AVEVA PI WORLD

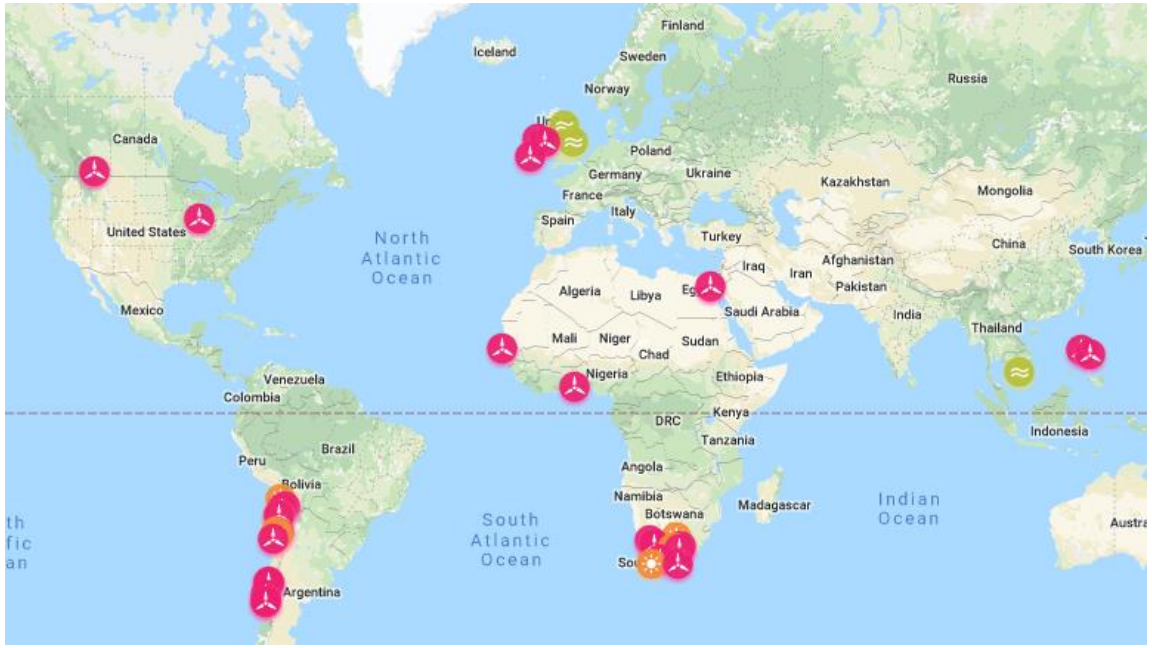
PI System for Renewables

Business Intelligence, Remote Monitoring and OT Health

Presented By: Alan McCarthy

About Mainstream Renewable Power

- 2008 – Company founded
- 2021 - Part of Aker Horizons
- Development pipeline
  - Onshore wind: 5,345 MW
  - Offshore wind: 1,700 MW
  - Solar : 5,931 MW
- In Pre-Construction & Construction
  - Onshore wind: 1264 MW
  - Solar: 350 MW
- Delivered into Operation
  - Onshore wind: 1,143 MW
  - Solar: 100 MW



About Alan McCarthy

- BE Energy Engineering
- Managed PI System install in Q2 2012
- Previously Managed Wind Farms in Ireland and AB, Canada
- Currently Central Generation Operations and Business Analytics Manager

Business Challenge

- Multiple Wind/Solar OEMs and Substation SCADAs
- External data sources (HTML, SQL)

Multiple Data Sources

- Offices & Sites in 6 continents
  - Reduce time spent
    - Reporting
    - Finding problems
    - Performing Analysis

Dispersed Sites & Staff

- Usability and Scalability
- Integrate with
  - MS Office
  - Maintenance Management System (RGC)
  - Preconstruction Energy Analysis System (EAG)
  - Analytics Tools (MS Power BI)

Integration, Long-term Architecture

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The solution – OSIsoft PI & Complimentary Systems

- OSIsoft PI System as central data historian
  - MS SQL database in parallel
- Integrates with all of data sources/protocols
- Integrates with external systems
  - Preconstruction Energy Analysis (EAG)
  - Maintenance Management System (RGC)
  - MS Power BI
- Excellent online resources and training
- “Off the shelf” software systems
- Asset Framework acts as Asset Register and “link point” for data & documents.
- Remote Monitoring through PI Vision and PI Notifications
- High Resolution data allows for Grid Code Compliance monitoring
- PI SNMP and PI Ping Interfaces used to monitor OT Health

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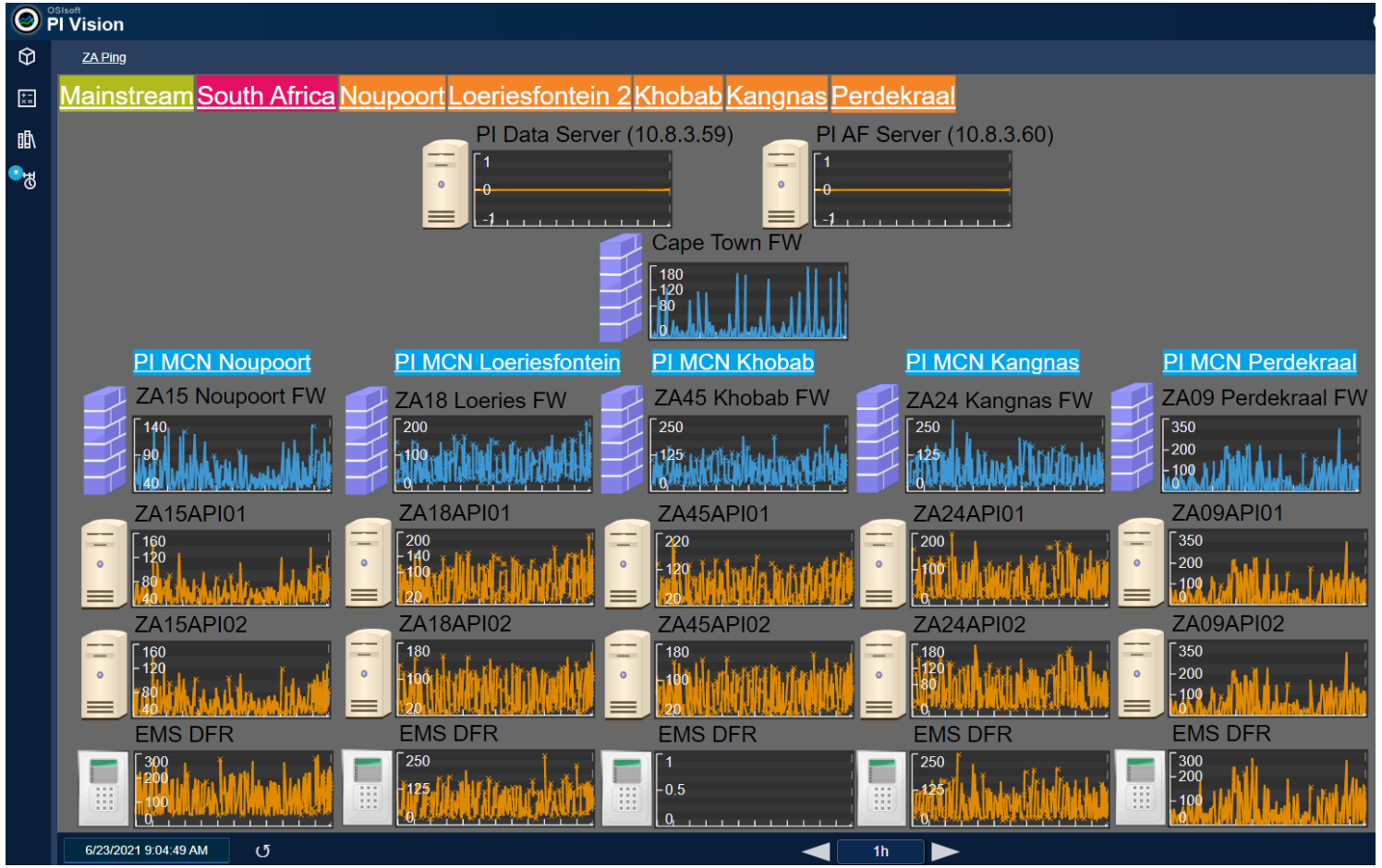
Today’s Agenda

- Remote Assets – PI Interfaces – How we collect data
- OT Health and Cybersecurity
- PI Core – PI Asset Framework, PI Notifications
- Putting the data to work - PI Datalink, PI Vision, MS Power BI

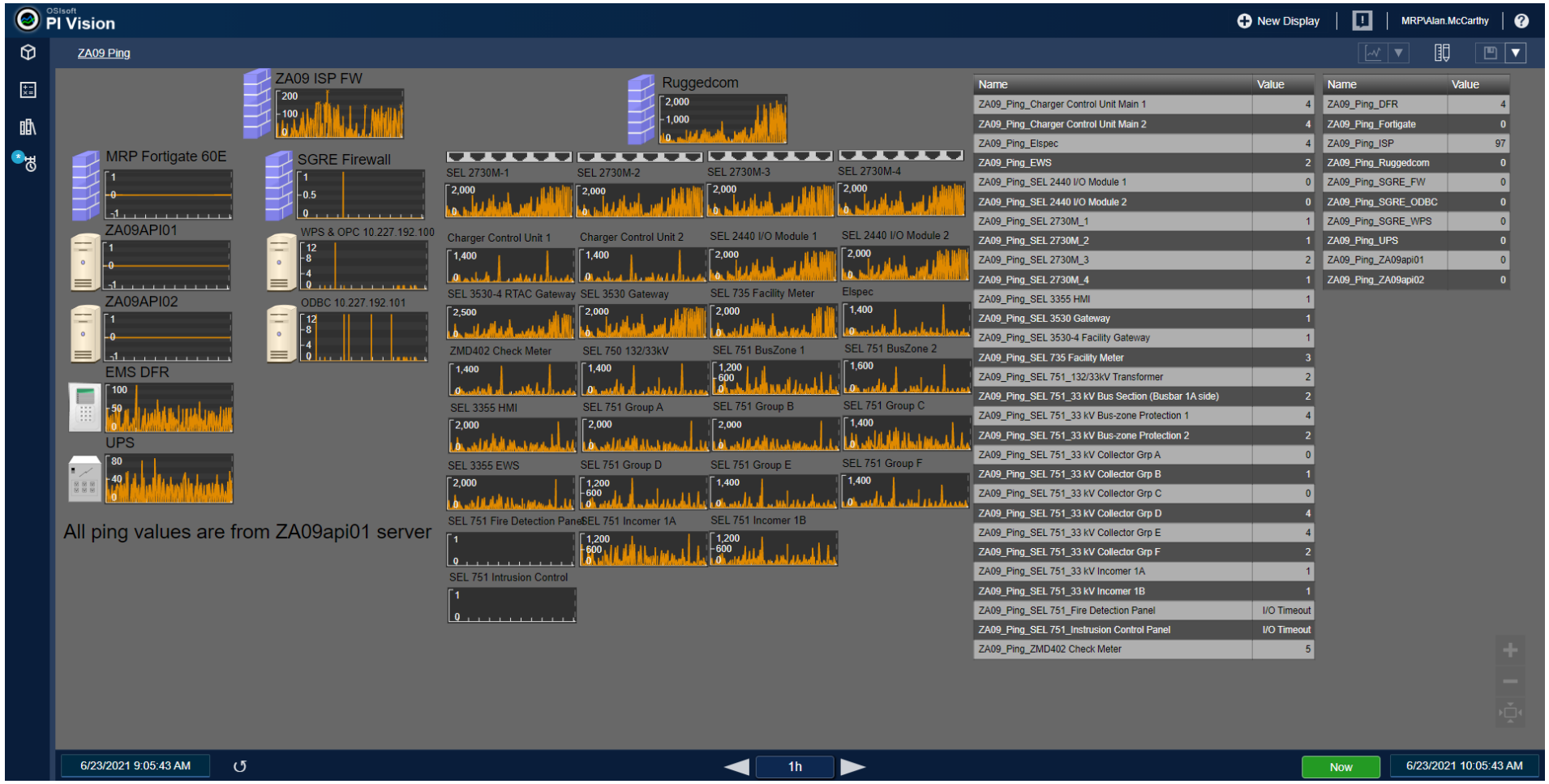
Interfaces – Traditional and PI MCN

- PI OPC XML DA, PI DNP3 & PI Modbus have been used since inception
  - WTG SCADAs offer OPC DA or OPC XML DA interfaces
  - Substation and BOP SCADA offer Modbus or DNP3 interfaces
- OT Health monitoring is increasingly important on projects that are out of BOP Warranty period
- PI Ping has been rolled out on all projects, with PI Notifications set up to alert if any equipment drops off the network
  - Set up for PI Core and PI API Nodes
  - Set up for OT equipment



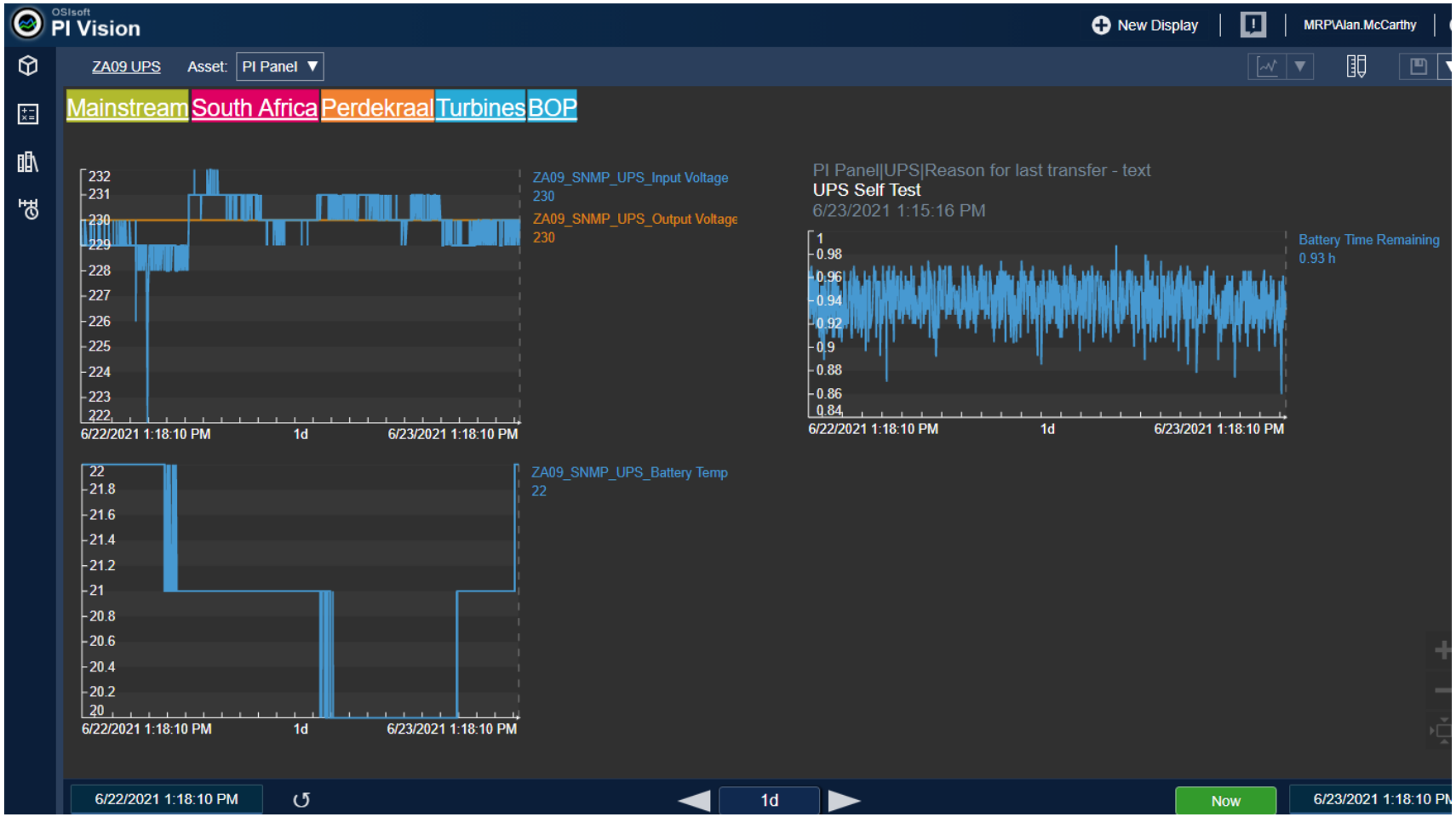
Interfaces – Traditional and PI MCN

- PI Ping – OT
- Ping
  - Substation Firewall
  - Substation Switches
  - Relays
  - Gateways
  - Meters
  - Servers
  - UPS
- PI Notifications synced with Email to Voice services for critical faults



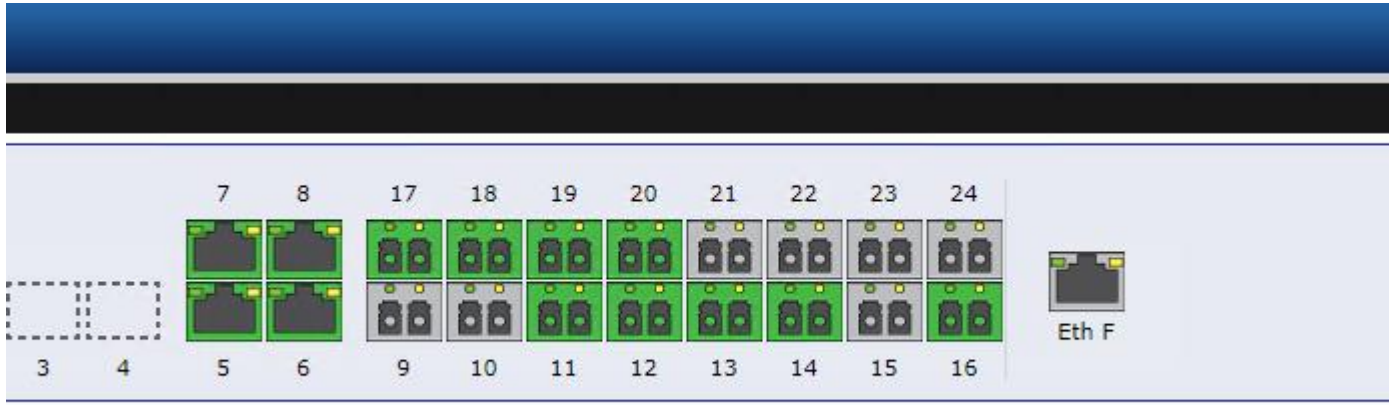
Interfaces – Traditional and PI MCN

- PI SNMP – OT
- SNMP
  - UPS
  - Firewalls & Switches
  - Relays
  - Servers
  - Automation PCs (HMIs)
- SNMP rollout in early stages
- APC UPS monitoring
  - Input & Output Voltages
  - Reason for last transfer to Battery
  - PI Notification when on battery power
  - Battery Life Remaining
  - Battery Temp



Interfaces – Traditional and PI MCN

- SEL 3355 HMI monitoring
  - CPU Load & Core Temp
  - Drive Health
- Switches and Firewall monitoring
  - Will shortly bring main health points into PI
- OT equipment failures are costly
  - Can cause collector circuits to be forced offline
  - Can leave the WF uncontrollable remotely, and at risk of temporary disconnection
- PI SNMP offers a huge increase in our OT health monitoring capabilities



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System Statistics

Active Session(s):	1
System Uptime:	311d 5h 22m 31s
Power Cycles:	129
Total Runtime:	8601 Hours

Diagnostics

Power Supply A:	Model: SEL-9330-A S/N: Voltage: 12.386
Power Supply B:	Model: SEL-9330-A S/N: Voltage: 12.253
RAM:	OK
FLASH:	OK
FPGA:	OK
Clock:	OK
Clock Battery:	OK
Ports 1-8 Temperature:	55°C
Ports 9-24 Temperature:	56°C

Interfaces – Traditional and PI MCN

- PI SNMP – Next Steps
  - Most Substation OT hardware on our projects have SNMP interfaces
  - This has typically been under utilized – many valuable early warnings on critical plant equipment are not being monitored
    - Would be extremely interested in other users' experiences with this interface
  - Stop waiting for OT equipment to fail when any substation issue can be a major revenue loss
  - By Q4, we are aiming to have all OT equipment's critical SNMP points in PI

- In parallel, we are looking at better backup of config of OT equipment settings
  - A large percentage of our plants OT is SEL equipment – investigating SEL 5045 software package to auto backup configs
  - A library on MS Sharepoint is set up for SCADA Configs for other backups

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Cybersecurity and Infrastructure

- PI Core currently on “on-premises” servers
- Planning to migrate these to Azure AD joined servers
  - PI Vision will be on separate VLAN to PI Data Archive & PI Asset Framework, in line with OSIsoft recommendation
- VPN links between Wind Farms and PI Core is locked to only the required ports and IP addresses
  - FW Policies minimized – specific rules for all traffic, “deny first” approach
- Regular plant based staff increasingly using PI Vision & MS Power BI – minimizing need for VPN access to PI Core
- Windfarm based PI Infrastructure (PI API Nodes) on a separate VLAN to OT equipment – connections limited to necessary only
- Carry out external pen-tests to each Wind Farm
- Investigating rollout of Darktrace AI based cybersecurity on PI API Node VLAN and Substation Automation OT VLAN

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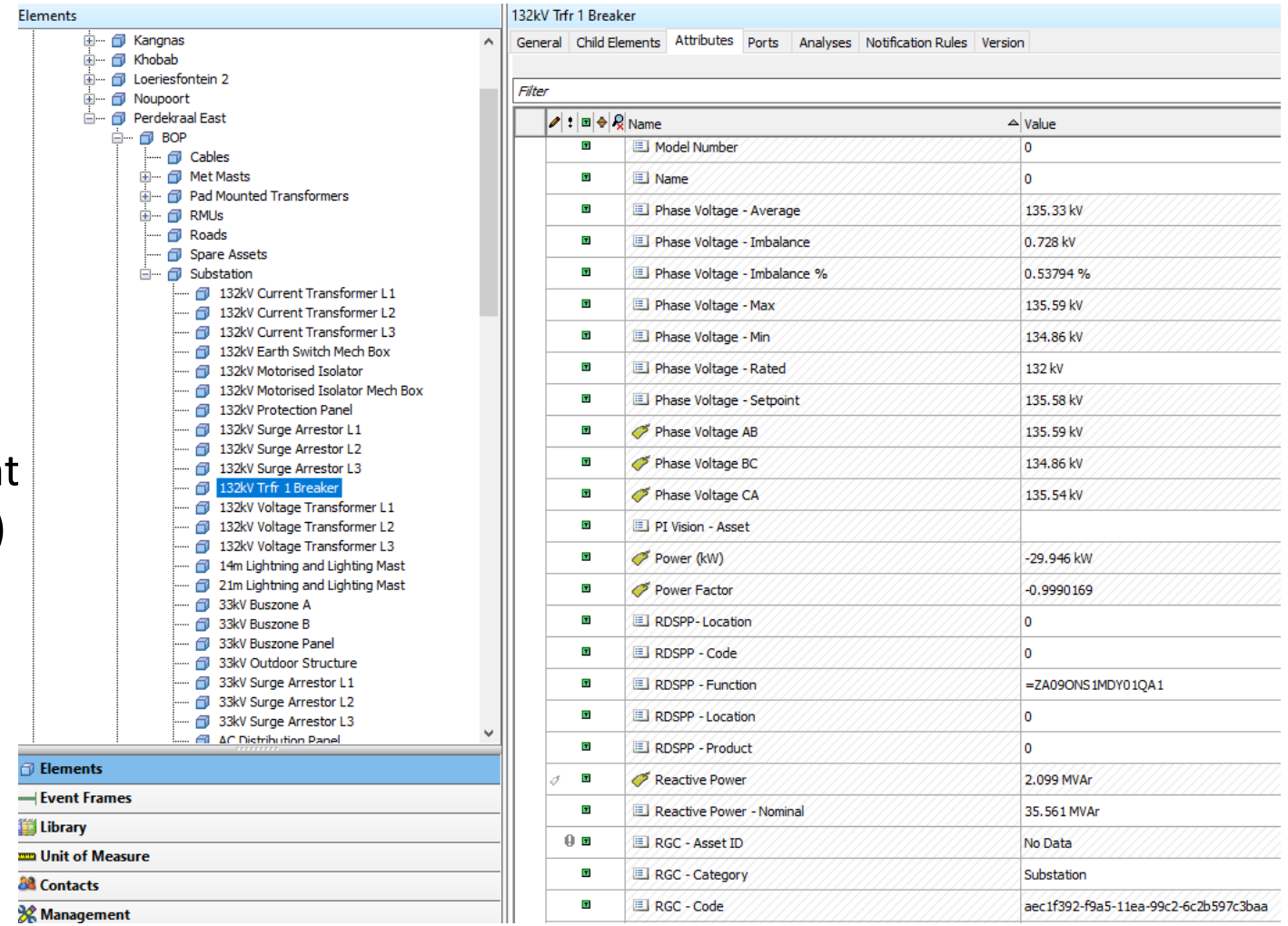
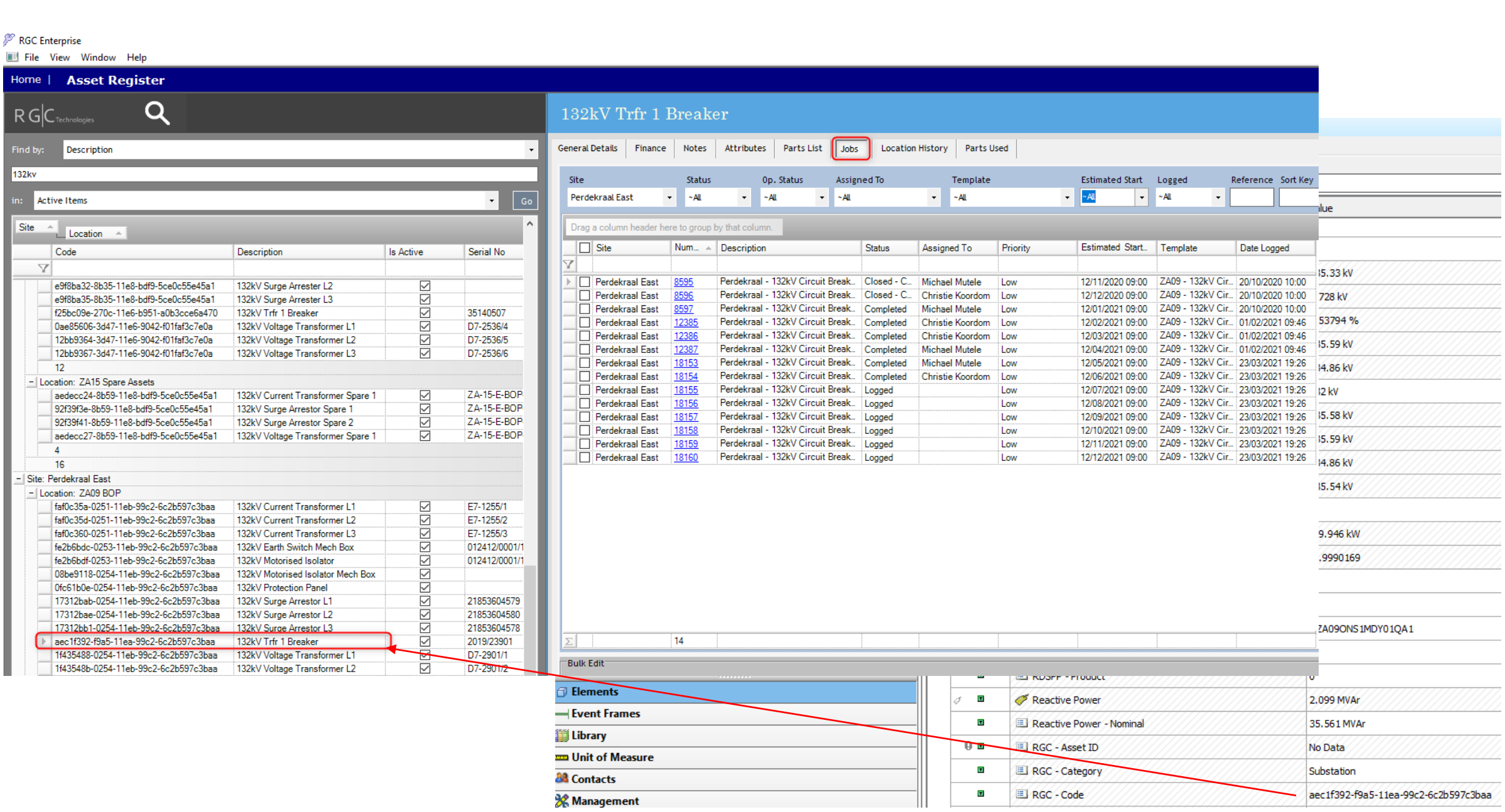
PI Asset Framework – The central link

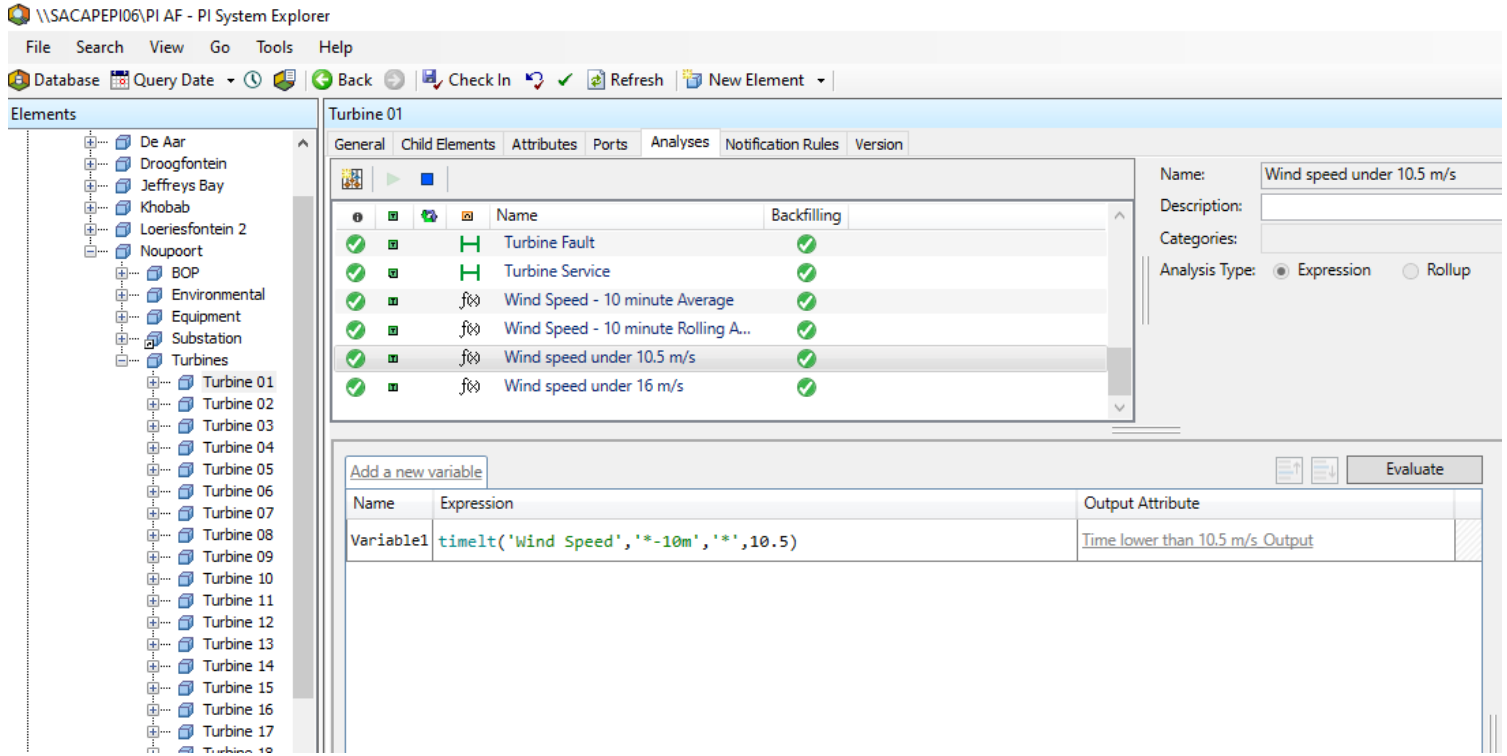
- "Single Version of the Truth" for asset register
- All Assets are accounted for here
- Avoids a Data Swamp of PI tags
- Unique Identifier codes (PI AF Element ID)
- Replicated in Maintenance Management System (RGC) and Energy Analysis (EAG)
- Enables Process Data and Maintenance Data to be viewed within context





PI AF Analytics – B.I. – PI Notifications

- PI AF Analytics used for both PI Notifications, ongoing calculations and PI Event Frames
- PI Notifications triggered by certain PI Event Frames
- Emails for non-critical alarms
- Emails for WTG faults/entry to service mode
- Email to voice & SMS service used for critical faults, substation and collector circuit trips



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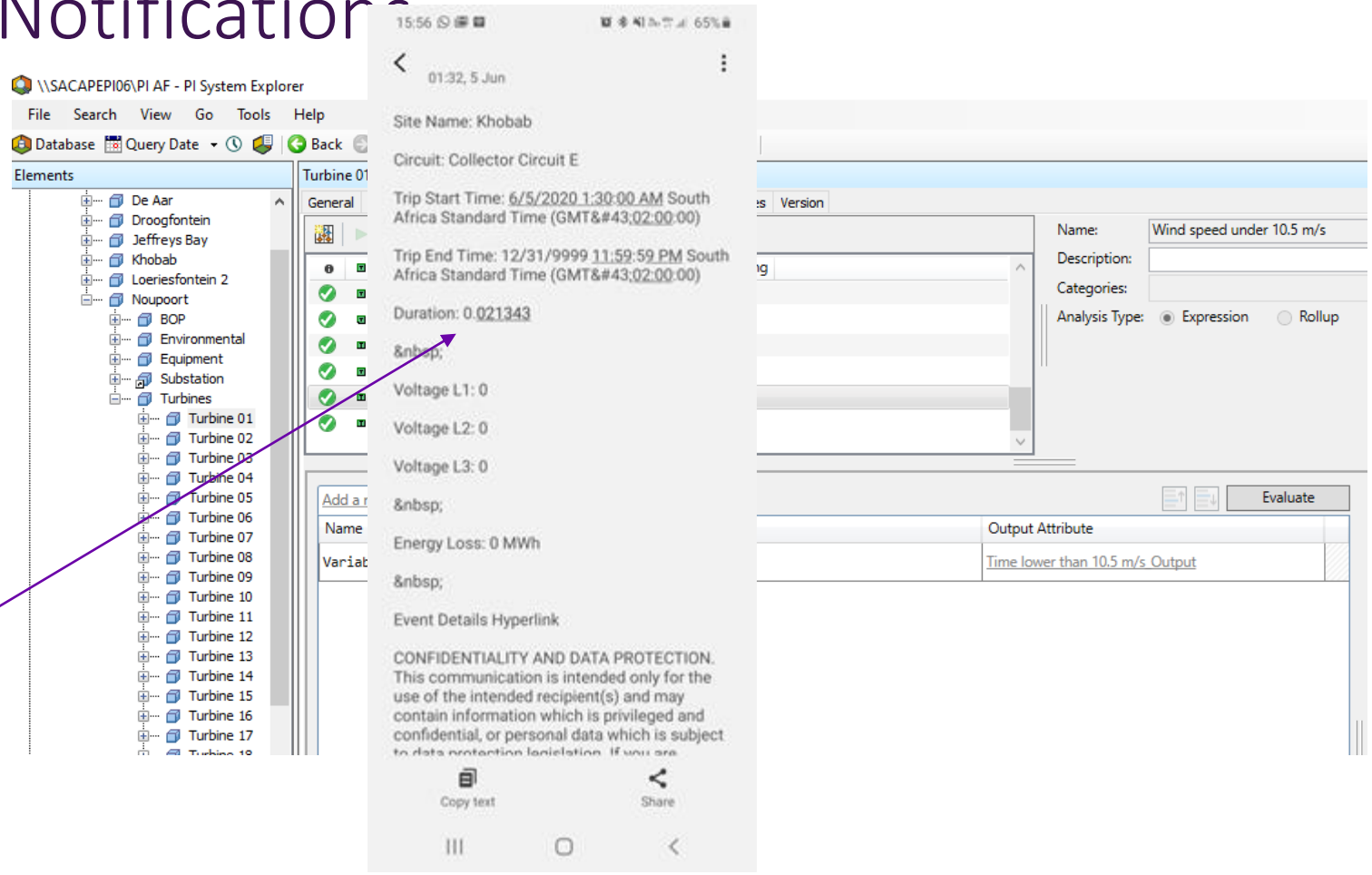
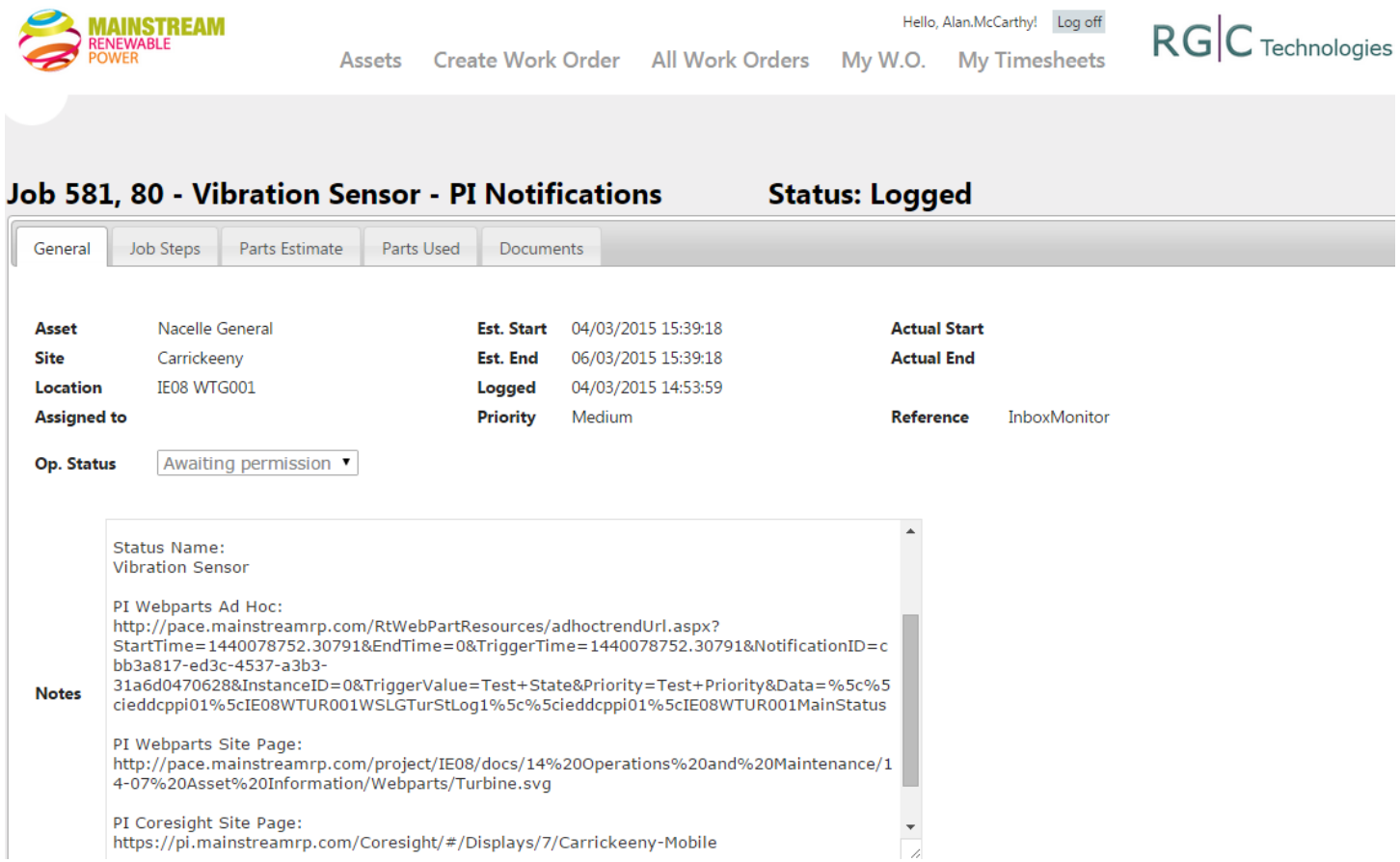


PI Notifications – B.I. – Work Order Integration

- Interlink PI Notifications/PI Event Frames with Work Orders
- Inbox Monitor in RGC
- Autogenerates Work Order using common Element ID from PI AF



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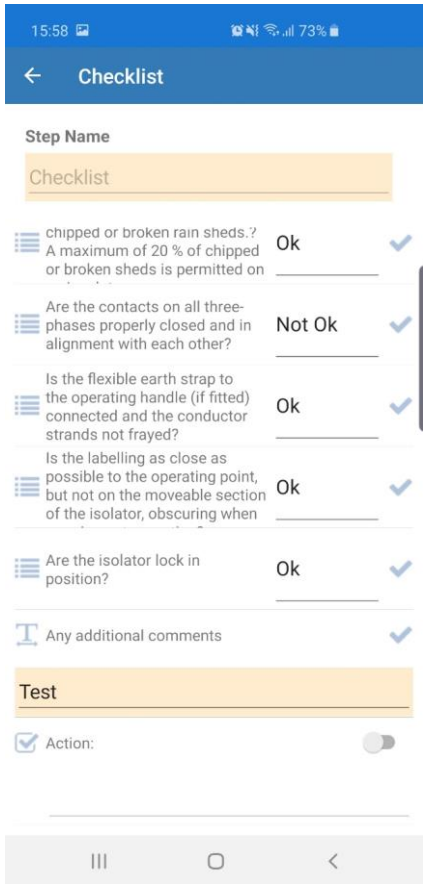
PI Notifications – B.I. – Work Order Integration

- The unique IDs from PI AF are used in RGC so that all Inspections and Maintenance are tagged against specific equipment
  - QR codes are printed for each asset on site
- Allows easily searchable maintenance records
- Overlay WTG fault data from PI with Work Orders in MS Power BI
- Specific triggered faults can have specific checksheets to be carried out on mobile app
- Eg Circuit Breaker Trips require an Electrical Switching Work Order

80a4d3c6-fb19-11e5-b577-a0b3cce6a16e
Turbine 31
2309206

06bf7aa2-47ad-11e6-93b8-f01faf3c7e0a
WTG 008 2.7 MVA
Pad Mounted
Transformer
303397-26

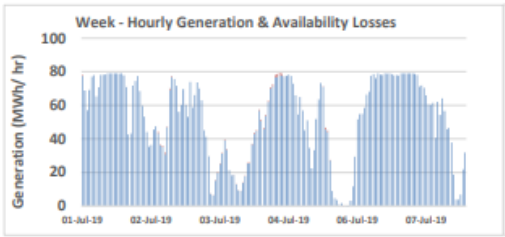


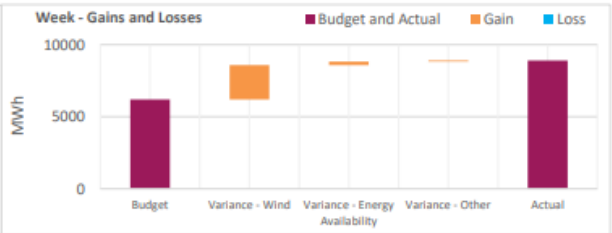
PI Datalink

- Weekly, Monthly, Quarterly, Annual reports generated automatically in excel and exported to pdf
- Additional data required (costs, budget) stored in PI Asset Framework tables
- Maintenance Data from Site embedded in reports

1. Executive Summary

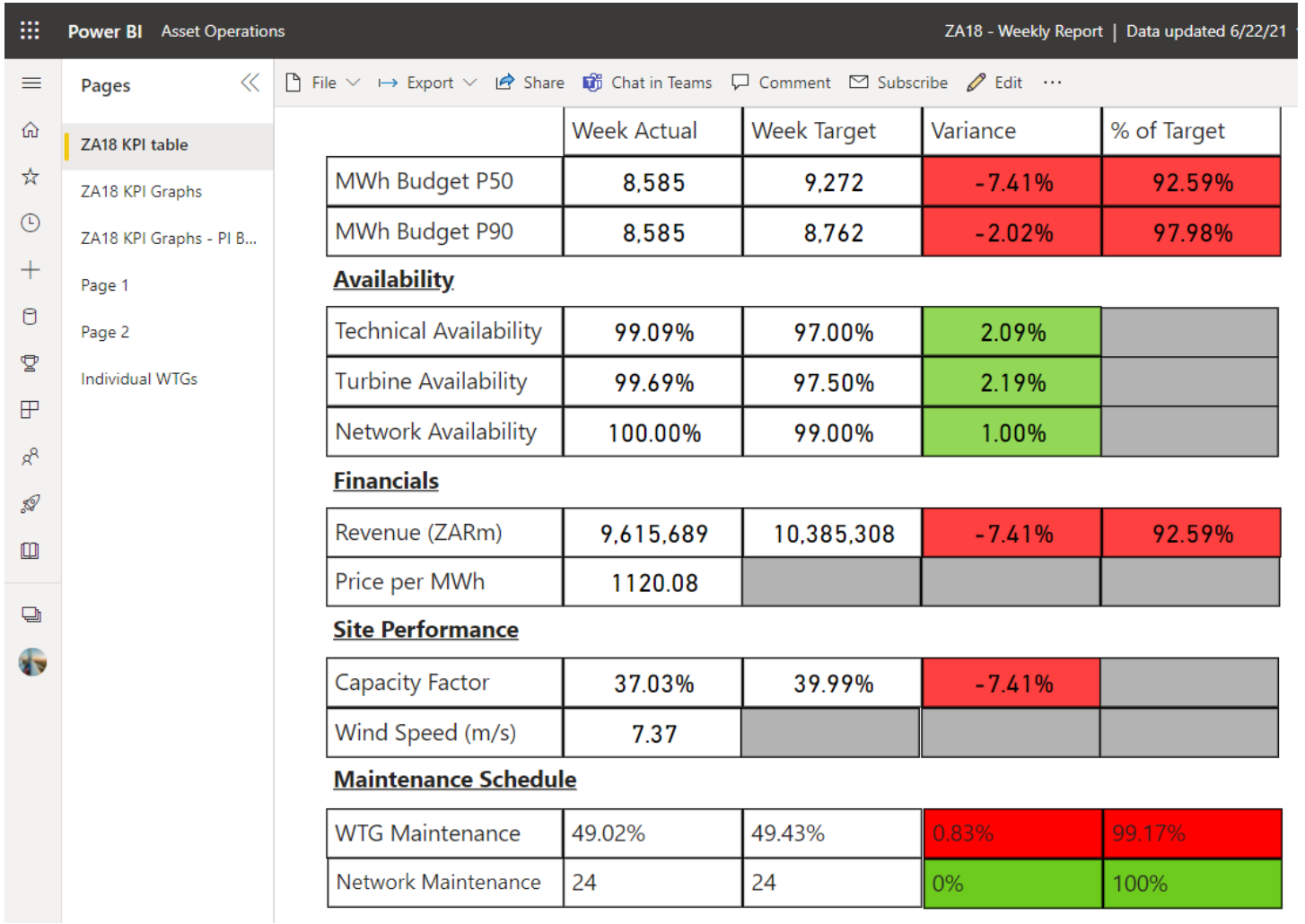
	Week Actual	Week Target	Variance	% of Target	Month Actual	Month Target	Variance	% of Target
Energy Production								
MWh sold (Elspec)	8,905	6,201	43.6%	143.6%	9,043	6,201	45.8%	145.8%
Revenue Electricity (ZAR)	10,094,000	7,029,376	43.6%	143.6%	10,250,847	7,029,376	45.8%	145.8%
MWh Budget P50		6,201				27,462		
MWh Budget P90		5,245				23,228		
Availability and Capacity Factor								
Technical Availability	99.3%	97.0%	2.4%		99.3%	97.0%	2.4%	
Capacity Factor	67.1%	46.7%	43.6%		68.1%	46.7%	45.8%	
Maintenance Schedule								
Turbine Scheduled Maintenance				100.0%				100.0%
BoP Scheduled Maintenance				100.0%				100.0%
Financials								
Total Revenue (ZAR)	10,094,000	7,029,376	43.6%	143.6%	10,250,847	7,029,376	45.8%	145.8%
Price per MWh	1,134	1,134	0.0%	100.0%	1,134	1,134	0.0%	100.0%
Site Performance								
Turbine Contractual Availability	99.3%	98.0%	1.3%		99.3%	98.0%	1.3%	
Curtailment (MWh)	-	-	0		-	-	0	
Wind Speed (m/s)	9.5				9.5			





MS Power BI – Weekly Reports

- New Weekly Reports take PI data into MS Power BI
- PI ODBC interfaces are used in conjunction with MS Power BI Gateway and MS Power BI Dataflows
- SQL Data imported into the Weekly Report data models
- CMMS and Health and Safety data imported into the Weekly Report data
- Next Steps:
  - Use Event Frames to more accurately calculate Energy/Yield Availability for the Weekly Reports



	Week Actual	Week Target	Variance	% of Target
MWh Budget P50	8,585	9,272	-7.41%	92.59%
MWh Budget P90	8,585	8,762	-2.02%	97.98%
Availability				
Technical Availability	99.09%	97.00%	2.09%	
Turbine Availability	99.69%	97.50%	2.19%	
Network Availability	100.00%	99.00%	1.00%	
Financials				
Revenue (ZARm)	9,615,689	10,385,308	-7.41%	92.59%
Price per MWh	1120.08			
Site Performance				
Capacity Factor	37.03%	39.99%	-7.41%	
Wind Speed (m/s)	7.37			
Maintenance Schedule				
WTG Maintenance	49.02%	49.43%	0.83%	99.17%
Network Maintenance	24	24	0%	100%

PI DataLink – B.I. – Faults & Event Analysis

- Energy and revenue availability monitored to maximise returns in monthly reports
  - Energy Production varies hour by hour
  - Variable prices in certain markets
  - Many OEMs now offer Energy Availability as a contractual guarantee
- PI Event Frames brought into PI Datalink to calculate lost energy & revenue Event by Event
- Allows staff to focus on biggest revenue losing Assets/Faults

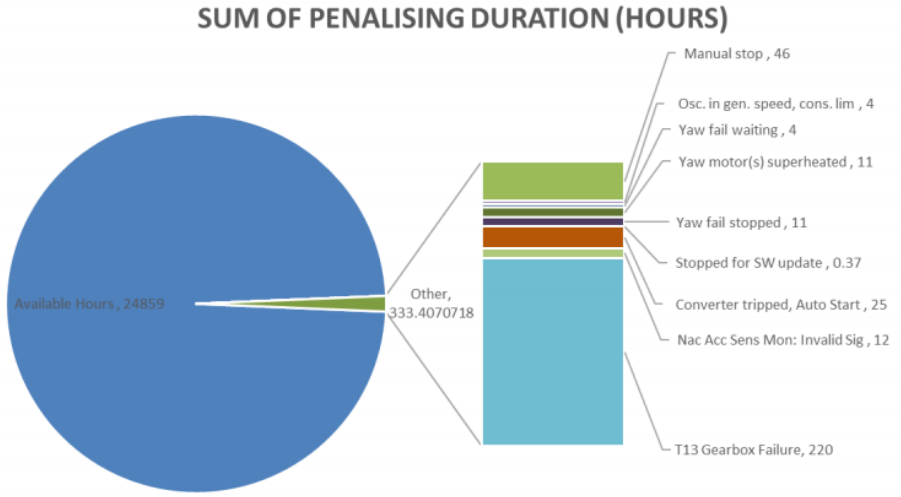
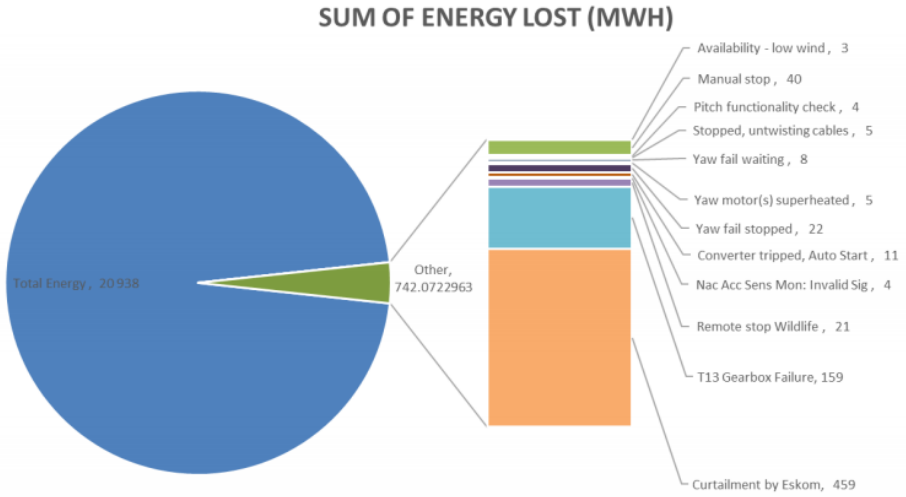
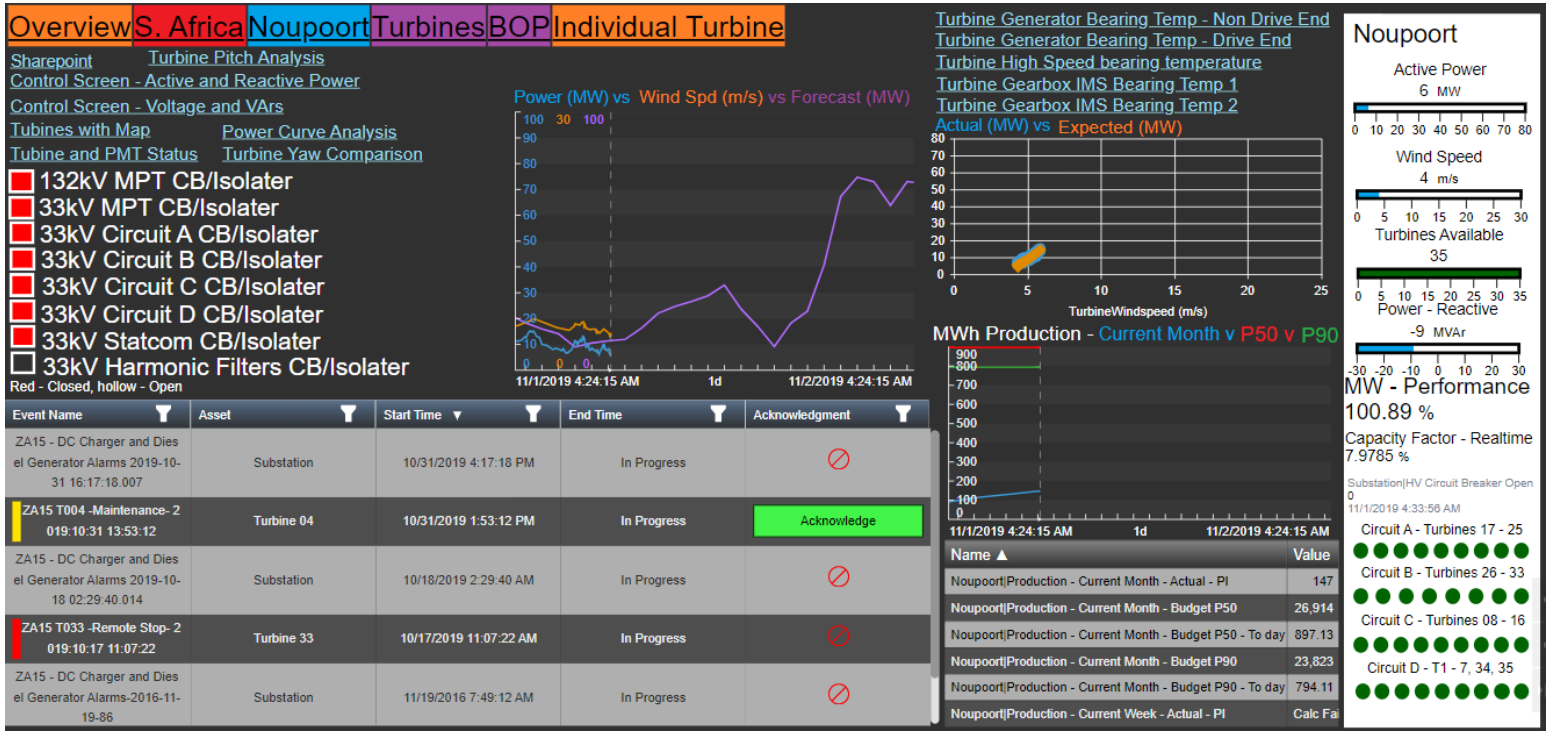


Figure 10: WTG Penalizing Duration Downtime Analysis



PI Visuals – PI Vision

- Data Visualisation in PI Vision, published externally through pi.mainstreamrp.com
  - Site “homepage” with all KPIs
  - Hyperlinks to further pages
  - Fixed data (Budgets)
  - Event Frames (Alarms)
  - Live Data and Forecast
  - Navigation bar at the top of each page mimics PI AF hierarchy



PI Vision – Grid Code Compliance

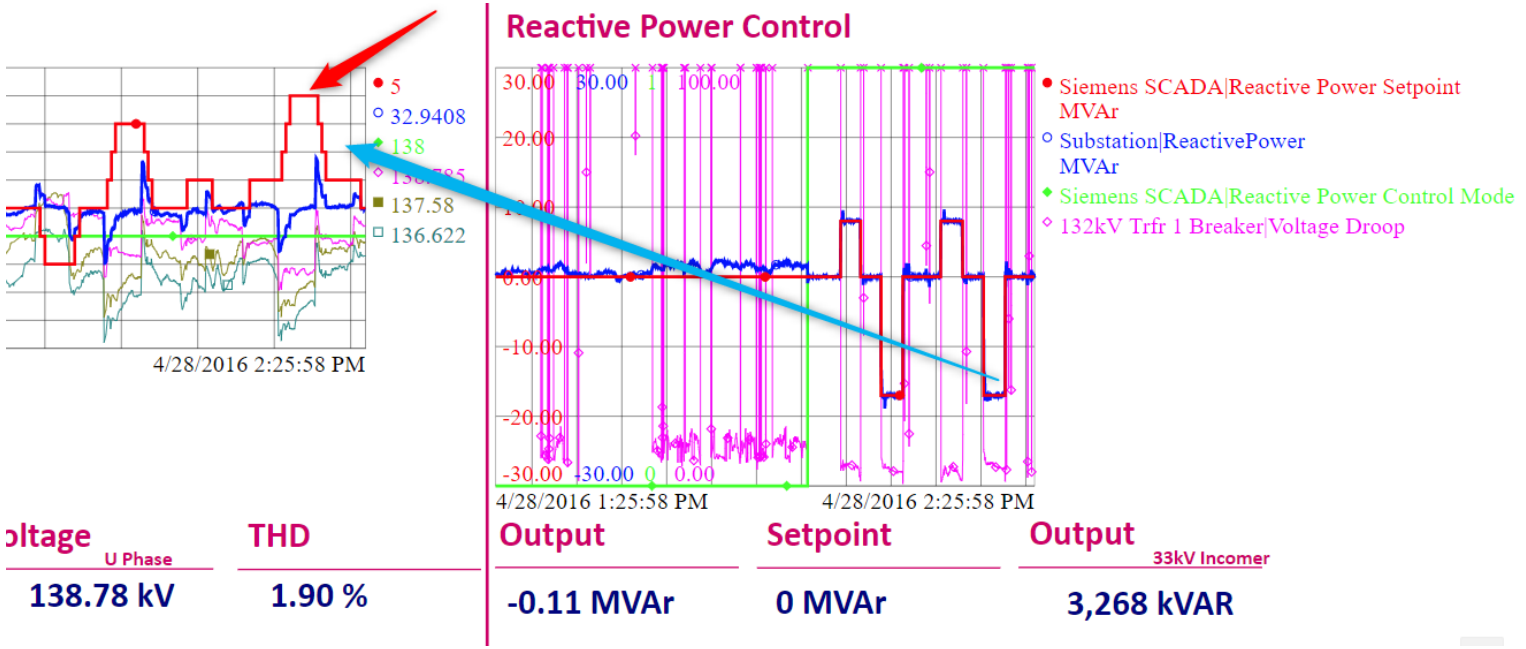
- High resolution data allowed Mainstream carry out self testing prior to Grid Code Compliance in South Africa – ironing out any issues before formal testing
  - Being able to visualise high resolution data allows for issues to be easily spotted. Without this, it is a “needle in a haystack approach”
  - Successful passing of these tests allow the projects to start collecting early revenue.

PI Vision – Grid Code Compliance

- High resolution data allowed Mainstream carry out self testing prior to Grid Code Compliance in South Africa – ironing out any issues before formal testing
  - Reactive Power setpoint taking too long to meet a challenging setpoint
  - Quickly identified the issue as the Main Power Transformer's tap changer settings
  - Retested with success

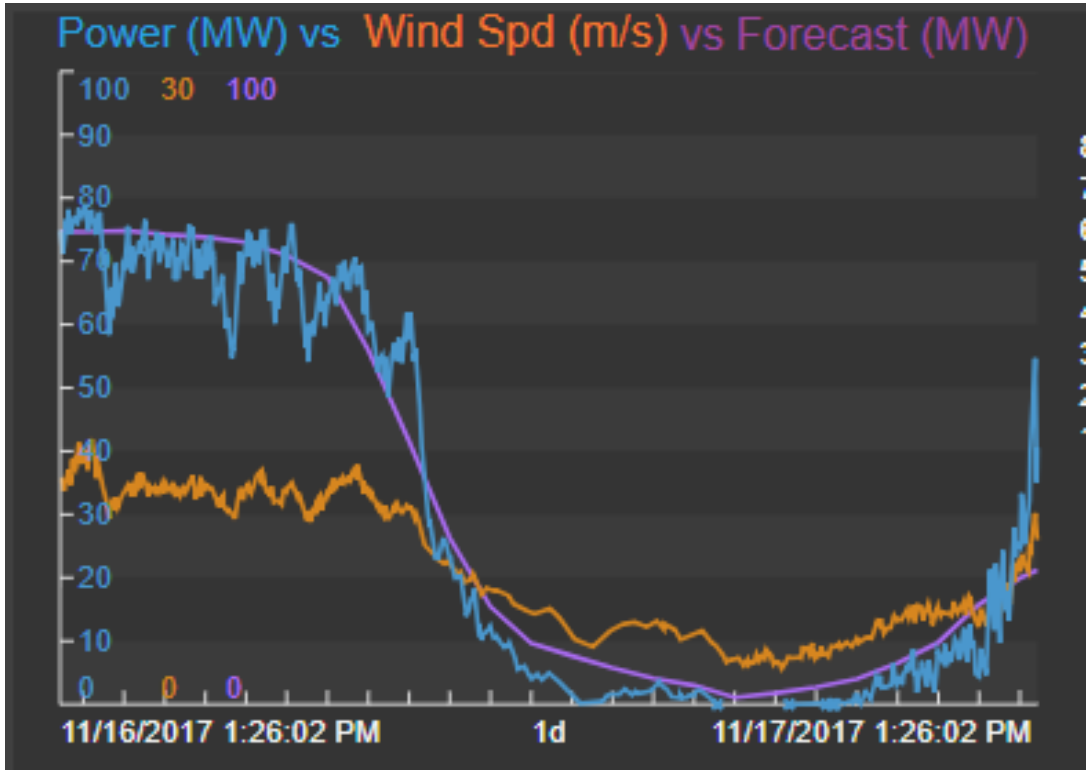
PI Vision – Grid Code Compliance

- PI allows the full plant to be analysed from different data sources
  - Substation Tap Changer (red arrow)
  - Power Plant Controller setpoint and ION Meter Reactive Power



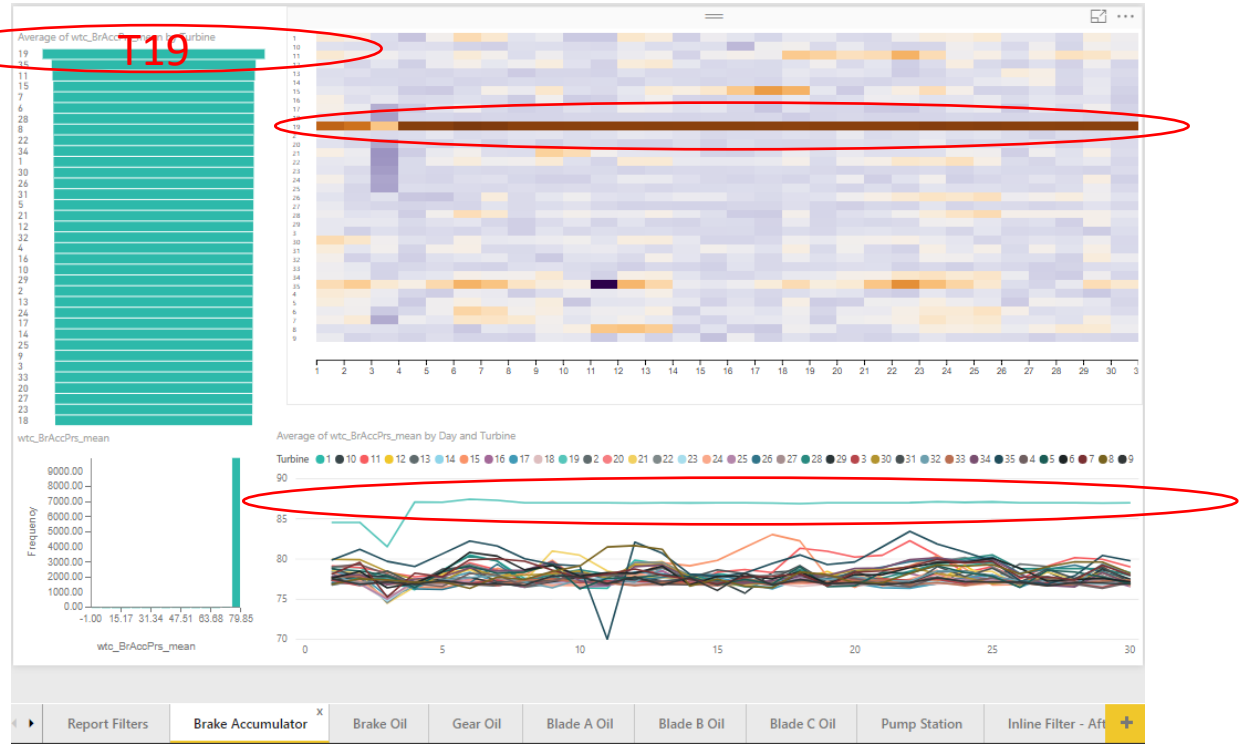
MS PowerShell ISE – Import and Export Data

- Forecasting data available via ftp
  - Imported to PI via MS PowerShell ISE and piconfig
- Wind Farms in Chile and South Africa auto upload all turbines' power outputs to forecasting providers who train their models to improve accuracy
  - Exported using MS PowerShell ISE and Task Scheduler
- Better planning of maintenance reduces energy lost
- 3 MW turbine off for 12 hours at $60/MWh is $2,000 on a windy day
- Minimal revenue lost during maintenance on a calm day



MS Power BI – B.I. Analytics

- “Portal” in MS Power BI where all component temperature or pressure sensors can be examined on a relative basis against other identical turbines
- Filters can be applied to exclude data during curtailment, fault times
- Fed by PI via PI ODBC Driver, and SQL Server DB
- Filters can be applied to exclude data during curtailment, fault times



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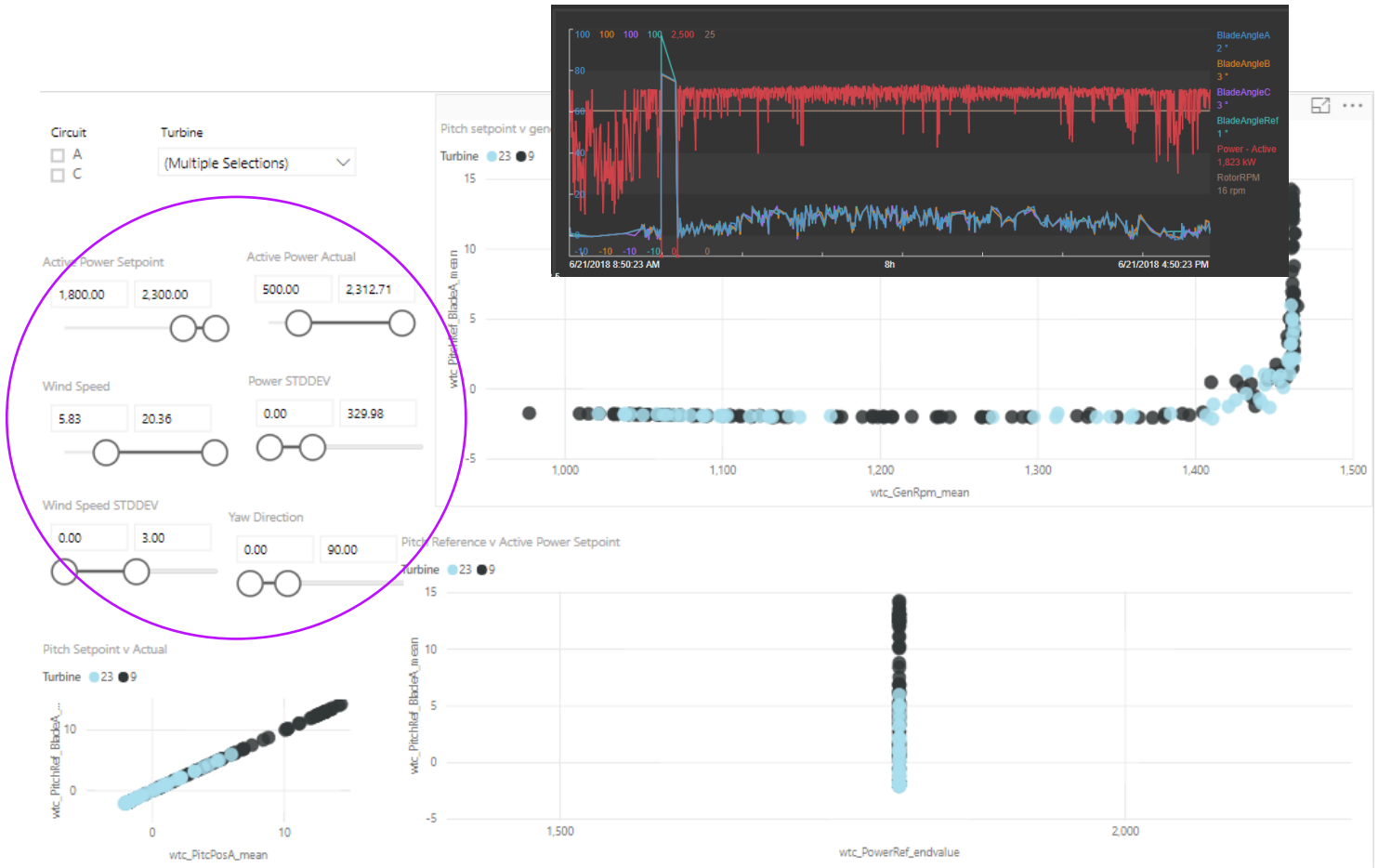
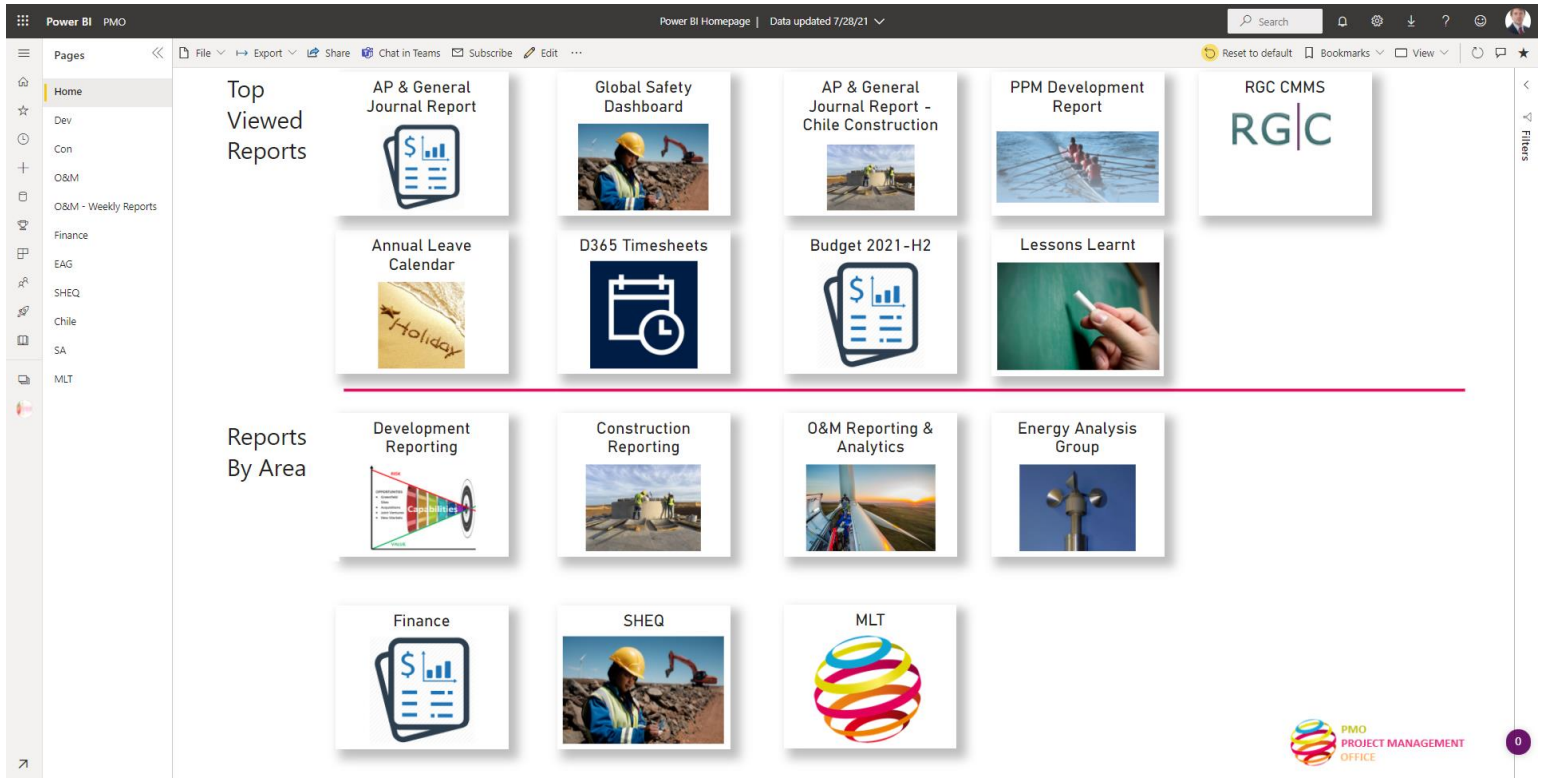
- “Portal” in MS Power BI where all component temperature or pressure sensors can be examined on a relative basis against other identical turbines
- Filters can be applied to exclude data during curtailment, fault times
- Fed by PI via PI ODBC Driver, and SQL Server DB
- Fleet wide Performance Analysis
- Power Curves (Wind Speed v Power Output)
- Torque Curves
- Blade Pitch angle analysis (left)
- Outlier points can be analysed in high resolution (1s) in PI Vision



MS Power BI – B.I. Analytics

- MS Power BI used for PI, SQL and CMMS Data visualisations for O&M Team
- Elsewhere, Mainstream use it to display
  - SHEQ (Safety, Health, Environmental and Quality) statistics logged in MS Sharepoint Online Lists
  - Financial reporting and analytics for MS Dynamics 365 Finance & Operations
  - Development/Permitting progress reporting from MS Project & Portfolio Manager
  - Construction progress reporting from MS Project & Portfolio Manager
  - Companywide Risk management from MS Project & Portfolio Manager
  - Timesheets analysis
- Working towards fully unified reporting
- PI data a central pillar of reporting and analysis during O&M Phase



PI Tools and Complimentary Systems Used

- Asset Framework – Asset Register, PI Data, MS Sharepoint document hyperlinks, Asset Work Order history from RGC web portal hyperlinks
  - Element Structure easily replicated using PI Element ID
  - Data queried though PI ODBC by MS Power BI & EAG team
- PI Interfaces – PI OPC XML DA, PI DNP3, PI SNMP, PI Ping

- Visuals – PI Vision and MS Power BI
- Reporting – PI DataLink and MS Power BI
- Analysis – PI Event Frames, PI DataLink, MS Power BI
- Alerts – PI Notifications
  - Trigger Work Orders in RGC
  - Integrate with Email to Voice services for critical faults
  - Reference PI Vision links

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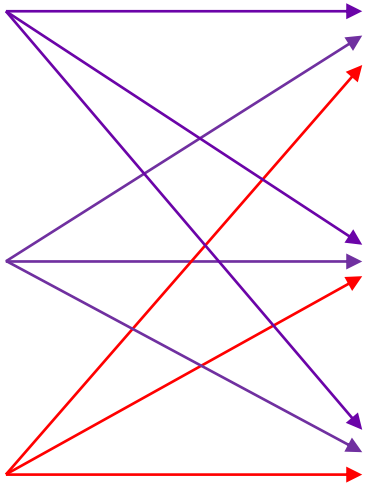
Results and Benefits

- Single Version of the Truth for all Time Series Data, Asset Registers & Maintenance History
- Easily accessible data to all stakeholders
- Streamlined, automated process for Reports, Analytics, Work Order Creation



- Staff can quickly access all data required with full confidence that it is correct
- Minimize time spent before work has value
- Asset Integrity – ability to see problems before they cause material damage

The right data finds the right person at the right time

Challenge

- Multiple Data Sources
- Dispersed Sites & Staff
- Integration, Long Term Architecture

Solution

- OSIsoft takes in all required data
- Standardised Reports & Visuals
- PI AF Analytics and PI Notifications trigger alerts and Work Orders
- Scalable, integrated management system developed

Benefits

- Single Version of the Truth for all data, Asset Registers & Maintenance
- Easily accessible data to all stakeholders
- Streamlined, automated process for Reports, Analytics, Work Order Creation

AVEVA

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ABOUT AVEVA

AVEVA, a global leader in industrial software, drives digital transformation for industrial organizations managing complex operational processes. Through Performance Intelligence, AVEVA connects the power of information and artificial intelligence (AI) with human insight, to enable faster and more precise decision making, helping industries to boost operational delivery and sustainability. Our cloud-enabled data platform, combined with software that spans design, engineering and operations, asset performance, monitoring and control solutions delivers proven business value and outcomes to over 20,000 customers worldwide, supported by the largest industrial software ecosystem, including 5,500 partners and 5,700 certified developers. AVEVA is headquartered in Cambridge, UK, with over 6,000 employees at 90 locations in more than 40 countries. For more details visit: www.aveva.com

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