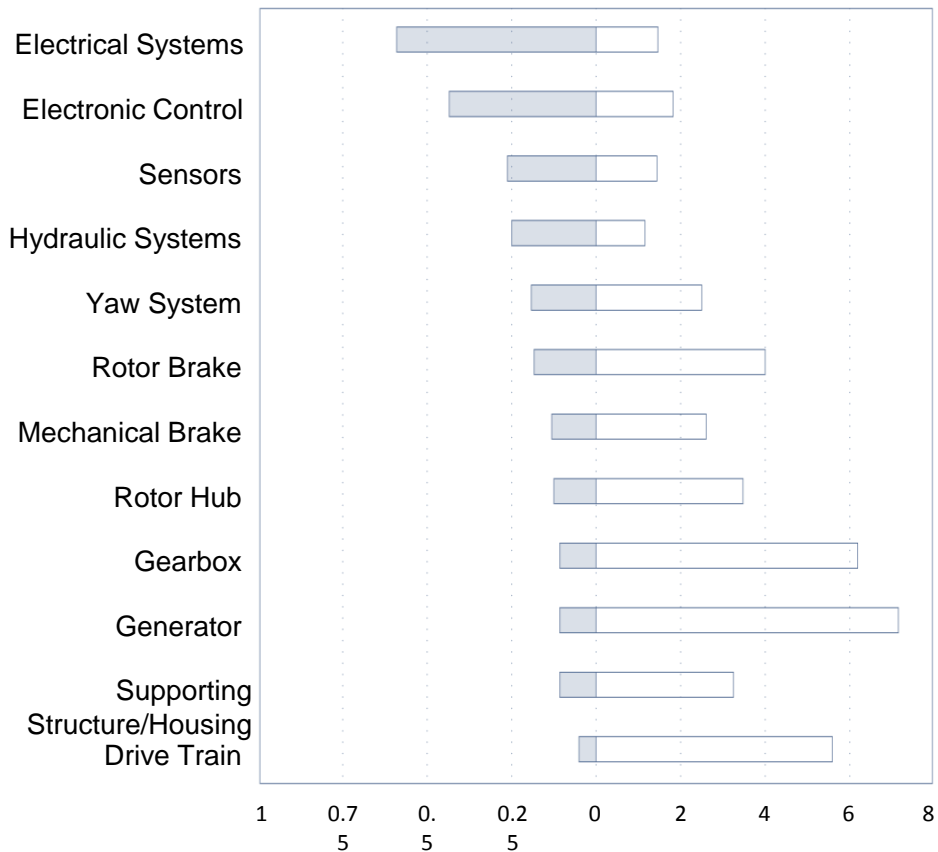
“It is estimated that in 2011, nearly \$40 billion worth of wind equipment in the U.S. will be out of warranty, thrusting the financial risk on the owner to provide cost-effective operation and maintenance.”



<http://www.renewableenergyfocus.com/view/26582/wind-getting-o-m-under-control/>

Cost of Gearbox Failures

- Romax Study estimated cost of planetary bearing failures >350k^[1]
- In 2014 Siemens wrote down €223M to replace bearings in fleet <2 yrs. old^[2]
- Controlling wind turbines with data-driven software could, models show, increase energy production by at least 10% and gains of 14-16% are possible^[3]
- The average gearbox failure rate over 10 years is estimated at 5%^[4]

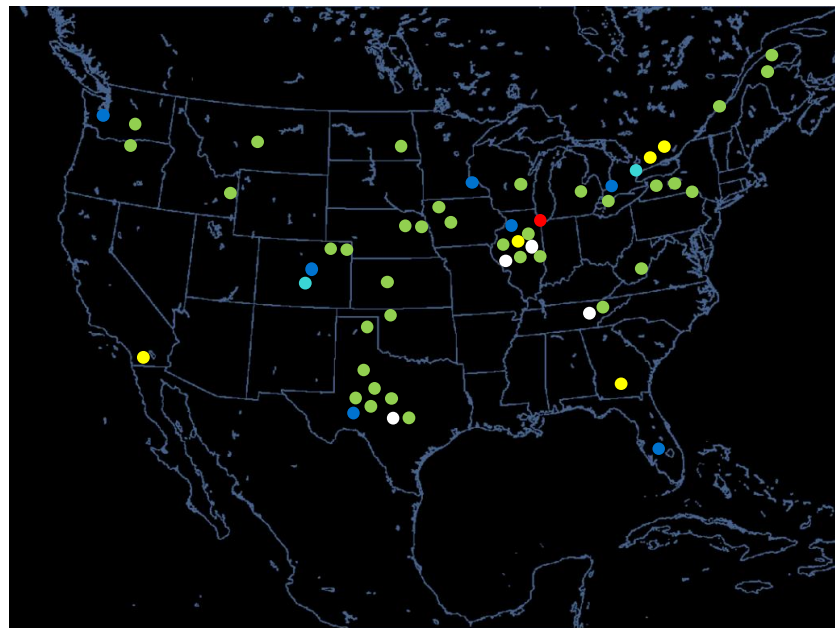




Invenergy Use Case

About Invenergy

- Develops, owns, and operates Power Generation and Energy Storage Units in US and Europe
- North America's largest independent wind power generation company
- Currently operating over 4GW of wind



● Headquarters

● Wind Project

● Solar Project Storage

● Regional Office

● Natural Gas

History of PI System

2008

- Entered into EA with 8 PI Systems

2012

- PI Coresight
- First solar project

2014

- Asset Analytics
- Migration to PI Web API

2016

- 45+ PI Systems
- Begin integration with SparkCognition

2011

- Notifications

2013

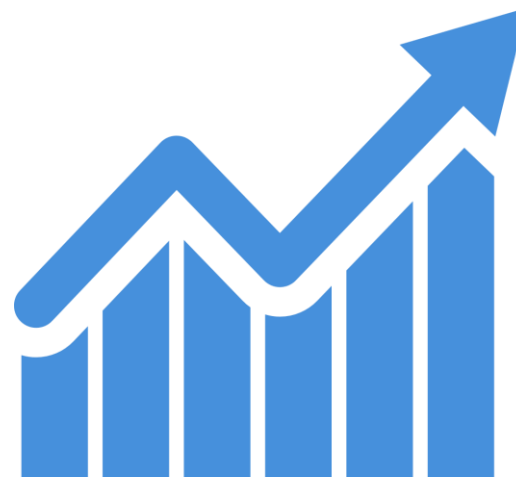
- Custom web apps using PI Web Services

2015

- First battery storage project

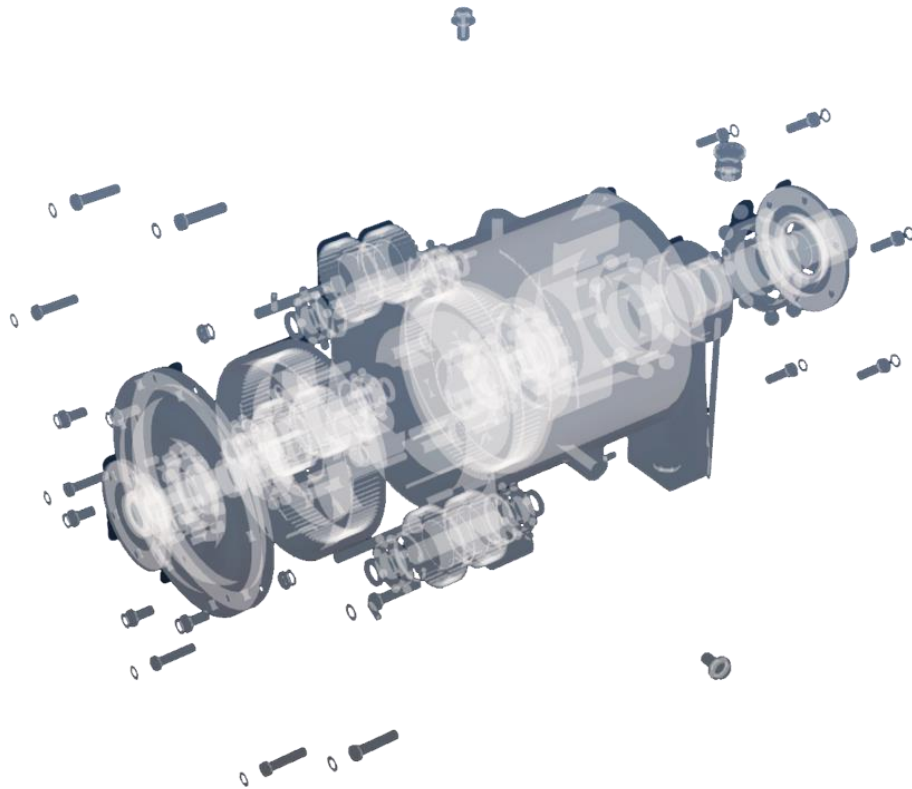
Analytics

- Metrics
 - Availability
 - Curtailment Losses
 - Performance
 - Turbine Anomalies
- Methods
 - MATLAB
 - Via PI OLEDB
 - PI DataLink
- Focused on recent history



Gearbox Monitoring Application Trial

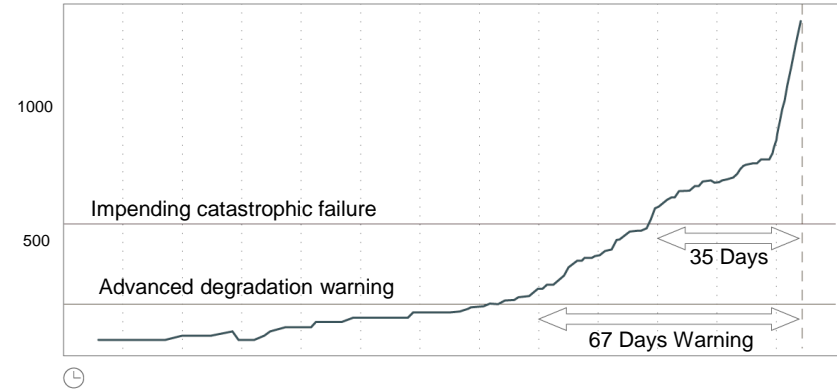
- Desired Results
 - Predict gearbox failures with 30-60 day advanced notice
 - Zero or minimal false positives
- Data Provided
 - 4 years of historical data from site of ~100 turbines
 - 27 data variables at 10 minute resolution, no vibration variables collected
 - Major component failure logs



SparkCognition giving Invenergy strategic value



- Application provides global wind fleet visibility
- Overall risk index determines asset health
- Component risk index allows for actionable maintenance insight



- Catastrophic failure forewarning > 1 month
- Advanced degradation forewarning > 2 months

Ongoing Engagement

- Rolling out to remainder of fleet (~3,000)
- Explore predictive models for other major components (pitch systems, blades, generators, etc.)

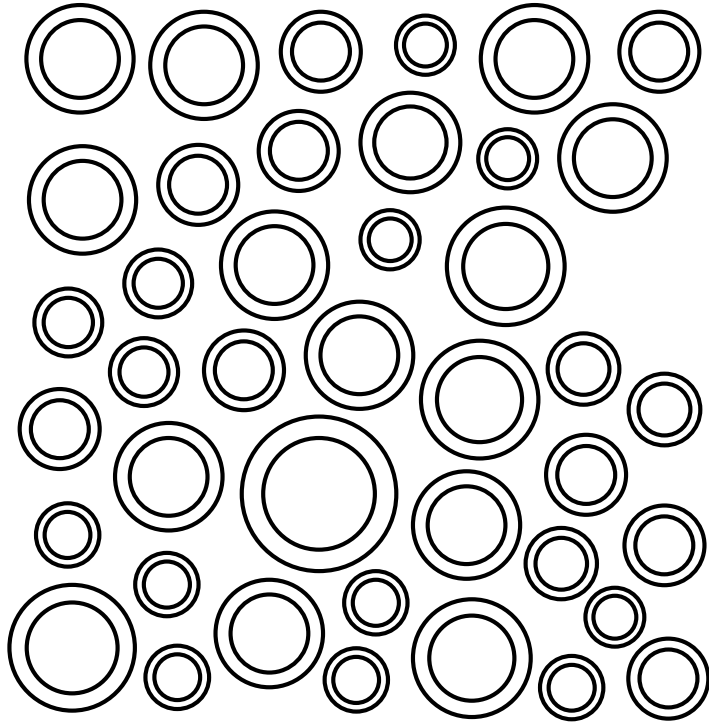


Basics of Machine Learning

Machine Learning is already everywhere

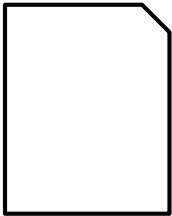
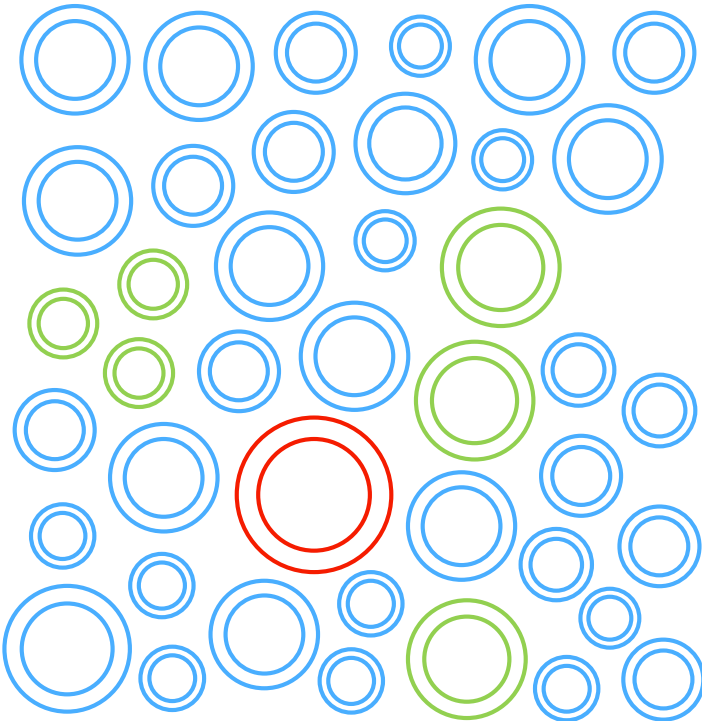


Unsupervised Learning

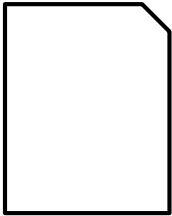


How do you label these?

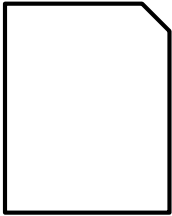
Unsupervised Learning



Small

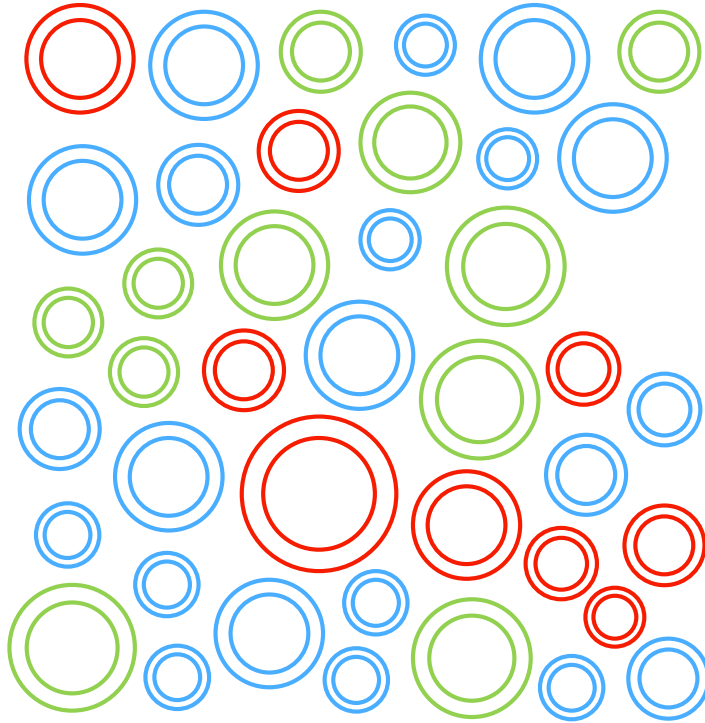


Medium



Large

Supervised Learning



Red



Green



Blue

Unsupervised vs. Supervised Learning

Unsupervised

Index	Date	Time	Asset ID	Value
2	5-Apr-10	7:01	750	89
93	22-Mar-13	8:19	904	79
27	20-Oct-14	8:26	545	74
5	10-Jul-12	7:38	552	86
68	15-Sep-11	8:13	942	74
29	1-Jun-11	8:44	900	72
91	20-Jul-11	7:14	587	50
54	12-Jun-10	7:36	765	95
20	5-Sep-14	8:25	813	39
44	30-Jun-11	7:07	983	71
100	5-Oct-12	7:35	802	34
66	12-Mar-10	7:39	726	47
45	6-May-11	7:30	973	98
84	10-Dec-12	7:17	504	68
43	9-Jul-14	8:07	567	74

Supervised

Action Taken	Component
Repair	Blade
Unknown	Blade
Repair	Gearbox
Replaced	Gearbox
Replaced	Gearbox
NTF	Generator
Good	Generator
NTF	Blade
Repair	Generator
NTF	Gearbox
NTF	Blade
Repair	Gearbox
Unknown	Gearbox
Repair	Blade
Repair	Gearbox

Impending catastrophic failure

Advanced degradation warning

35 Days

30 Days Warning

Cognitive Analytics – Beyond Machine Learning

Powerful advancements in state of the art



Natural language processing

- Enables recall of answers, in context
- Analysis of human readable text for clues, insights and evidence



Deep Learning and Reasoning algorithms

- Improves accuracy
- Learns complex patterns
- Scales efficiently: High speed, large data implementations
- Make decisions in the absence of training data



Automated Model Building and Infinite Learning

- Watches data and derives rules
- Incorporates human feedback to strengthen or dismiss conclusions
- Automatically learns from feedback and greater volumes of data
- More data = more accuracy, capability & insight.



Powerful Visualization with Evidential Insights

- Provides transparency and evidence about what the cognitive system is learning and proposing
- Presents data elegantly – Analyst friendly interface, easy feedback
- Elevates evidence / reasoning for machine decisions

AI successfully tackling multiple wind use cases



Prognostics for Gearboxes, Main Bearings, Blades, Pitch Bearings
(We work across any data and any asset type)



Yaw Drive Misalignment



Safety Applications using NLP

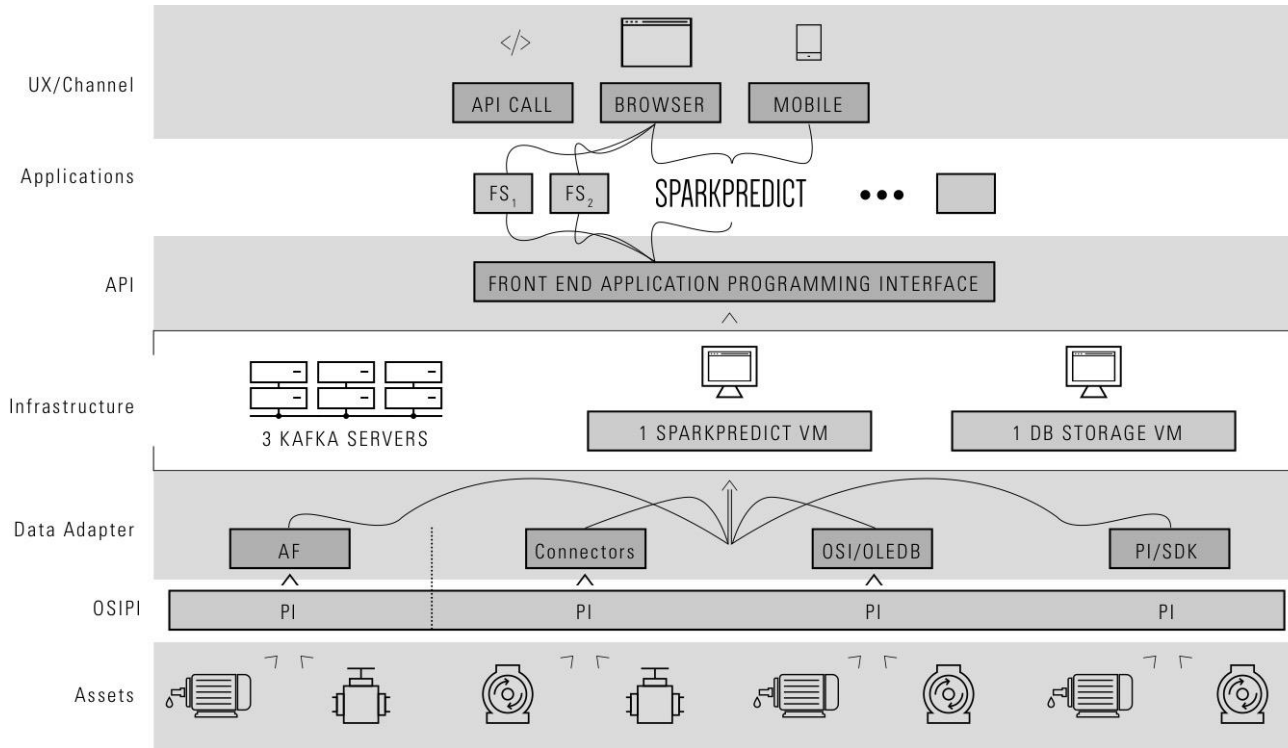


Predicting Icing on Wind Turbine Blades



AI Architecture

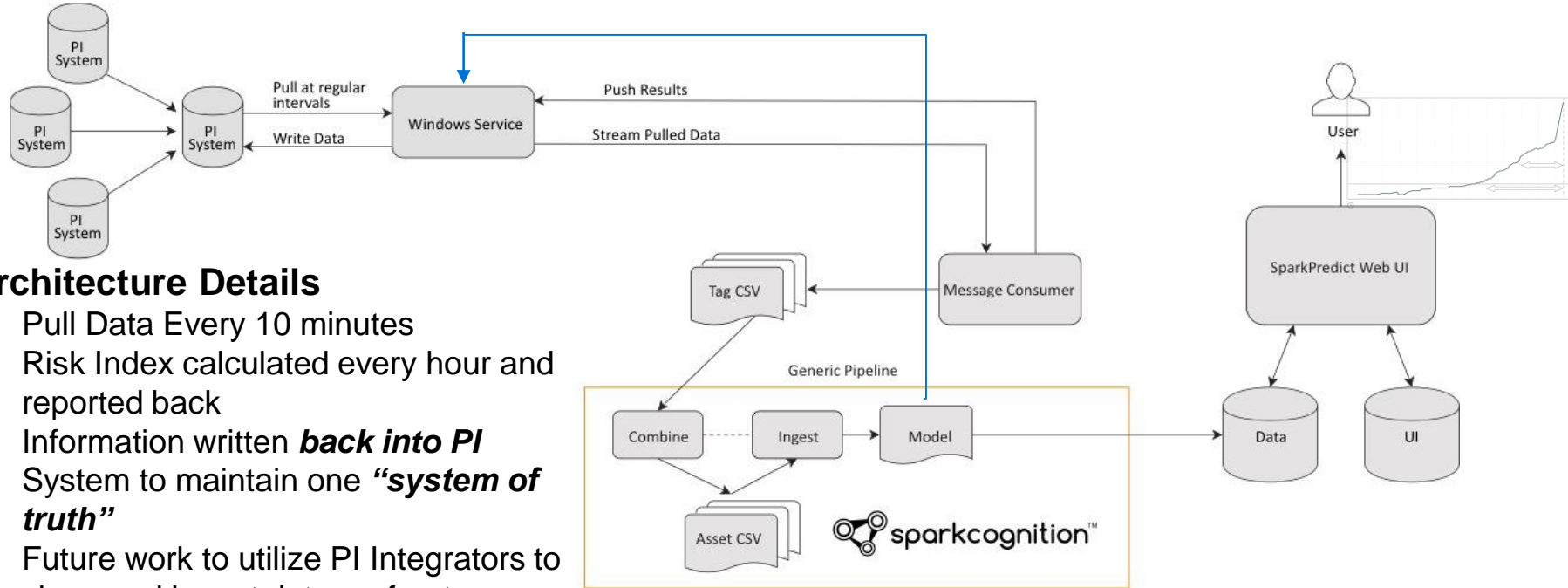
Data adapters provide flexible approach to system architecture



Benefits of the PI System

- Asset Abstraction
- Built-in Asset Framework (AF)
- Metadata Support
- Multiple Interfaces for Data Exchange
- Archiving Capabilities
- Compression Support

Machine Learning requires a robust, agile and Big Data Architecture



Architecture Details

- Pull Data Every 10 minutes
- Risk Index calculated every hour and reported back
- Information written **back into PI System** to maintain one **“system of truth”**
- Future work to utilize PI Integrators to clean and ingest data up-front
- Triggering AF Event frames based on alarms from SparkPredict

Leveraging Artificial Intelligence and the PI System for Predictive Maintenance

COMPANY and GOAL

Invenergy, a wind power company, and SparkCognition, an AI company, wanted to **predict gearbox failures in advance** to reduce maintenance costs



Invenergy

Maintenance costs in wind operations are increasing at an unsustainable rate.



CHALLENGE

Unexpected gearbox failures costing Invenergy large amounts in repairs and unscheduled downtime

SOLUTION

SparkCognition used PI System to build a machine learning application capable of predicting failures

RESULTS

Invenergy has forewarning of catastrophic failures >1 month in advance and advanced degradation >2 months in advance

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Questions

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谢谢

Danke

Merci

Gracias

Thank You

ありがとう

Спасибо

Obrigado