PI World 2019 Lab

Using AF to Analyze Asset Performance



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1. Introduction

1.1 Overview of Lab

Calculation of and immediate feedback on wind turbine performance is an important part of maximizing revenue from wind generation assets. Waiting for a daily or monthly rundown of performance of a wind farm can cost thousands of dollars of lost production each day. Common causes of deviations from the expected power can be due to equipment issues such as the pitch or jaw system, a curtailment, or an outage. Being able to determine the generation shortfalls from the expected power in near or real time allows the site to take prompt corrective action with the intent to either resolve the performance issue quickly or schedule maintenance to inspect or repair the turbine. Monthly reporting is also helpful in understanding performance issues but if the issues can be resolved sooner, the lost generation can be minimized because the cause may be able to be promptly resolved. Monthly reporting can then be utilized to track top outage causes and plan long term maintenance to correct issues and schedule tower inspections.

In this lab you will learn how to use AF to calculate the expected power from a power curve and give immediate feedback on turbines that are not giving their expected output. We will look at tools to build feedback mechanisms into real-time displays as well as creating electronic notifications. You will also learn how to use tools within PI to automate reporting functions such as site power rollups and reports.

1.2 Tasks of This Lab

Getting started with AF can seem like a daunting task. In this lab we will start with a nearly empty AF database. We will take a simple AF hierarchy for a wind turbine, built on templates and scaled out to a small wind farm. An AF hierarchy is an effective way to organize the information in the PI System in an intuitive manner. The PI tags are stored as AF attributes and can be organized together for each wind turbine so they can be easily viewed and modified in PI System Explorer or visualized in PI Vision.



We will be using Analytics within AF to determine the expected power from a wind turbine. This can be done in three different ways: a Table look-up, curve function and analytical equation

using a combination of a polynomials and IF/THEN statements. You will see how to compare expected power to actual power and create notifications and visual prompts when the deviation is greater than a certain value.

Finally, we will use tools within PI and PI-DataLink to create reports (daily, monthly, etc...) that can be replicated quickly between wind farms and as they are needed by management.

So, you will learn (by doing!):

- Three ways to calculate expected power within AF (and when you might want to use each method)
 - A PI AF Table look-up allows the input of the power curve wind speed and corresponding active power to be input into a table which can be manually entered, copied from Excel and pasted into AF, or accessed via a link.
 - The CURVE function allows the use of multiple (x,y) points to accurately define the power curve.
 - The power curve analytic equation The power curve can be represented by a 2nd or 3rd order polynomial equation with the wind speed. This equation takes a few minutes of effort up from to be developed if it is not known, but combining it with some simple IF/Then logic to confine the power curve calculation to the points when the turbine should be on line or at full power capacity, can result in the power curve evaluations being done very quickly.
- How to report deviations in real time visually and through notifications. As mentioned above, being able to report deviations in real time provides the opportunity to take corrective action before the opportunity to improve and optimize is lost.
- How to do wind site roll up calculations for reporting purposes through PI-DataLink. This is valuable for viewing real time generation and plant status and as well as efficiency issues on a site or fleet level.

1.3 Which analysis method is best?

The answer to this question depends on the amount of wind turbines in the AF model. If there are under 100, it can be based on personal preference. If there are hundreds or thousands of wind turbines in your fleet, the analytics equation can utilize less server resources than a table or curve because the analytical expression is executed each time without needing to store anything in the cache. Therefore, for large amounts of wind turbines, although the analytic equation may take a little longer to input, it may also help optimize the memory usage. For this application, the analytic polynomial will provide the best performance, followed by the curve function, and lastly the table look-up.

1.4 How does this lab apply to my assets?

This lab focuses specifically on Wind Assets as the example. Therefore, if you are in a different space, you may wonder: How can I use these concepts to improve my own process? Below are a few examples of variables involved in calculating efficiency in other assets. Many manufacturers provide metrics for expected efficiency of their assets. These metrics typically define how the relationship between different variables should correlate (on an XY-plot).

- Centrifugal Pump: Head and Flow
- Centrifugal Pressure: Differential Pressure or Brake Power and Flow
- Cake Filtration: Flow Rate and Pressure Drop
- Transformer Tap Changer: Tap Position and Voltage Ratio
- PV Solar Output: Incident Luminance and Power
- Separation Columns (Distillation/Absorption/Stripping): Column Pressure Drop and Liquid/Vapor Flow
- Gas Turbine: Thermal Efficiency and Turbine Inlet Temperature
- Any Asset: Energy Loss

2. Challenge 1A: Use a Table Lookup Data Reference to Model the Power Curve

2.1 Objective of Activity

As an engineer at the Wind Farm you have already created two Tables in AF – one containing the Power Curve information for a turbine and the other containing the location, installation date, manufacturer, and turbine model. The task ahead of you is to provide the relevant information from these tables to the **Attributes** of the turbines using the **Table Lookup** data reference. This information will be needed and used in the rest of the lab to complete the solution. You will learn how to use the AF **Template** and substitution syntax to achieve this in the most efficient and maintainable manner.

2.2 Tasks

- Find the **Turbine Template** and identify the **Attributes** that will have the **Table Lookup** data reference
- Identify the columns in each Table and which ones apply to each Attribute
- Assign the **Table Lookup** data reference to each of these **Attributes** and create the **Settings** for each one
- Validate that you have the correct syntax in the **Settings** by looking at the **Attribute** values of the turbine **Elements** and cross-check them with the values in the **Tables**

2.3 Step by Step Explanation of this Lab Section

Step 1: Identify Attributes and Table Columns

First thing to do is to identify which **Attributes** in the **Turbine Template** will need to be mapped to the **Table Lookup** data reference.

1. Navigate to the Library section in the PI System Explorer (PSE). Open the Tables tree and click on PowerCurve. You should see the following table.

Challenge 1A: Use a Table Lookup Data Reference to Model the Power Curve

PowerCurve									
General Table Define Table Version									
PowerCurve									
Filter									
	Wind Sp	eed	Potential Power						
•	0		0						
	4		78						
	5		193						
	6		358						
	7		589						
	8		898						
	9		1289						
	10		1732						
	11		2172						
	12		2573						
			2856						
			2971	1					

You can navigate to the Library section by using Ctrl-3 key combination.

Step 2: Create Attribute and Assign Table Lookup Data Reference

- 1. Now click on the **Element Template > Turbine**, and in the center pane click the **Attribute Templates** tab.
- 2. Create a new attribute called Expected Power (Tabular)
 - a. Assign **kW** as the Unit of Measure



Tip

For the Default UOM a simple way to find the unit of measure is to highlight the <None> and then start typing kilow (or kW).
 You will see the intellisense showing you the available matching units of measure. From the matching list, select kilowatt

3. Next, click on the Data Reference combo-box and select Table Lookup.

The Data Reference compo-box and select Table Lookup.							
Curtailment Cause	Data Reference:	Table Lookup 🗸					
Kan CutOut	Display Digits:	<none></none>					
Elevation	Display Digits.	PI Point					
Kernet Curve (Curve)		PI Point Array String Builder					
🐔 Expected Power (Polynomial)	SELECT <field> FF ORDER BY <order< td=""><td>Table Lookup 🥔</td></order<></field>	Table Lookup 🥔					
Expected Power (Tabular)							
C Enrecast 1b Expected Power /P							

Step 3: Enter Settings for the Table Lookup Data Reference

1. First we will create the **Settings** for the **Attribute Expected Power (Tabular)** since that is the only one that will get data from the **Table PowerCurve**. We have simplified this for the lab and only have one power curve that will be used for all the turbines, in reality each **different turbine model** may have its own power curve. Select the Attribute **Expected Power (Tabular)** and click the **Settings** button.

EL Expected Power (Tabular)	0.600	Dįsplay Digits: -5
Installation Date	1/1/1970 12:00:00 AM	Settings
🗐 Latitude	0 °	SELECT <field> FROM <table> WHERE <filter> ORDER BY <order></order></filter></table></field>

2. You should see the following dialog pop up.

Table Lookup Data Ref	erence		×
Table:	<none></none>		 •• •
Result column:			Stepped
Unit of Measure:	<default> (kW)</default>		~
Behavior			
Rule:	Select first row matchi	ng criteria	~
Order by:			✓ ASC ✓
Where			
Column:	Operator:	Attribute or Value:	Add And
~	=	@Active Power V	Add Or
	2:		^ ~
Table Parameters			
Parameter		Value	
Replacement Values			
Value to return when n No Data	o matching row found:	Value to return when NULL I	result found:
			OK Cancel

Click the Table combo-box and select PowerCurve. Then in the Where section click the Column combo-box and select Wind Speed. Then click the Operator combo-box and select INTERPOLATE. Lastly, click the Attribute or Value combo-box and select @Adjusted Wind Speed. Click the "Add And" button. You should see the following text in the Complete WHERE Clause text-box.

Where Column:	Operator:	Attribute or Value:	Add And
Wind Speed $$	INTERPOLATE ~	@Adjusted Wind Spe $ \smallsetminus $	Add Or
Complete WHERE Clause: INTERPOLATE([Wind Spe	eed], @[Adjusted Wind Sp	eed;UOM=m/s])	^ ~

4. To validate that you have the correct syntax and everything is working by navigating to the Elements section. For example, open the tree under the Element Scirocco, then open the tree under Mieres and select GE006. In the center pane select the Attributes tab. Look at the Attribute Expected Power (Tabular) and you should see a value like below.

Elements RB007									
Elements	General	Child Ele	ements	Attributes	Ports	Analyses	Noti	fication Rules	Version
	Filter								
🗊 RB006						۸ ا	Value		
🗇 RB007		T	🧭 A	ctive Power				293.7 kW	
🗇 RB009 🎒 RB010		T	Ø A0	djusted Wind	Speed			5.668 m/s	
		T	Ø 🖓	pparent Pow	er			298.52 kW	
in in in santaelia in in i				sset Name			F	RB007	
🕰 Element Searches		T	Ø Ci	urtailment Ca	use			None	
		T	Ø CI	utOut				25 m/s	
		T	E	evation				35.005 m	
	0	•	🎺 Е	xpected Pow	er (Curv	e)		303.22 kW	
	4	∎ 🔶	Ø E)	kpected Pow	er (Polyn	nomial)		297.35 kW	
		T	E Đ	kpected Pow	er (Tabu	lar)		303.22 kW	
	0	•	Ø Fo	precast 1h Ex	opected I	Power (Polyr	n 2	218.25 kW	
		T	🗉 In	stallation Da	te			5/14/2010 12:0	00:00 AM
		T	🔳 La	atitude				29.74 °	

Tip

You can navigate to the **Elements** section by using **Ctrl-1** key combination.

5. Now click the Check In in the ribbon.

Tip	You can also ^{Check In} by using the Ctrl-S key combination.
V Best Practice	Contrary to popular belief you should not be checking in every time you make a change, in fact it is advisable not to do that. For example, if you have analytics running and you check in, then the analytics will restart for all elements affected by the check in. PSE will tell you if there is a need to check in.

3. Challenge 1B: Use the Curve Function with an Analysis to Model the Power Curve

3.1 Objective of Activity

As the Wind Farm process engineer, you have been asked to create an expected power calculation based on wind speed. You gathered empirical data in the following table and now determined that an AF analysis is the best option for deploying the calculation.

Wind Speed	Potential Power
0	0
4	78
5	193
6	358
7	589
8	898
9	1289
10	1732
11	2172
12	2573
	2856
	2971

3.2 Tasks

- Set Analysis Tag Naming default
- Create the Expected Power analysis template

3.3 Step by Step Explanation of this Lab Section

Step 1: Set Suggested PI Point Name Default for Analysis Generated Attributes (i.e. via mapping)

The Suggested PI Point Name default is configured on a per-user and per machine basis. For frequent analysis creators, setting the default configuration helps to save time as well as safeguard against creating tags that do not follow the convention in place.

1. In the PSE Management Pane, right mouse click in the white space of the Pending Operations space. Choose the Edit Analysis Service Configuration menu.

Elements Event Frames		Pending Operations No pending operations	s s ght Click
🎒 Library		View Analysis Service Statistics	his Space
🚥 Unit of Measure	[Edit Analysis Service Configuration	
Sa Contacts		Open Recalculation Log Folder	
🛠 Management	<	>	
Analyzer			

2. Set the **Suggested PI Point Name** to **%Database%_%Element%.%Attribute%**. This will ensure that your tag names are unique and do not conflict with other students. In addition, point source is added using ";pointsource=AFAnalysis" Click OK.

Global Service Configuration				
Property	Configuration			
AutoBackfillingEnabled	True			
AutoRecalculationEnabled	True			
AutoRecalculationIgnoreTimeInSeconds	30			
AutoRecalculationMinWaitTimeInSeconds	60			
CacheTimeSpanInMinutes	5			
CalculationWaitTimeInSeconds	5			
CreateFuturePIPointsForAmbiguousOutputTimes	True			
EvaluationPartitionSize	10000			
EvaluationsToQueueBeforeSkipping	50			
IsLoadSheddingEnabled	True			
IsTelemetryAllowed	True			
MaxAllowedAutoRecalculationSpanInDays	180			
MaxCacheEventsPerAttribute	1024			
MaxConcurrentRecalculationRequests	4			
MaximumAllowedAutoBackfillingSpanInHours	72			
MinCacheEventsPerAttribute	1			
NumberDataWriterThreads	4			
NumberEvaluationThreads	8			
NumberParallelDataPipes	4			
RuntimeStorageFolderPath	$C:\ProgramData\OSIsoft\PIAnalysisNotifications$			
PI Point Creation User Settings				
✓ Default to Auto Create PI Points for Template				
Suggested PI Point Name				
%Database%_%Element%.%Attribute%;pointsource=AFAnalysis				
	OK Close			

Setting the **pointsource** of analysis output tags easily allows you to segregate them from other PI tags.

In addition, although not shown here, it is critical to **set appropriate point & data security on the tags**. Use a dedicated identity for the PI Analysis Service that is only allowed to write to analysis output tags.

Best Practice

Step 2: Create an analysis to calculate Expected Power using the Curve Function

- 1. Create a new analysis template on the element template Turbine
- 2. In PSE, select the Library navigation tab, then Element Templates, then Turbine
- 3. Select the Analysis Templates tab
- 4. Right mouse click New, then change the name to Expected Power (Curve Function)

Turbine	
General Attribute Templates Ports Analysis Templates	Notification Rule Templates
	Name: Expected Power Production (Curve Function)
🕼 🗖 Name	Description:
* Expected Power Production (Curve Function)	Categories:
	Analysis Type: Expression Rollup Event Frame Generation SQC
	Enable analyses when created from template
× >	
Example Element: <u>Scirocco\Santaella\GE001</u>	
Add a new variable	t Evaluate > Functions
Name Expression	Output Attribute
Variable1 Type an expression	Map
	All

- 5. Define the analysis. Given the empirical data and the current wind speed, calculate the expected power. Hint: Check out the analysis **Curve** function.
- 6. Configure a variable that is mapped to a new attribute **Expected Power (Curve)**.



7. The **Curve** function is useful when one has a set of data points describing a curve or line.



8. Use the **Convert** function to explicitly apply UOM to the results.



9. Remember to comment your code.



10. A good approach would be to calculate a new expected power each time a new wind speed value is recorded. Hint: set the **Scheduling** to **Event Triggered**.



11. If you would like see how a fellow engineer did this see the table below. For your convenience, the content of the expression below is available in a text file on the desktop of your VLE.

Variable	Expression	Output Attribute
ExpectedPower	<pre>// Using data points of wind speed vs power, use curve function to return an Expected Power for a given Wind Speed. Convert function explicitly assigns UOM to calculation results. // Convert(Curve('Adjusted Wind Speed', (0,0) (3.99,0) (4,78) (5,193) (6,358) (7,589) (8,898) (9,1289) (10,1732) (11,2172) (13,2573) (14,2971) (15,2996) (16,3000) (25,3000) (25.01,0) (100,0)),"kW")</pre>	Expected Power (Curve)

Step 3: Test the expression

1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click **Evaluate** to make sure you have no syntax errors. You should see values next to each of the variables and no error messages in the Status bar.

Tu	bine	e																		
Ge	nera	al At	ttribute Templ	ates Po	rts	An	alysis Te	emplates	s N	Notification Rule To	emplates									
i														N	lame:	Exp	pected Power (Curve	Function)		
	0	•	Name			_		_	_			~	1.	_ D	escription:					
Ľ		н	EF Underp	erformin	g Ass	set							H	C	ategories:	Exp	pectedPower			
	2	*f60	Expected P	ower (Cu	irve F	Func	tion)						ļ,	A	nalysis Type:	۲	Expression	Rollup O Ever	nt Frame Generatio	n 🔿 SQC
		f(x)	Expected P	ower (Po	lynor	mial)								🖌 Enable ana	lyse	es when created from	m template		
L	fbit Forerast th Evnerted Dower (Dolumornial)																			
E	Example Element: <u>Scirocco\Mieres\GE006</u>																			
	Add a new variable Evaluate																			
	Nan	ne		Express	on												Value at Evaluatio	Value at Last Trigg	Output Attribute	
	Expe	ecte	dPower	// Usi Conver	ng (t(C	dat urv	apoin e('Ad	ts of juste	wi d W	ind speed vs /ind Speed',(power, 0,0) (3	use c .99,0	ur)	ove (4,	function 78) (5,19	to 3)	2998 kW	2998 kW	Map	

2. To check the logic it is always a good idea to preview the results before implementing the analyses. Right-click on the expression Expected Power (Curve Function) and select Preview Results.

		💿 🖪 Name		
	-	*1 EE Undernarforming	Asset	
		New	e Function)	
	×	Delete	nomial)	
	Q (Preview Results	Power (Polyno	
irbin	<i>7</i> .	Backfill/Recalculate	aella\GE001	
		Backfill/Recalculate Status		

3. In the pop up window click on the Generate Results button. You should see something like the picture below.

Preview results for Expected Power (Curve Function)							
Start Time: t		End Time: *		Generate Results			
Trigger Time	ExpectedPower (kW)	Adjusted Wind Speed (m/s)		Evaluation			
3/5/2019 12:00:00 AM	2809	13.593		^ (100%)			
3/5/2019 12:05:00 AM	2909.3	13.845					
3/5/2019 12:10:00 AM	2433.7	12.305		Progress			
3/5/2019 12:15:00 AM	2991.4	14.815					
3/5/2019 12:20:00 AM	2999	15.757		Oms			
3/5/2019 12:25:00 AM	2974.6	14.143		Min			
3/5/2019 12:30:00 AM	2796.2	13.561					
3/5/2019 12:35:00 AM	2980	14.361		(198ms)			
3/5/2019 12:40:00 AM	2999.9	15.975					
3/5/2019 12:45:00 AM	2992.7	14.869		~ Max			
2			EurostadDau				

Step 4: Map the analysis result to an attribute

1. Use the **Map** link and **New Attribute Template** to create a new attribute template for the output.



2. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.

Attribute Template Properties				
Save Output History:	● Yes ○ No			
Name:	Expected Power (Curve)			
Description:				
Data Server:	%Server% v			
Value Type:	Double v			
A PI Point data reference attribute template will be created.				
	OK Cancel			

It is a best practice to use the "New Attribute Template" option for outputs of analyses. There are a couple advantages over creating it "manually" on an element template. First, the Data Reference is automatically set. Secondly, the naming standards created in Step 1 are implemented.

- 3. Return to the attributes tab and verify the configuration of your PI Point (i.e. tag name, point source, etc.)
- 4. If everything looks good click the Close button and Check In your work.

Step 5: Add an attribute category to help organize the results

- 1. Add a **Category** such as **Calculated Data** to all of the attribute templates that are analysis results.
- 2. Change the attribute view to group by category.



Best Practice

4. Challenge 1C: Use a Polynomial Fit to Model the Power Curve

4.1 Objective of Activity

As the Wind Farm process engineer, you have been asked to fit a polynomial to the empirical data from the previous challenge. This polynomial will represent the Expected Power curve and allow the analysis to function without the need for interpolations.

4.2 Tasks

- Use the provided power curve to fit a polynomial equation using Microsoft Excel and verify the fit
- Create attributes to store the polynomial coefficients on the Turbine template
- Create an analysis to implement the polynomial expression with limits for low and high values where the polynomial does not apply.
- Test the expression and map the result to a PI Point

4.3 Step by Step Explanation of this Lab Section

Step 1: Create Expected Power Polynomial Analysis

- 1. Navigate to the Analysis Templates Tab in the Turbine Template
- Create a New Analysis called "Expected Power (Polynomial)" (right click or select the icon)
- 3. Create a variable called AdjustedWindSpeedVar

Adding **Var** (or similar) to the end of variables helps add clarity when referencing those variables. When an attribute shares the name of the variable, it can be confusing to determine which the item in the expression is when the only difference is the quotes surrounding it. 4. In this expression, we want to grab the current tag value of the Adjusted Wind Speed attribute so we can save it to use in the subsequent expressions.

```
AdjustedWindSpeedVar TagVal('Adjusted Wind Speed')
```

- 5. Create a new variable called **Polynomial**, this variable is this variable is at the heart of this analysis and contains the output of the polynomial expression calculation
- 6. Since we fit our curve to a 6th order polynomial, Our expression will use the following equation:

 $y = C_0 + C_1 x + C_2 x^2 + C_3 x^3 + C_4 x^4 + C_5 x^5 + C_6 x^6$

where y is the Expected Power and x is the Adjusted Wind Speed

7. To make the expression a bit easier to follow and troubleshoot (as well as repeatable), we will actually use the following form of the equation where we add x^0 to help make the expression more symmetrical:

$$y = C_0 x^0 + C_1 x^1 + C_2 x^2 + C_3 x^3 + C_4 x^4 + C_5 x^5 + C_6 x^6$$

 Begin by navigating to the C0 attribute from the Attributes Panel on the bottom right side of the analysis pane. Choose Choose to add it to the expression.



9. Multiply the C0 coefficient by AdjustedWindSpeedVar raised to the 0th power (i.e. multiplying C0 by 1). By multiplying by the 0th power now, this makes the expression reproducible:

'Polynomial Coefficients|C0'*AdjustedWindSpeedVar^0

10. Copy and paste the first line with a + in between then change the 0's to 1's:

```
'Polynomial Coefficients|C0'*AdjustedWindSpeedVar^0
+ 'Polynomial Coefficients|C1'*AdjustedWindSpeedVar^1
```

11. Repeat Step 10 until you have put in expressions through $C_6 x^6$

	<pre>// Calculate Expected Power based on polynomial model 'Polynomial Coefficients C0'*AdjustedWindSpeedVar^0</pre>
	+ 'Polynomial Coefficients C1'*AdjustedWindSpeedVar^1
Polynomial	+ 'Polynomial Coefficients C2'*AdjustedWindSpeedVar^2
FOLYHOMITAL	+ 'Polynomial Coefficients C3'*AdjustedWindSpeedVar^3
	+ 'Polynomial Coefficients C4'*AdjustedWindSpeedVar^4
	+ 'Polynomial Coefficients C5'*AdjustedWindSpeedVar^5
	+ 'Polynomial Coefficients C6'*AdjustedWindSpeedVar^6

12. Don't forget to add comments to your expression to describe what is happening, as well as line breaks to help make the expression more readable.

Both \\ and * work to begin a comment. Use Shift+Enter to create line breaks.
--

- 13. Add one last variable, Output
- 14. This expression will check which range we are in (Low, In Range, High or Fault) then assign the appropriate value for the Expected Power using IF THEN ELSE Statements

Output	<pre>//The calculated Expected Power is only valid in a range. At low end and high end of Convert(If AdjustedWindSpeedVar< 'Polynomial Coefficients LowWind_Limit' then 'Polynomial Coefficients LowWind_Power' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients LowWind_Limit' and AdjustedWi then Polynomial else if AdjustedWindSpeedVar>= 'Polynomial Coefficients FullPower_Limit' and Adjusted then 'Polynomial Coefficients FullPower' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HighWind_Limit' then 'Polynomial Coefficients HighWind_Power' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HighWind_Limit' then 'Polynomial Coefficients HighWind_Power' else 'Polynomial Coefficients HighWind_Power', "KW")</pre>
--------	---

Analyses do not provide UOM of variable expressions where calculations or functions are involved. It is a best practice to use the **Convert** function inside the analyses to properly apply a unit of measure.

Best Practice

15. Verify that the scheduling is set to Event-Triggered on Any Input

Scheduling	;) Event-Triggered	O Periodic	
Trigger on	Any Input		~

Always deliberately evaluate the scheduling plan for each analysis. Triggering analyses more often than needed, especially those with downstream dependencies, can tax the Analysis Service.

16. Summary of Variables and Expressions is below. For your convenience, the content of the expressions below is available in a text file on the desktop of your VLE.

Variable	Expression
AdjustedWind SpeedVar	TagVal('Adjusted Wind Speed')
Polynomial	<pre>// Calculate Expected Power based on polynomial model of Power vs Wind Speed //</pre>
	<pre>'Polynomial Coefficients C0'*AdjustedWindSpeedVar^0</pre>
	+ 'Polynomial Coefficients C1'*AdjustedWindSpeedVar^1
	+ 'Polynomial Coefficients C2'*AdjustedWindSpeedVar^2
	+ 'Polynomial Coefficients C3'*AdjustedWindSpeedVar^3
	+ 'Polynomial Coefficients C4'*AdjustedWindSpeedVar^4
	+ 'Polynomial Coefficients C5'*AdjustedWindSpeedVar^5
	+ 'Polynomial Coefficients C6'*AdjustedWindSpeedVar^6
Output	//The calculated Expected Power is only valid in a range. At low end
·	and high end of range, fixed (low & high) values apply //
	Convert(If AdjustedWindSpeedVar< 'Polynomial Coefficients LowWind_Limit'
	then 'Polynomial Coefficients LowWind_Power'
	else it Adjustedwindspeedvar>= Polynomial Coefficients[Lowwind_Limit and AdjustedWindSpeedVarz 'Polynomial Coefficients[EullPower Limit'
	then Polynomial
	else if AdjustedWindSpeedVar>= 'Polynomial Coefficients FullPower Limit' and
	AdjustedWindSpeedVar< 'Polynomial Coefficients HighWind_Limit'
	then 'Polynomial Coefficients FullPower_Power'
	<pre>else if AdjustedWindSpeedVar>='Polynomial Coefficients HighWind_Limit'</pre>
	then 'Polynomial Coefficients HighWind_Power'
	else 'Polynomial Coetticients HighWind_Power' ,"KW")

Best Practice

Step 2: Test the expression

1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click Evaluate to make sure you have no syntax errors. You should see values next to each of the variables and no error messages in the Status bar.

Add a new variable				E↑ E	aluate
Name	Expression	Value at Evaluatio	Value at Last Trigg	Output Attribute	
AdjustedWindSpeedVar	TagVal('Adjusted Wind Speed')	4.7854 m/s	4.7854 m/s	<u>Map</u>	\otimes
Polynomial	<pre>// Calculate Expected Power based on polynomial model of Power vs Wind Speed // 'Polynomial Coefficients[C1*AdjustedWindSpeedVar^0 + 'Polynomial Coefficients[C1*AdjustedWindSpeedVar^1 + 'Polynomial Coefficients[C2*AdjustedWindSpeedVar^3 + 'Polynomial Coefficients[C4*AdjustedWindSpeedVar^4 + 'Polynomial Coefficients[C5*AdjustedWindSpeedVar^6 + 'Polynomial Coefficients[C5*AdjustedWindSpeedVar^6 + 'Polynomial Coefficients[C5*AdjustedWindSpeedVar^6</pre>	162.32	162.32	Map	8
Output	<pre>//The calculated Expected Power is only valid in a range. At low end and high end of range, 1 Convert(If AdjustedWindSpeedVar< 'Polynomial Coefficients LowWind_Limit' then 'Polynomial Coefficients LowWind_Dower' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients LowWind_Limit' and AdjustedWindSpeedVa then Polynomial coefficients FullPower_Power' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HulPower_Limit' and AdjustedWindSpeedVarbe' then 'Polynomial Coefficients FullPower' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HulPower_Limit' and AdjustedWindSpeedVarbe' then 'Polynomial Coefficients FullPower' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HulPower' else 'Polynomial Coefficients HulPower' , "KW")</pre>	162.32 kW	162.32 kW	Expected Power (Poly	nomial) 🛞

 To check the logic it is always a good idea to preview the results before implementing the analyses. Right-click on the expression Expected Power (Polynomial) and select Preview Results.

		💿 🖻 Name	
	-	*1 I SE Undernarforming	Asset
		New	e Function)
	×	Delete	nomial)
	<u>à</u> (Preview Results	Power (Polyno
Irdin	<i>7</i> .	Backfill/Recalculate	aella\GE001
		Backfill/Recalculate Status	

3. In the pop up window click on the Generate Results button. You should see something like the picture below, though the numbers may not match exactly as wind speed is variable.

Preview results for	Expected Power (Polynon	nial)				
Start Time: t		End Time:	*		Ge	nerate Results
Trigger Time	AdjustedWindSpeedVar	Polynomial	Output (kW)	Adjusted Wind Speed		Evaluation
3/7/2019 12:00:00 AM	12.347	2699.1	2699.1	12.347	^	100%
3/7/2019 12:05:00 AM	13.024	2873.3	2873.3	13.024		\bigcirc
3/7/2019 12:10:00 AM	12.339	2696.5	2696.5	12.339		Progress
3/7/2019 12:15:00 AM	12.81	2825.6	2825.6	12.81		
3/7/2019 12:20:00 AM	11.864	2536.5	2536.5	11.864		0.1ms
3/7/2019 12:30:00 AM	16.643	3364	3000	16.643		Min
3/7/2019 12:35:00 AM	13.279	2921.4	2921.4	13.279		\frown
3/7/2019 12:40:00 AM	14.758	3036.6	3036.6	14.758		(222.8ms)
2/7/2010 12-45-00 AM	12 003	28/17 2	28/17 2	12 003	\sim	Max

Step 3: Map Expected Power output to an attribute

1. Use the **Map** link and **New Attribute Template** to create a new attribute template for the output.



2. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.

Attribute Template Properties				
Save Output History:	● Yes ○ No			
Name:	Expected Power (Polynomial)			
Description:				
Data Server:	%Server%	¥		
Value Type:	Double	¥		
A PI Point data referen	ce attribute template will be creat	ed.		
	OK Cance	1		

It is a best practice to use the New Attribute Template option for outputs of analyses. There are a couple advantages over creating it "manually" on an element template. First, the Data Reference is automatically set. Secondly, the naming standards created in Challenge 1B are implemented.

Best Practice

3. Return to the attributes tab and verify the configuration of your PI Point (i.e. tag name, point source, etc.)

Name:	Expected Power (Polynomial)				
Description:					
Properties:	<none></none>	\sim			
Categories:					
Default UOM:	<none></none>	~			
Value Type:	Double	~			
Default Value:	0				
Data Reference:	PI Point	~			
Display Digits:	-5				
Settings					
\\%Server%\%Da %;pointsource=A	\\%Server%\%Database%_%Element%. %Attribute %;pointsource=AFAnalysis;pointtype=Float64				

4. Once you are happy with the PI Point configuration, Check In your changes

5. Challenge 1D: Backfill Analyses to Provide Two Weeks of Data

5.1 Objective of Activity

Your manager has approved the previous analytics but would like to see a few weeks of history.

5.2 Tasks

- Use the Management tab in PI System Explorer to create analysis searches
- Backfill analyses over a given time range

5.3 Step by Step Explanation of this Lab Section

Step 1: Create Filter

Navigate to the Management section in the PI System Explorer (PSE). Since there can be a large number of analyses you should create a view of only the analyses that pertain to the Expected Power (Polynomial). Click the
 in the Analysis Searches section in the left pane. You should see the following. Note: A tip, you can navigate to the Library section by using Ctrl-0 key combination.

Analysis Searches
Enabled
Disabled

 In the dialog that shows up, enter Expected Power (Polynomial) in the Search Name field. Then click on the Add Criteria combo-box and select Template. The Template field combobox appears. Click this combo-box and select Turbine\Expected Power (Polynomial). Click the OK button.

Search Name: E	Expected Power (Polynomial)								
Template:	Turbine\Expected Power (Polynomial)								
Add Criteria 🔻									
* Analyses that m	atch all of these criteria will be displayed.								

Step 2: Backfill Analyses

1. Click on the search you just created, Expected Power (Polynomial). You will see the Expected Power (Polynomial) analyses for all the turbines. Click the check-box next to Status to select all the analyses.



2. To backfill the events click on Backfill/Recalculate in the right pane under Operations. The Start and End fields appear. Change the start time to "*-1w", we will backfill for the last week. Click the radio button: "Permanently delete existing data and recalculate" and the click the Queue button. You will see the Backfilling column in the center pane show the progress of the backfilling operation.

Operations	✓	Status	٥	A	Element	Name	Template	Backfilling
Enable Disable selected analyses	-	0		f69	Scirocco\Talavera\RB003	Expected Power (Polynomial)	Expected Power (Polynomial)	9
	✓	0		.f63	Scirocco\Talavera\RB004	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Enable Disable automatic recalculation for selected analyses	-	0		fø)	Scirocco\Talavera\RB005	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Backfill/Recalculate selected analyses	✓	0		f63	Scirocco\Santaella\GE005	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
	✓	0		f63	Scirocco\Talavera\RB002	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Start *-1w	✓	0		f(<)	Scirocco\Talavera\RB001	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
	✓	0		f(s)	Scirocco\Santaella\GE004	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
End	✓	0		f(<)	Scirocco\Santaella\GE003	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
What should us do with existing data?	✓	0		f(<)	Scirocco\Santaella\GE002	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Leave existing data and fill in gans	✓	0		f(s)	Scirocco\Santaella\GE001	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Course existing data and him in gaps	✓	0		f(0)	Scirocco\Mieres\GE010	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Permanentiy delete existing data and recalculate	-	0		f(s)	Scirocco\Mieres\GE009	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Recalculate dependent analyses	-	0		f(s)	Scirocco\Mieres\GE008	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
0	-	0		f60	Scirocco\Mieres\GE007	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Queue	-	0		f60	Scirocco\Mieres\GE006	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
Developed attact will a surrough the delete all the	-	0		f60	Scirocco\Finisterre\RB010	Expected Power (Polynomial)	Expected Power (Polynomial)	9
data within the time range. For event	-	0		f60	Scirocco\Finisterre\RB009	Expected Power (Polynomial)	Expected Power (Polynomial)	0
frames this will result in loss of annotations	-	9		f60	Scirocco\Finisterre\RB008	Expected Power (Polynomial)	Expected Power (Polynomial)	9
and acknowledgements.	-	0		f60	Scirocco\Finisterre\RB006	Expected Power (Polynomial)	Expected Power (Polynomial)	0%
	1	0		fø)	Scirocco\Finisterre\RB007	Expected Power (Polynomial)	Expected Power (Polynomial)	0%

Step 3: Repeat for Other Analyses by Updating the Template Criteria in Step 1

- 1. After you backfill, return to the Elements Tab and navigate to Scirocco>Finisterre>RB006.
- 2. Right click on the Expected Power (Polynomial) attribute and choose Trend to see the historical data.



6. Challenge 2: PI Vision Turbine Display

6.1 Objective of Activity

In this activity you will create a PI Vision Display that uses the Power Curves you developed in the previous section. Specifically, you will use the XY Plot in PI Vision to achieve this.

6.2 Tasks

- Plot Polynomial Expected Power and Live data on PI Vision XY Plot
- Display other Attributes of interest in PI Vision

6.3 Step by Step Explanation of this Lab Section

Step 1: Create Polynomial Expected Power XY Plot

- 1. Find the attributes Adjusted Wind Speed and Expected Power (Polynomial) and select them both by clicking with Ctrl held down. Ensure the XY plot option 🖾 is selected on the top left and then drag them both onto the main display.
- 2. Once the two items are in the XY Plot the Configure XY Plot sidebar should open on the right hand side. Now add a second set of data to compare the live data with the Expected Power (Polynomial) calculation. With the Configure XY Plot sidebar open complete the following:
 - a. Find the Adjusted Wind Speed attribute and drag it to the new X-Axis slot
 - b. Find the Active Power attribute and drag it to corresponding Y-Axis spot



Step 2: Display other Attributes of interest in PI Vision

- 1. While on the Asset sidebar, add the following information to the display
 - a. I <u>Table</u>: Longitude, Latitude, Elevation
 - b. <u>ITrend</u>: Active Power, Adjusted Wind Speed
 - c. Madial Gauge: Active Power, Adjusted Wind Speed
 - d. Note: If the scales are not as desired you can correct them by right clicking the gauge and then Format Gauge
 - e. Im Value: Site, Asset Name, Status, Manufacturer, Model, Installation Date
 - f. Note: If you want all Value objects to come in with the same formatting you can copy and paste the correctly formatted Value objects and simply drag and drop new attributes over the copies to update the data item
 - g. Text Labels: Site, Asset Name, Status, Manufacturer, Model, Installation Date
- 2. Change to the Symbol Library III on the left hand side and add a Wind Turbine graphic.



3. Save your display as "Wind Turbine Details"

7. Challenge 3: Production Delta and Operating Efficiency

7.1 Objective of Activity

Now that you've calculated the expected power from each turbine based on wind speed, you need to calculate the production loss and the production efficiency from each turbine. You have calculated expected power three ways and have been asked to use the Expected Power (Polynomial) as the expected power to do this calculation.

7.2 Tasks

- Create Attributes for Production Delta and Production Efficiency in the Turbine template.
- Create the Analysis to calculate the Production Delta and Production Efficiency in the Turbine template and map them to the Attributes, creating PI tags for those attributes.

7.3 Step by Step Explanation of this Lab Section

Step 1: Create an analysis to calculate Production Delta for current operation

- 1. In PSE, select the Library navigation tab, then Element Templates, then Turbine
- 2. Select the Analysis Templates tab
- 3. Right mouse click New, then change the name to Production Delta / Efficiency

Library	Turbine				
Challenge 3 Solution-Challenge 4 Reset	General Attribute Temp	ates Ports Analysis Templates Notification Rule Templates			
Templates Templates				Name:	Production Delta / Efficiency
- G Farm	A R Name			Description:	
📠 PI Data Archive	fià Expected	wer (Polynomial)	^	Categories:	
Region	fix) Expected f	Expected Power (Polynomial)		Analysis Type	Expression Rollup Event Frame Generation
Event Frame Templates	260 Productio	Delta / Efficiency		Enable an	alyses when created from template
🗈 📽 Model Templates		,,	~		· ·
Transfer Templates	Commits Flowersh Co	\ Ct!!\ CE001			
Keference Types	Example Element: 30	occo/santaelia/deoon			
🗈 🛅 Tables	Add a new variable				Evaluate Evaluate
Table Connections	Name	Expransion			Output Attribute
Analysis Categories	Ivalle	Expression			Insert func
🗎 Attribute Categories	Variable1	Type an expression			Map
Im Im Flement Categories					

- 4. Define the analysis. This is not complicated mathematically, but so those who look at your work later will know how you did the calculation, we will do it in steps. Add 5 variables:
 - a. ExpectedPowerVar
 - b. ActivePowerVar
 - c. ProductionDelta
 - d. Running
 - e. Efficiency



A tip, unless you like clicking a lot just hit the **Enter** key on your keyboard and you will see that **Variable2** is now highlighted. Rename the variables as shown in the table below.

- 5. For ExpectedPowerVar and ActivePowerVar, use the TagVal function to bring in the **Expected Power (Polynomial)** and **Active Power**, respectively
- 6. Now calculate the variable **ProductionDelta** = ExpectedPower ActivePower.
- 7. Use the **Running** variable to check if the unit is actively running (i.e. in the "Run" or "Partial Run" status)
- 8. Set the **Efficiency** variable to be equal to the ActivePower / ExpectedPower unless ExpecterPower=0 or the unit is not Running. If either of those conditions are true then do not write a result. Hint: Use IF-THEN-ELSE and NoOutput() functions.
- 9. If you would like to see how a fellow engineer did this:

Name	Expression	Output Attribute
ExpectedPowerVar	<pre>TagVal('Expected Power (Polynomial)','*')</pre>	<u>Map</u>
ActivePowerVar	TagVal('Active Power','*')	<u>Map</u>
ProductionDelta	ExpectedPowerVar-ActivePowerVar	Production Delta
Running	<pre>If 'Status' = "Run" or 'Status' = "Partial Run" then true else false</pre>	Map
Efficiency	<pre>//Suppress efficiency calc if expected power = 0 (likely wind outside cutoffs) or if turbine not running, which could be due to reasons such as maintenance or curtailment// IF ExpectedPowerVar = 0 or Not Running then NoOutput() else ActivePowerVar/ExpectedPowerVar*100</pre>	<u>Production</u> <u>Efficiency</u>

10. Test the analysis

11. Use Evaluate to test the analysis. Hint: when in a template, you must first choose an Example Element before you can test the analysis. You may need to check several elements to be sure your calculation is correct in all possible scenarios.

Add a new variable				≣t E	valuate
Name	Expression	Value at Evaluatio	Value at Last Trigg	Output Attribute	
ExpectedPowerVar	TagVal('Expected Power (Polynomial)','*')	942.1 kW	942.1 kW	<u>Map</u>	\otimes
ActivePowerVar	TagVal('Active Power','*')	895.63 kW	895.63 kW	<u>Map</u>	\otimes
ProductionDelta	ExpectedPowerVar-ActivePowerVar	46.471 kW	46.471 kW	Production Delta	\otimes
Running	If 'Status' = "Run" or 'Status' = "Partial Run" then true else false	True	True	Map	8
Efficiency	<pre>//Supress efficiency calc if expected power = 0 (likley wind outside cutoffs) or if t IF ExpectedPowerVar = 0 or Not Running then NoOutput() else ActivePowerVar/ExpectedPowerVar*100</pre>	95.067	95.067	Production Efficiency	8

12. A good approach would be to calculate new expected production delta and efficiency any time expected power OR Active Power changes. Hint: set the Scheduling to Event Triggered and choose the events you'd like to trigger a new calculation.



- 13. Don't forget to Check In the analysis after testing is complete!
- 14. After Check In, review a couple of actual turbines to ensure the analyses are operating properly.

Step 2: Map Production Delta and Efficiency outputs to attributes

- 1. Map the ProductionDelta and Efficiency outputs each to their own attribute following the instructions below
- 2. Use the **Map** link and **New Attribute Template** to create a new attribute template for the output.



3. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.

Attribute Template Properties ×		Attribute Template Properties		
Save Output History:	● Yes ○ No		Save Output History	: • Yes 🔿 No
Name:	Production Delta		Name:	Production Efficency
Description:			Description:	
Data Server:	%Server%	~	Data Server:	%Server% v
Value Type:	Double	~	Value Type:	Double
A PI Point data referer	nce attribute template will be	e created. Cancel	A PI Point data refer	ence attribute template will be created. OK Cancel

It is a best practice to use the New Attribute Template option for outputs of analyses. There are a couple advantages over creating it "manually" on an element template. First, the Data Reference is automatically set. Secondly, the naming standards created in Step 1 are implemented.

4. Return to the attributes tab and verify the configuration of your PI Point (i.e. tag name, point source, etc.)

Name:	Expected Power (Polynomial)
Description:	
Properties:	<none> ~</none>
Categories:	
Default UOM:	<none> ~</none>
Value Type:	Double ~
Default Value:	0
Data Reference:	PI Point ~
Display Digits:	-5
Settings	
\\%Server%\%Database%_%Element%.%Attribute %;pointsource=AFAnalysis;pointtype=Float64	

5. Once you are happy with the PI Point configuration, Check In your changes

Step 3: Create two weeks of history

1. Follow the steps in Challenge 1D: Backfill Analyses to Provide Two Weeks of Data to backfill the data for the new analysis.

Best Practice
8. Challenge 4: Event Frame for Low Operating Efficiency

8.1 Objective of Activity

As an engineer at the Wind Farm you want to monitor the turbine efficiency and identify which turbines are running below 85% and for how long. You also want to eliminate fluctuations to the efficiency that may cause events of a duration of less than 5 minutes.

8.2 Tasks

- Define the logic for the generation of low efficiency events and implement in the Turbine Template
- Test and backfill the events

8.3 Step by Step Explanation of this Lab Section

Step 1: Add Efficiency Limit to Turbine Template and Naming Pattern for Event Frame Template

 Navigate to the Library section in the PI System Explorer (PSE). Open the Element Templates tree and click on Turbine. Then click on the Attribute Templates tab in the center pane. You should see the following. Note: Remember, you can navigate to the Library section by using Ctrl-3 key combination.

Element Templates	Filter				<u>ب</u> م
		1 -1			
PI Data Archive	🖉 🖊 i	Representation of the second secon	∇	Description	Default Value
🔂 Region		-			
🛄 Turbine		🖓 Status Cause			
Event Frame Templates		C Status			
- Bowntime		Ve Status			
Under-Performing Turbine		💷 Site			
		and one			
		Production Efficie	ncv		0 %
Transfer Templates		V			
Enumeration Sets		Production Delta			0 kW
Reference Types					
Tables		Kara Power Factor			0
Table Connections					-
Categories		Model			0
Analysis Categories		- Manufacturer			0
Attribute Categories					
Element Categories		📇 Longitude			0 °

2. Right-click on the Attribute **Production Efficiency** and select **New Child Attribute Template**. This creates an Attribute below **Production Efficiency**.

0	÷	K Production Efficiency	0 %
		📇 Attribute 1	0
		Z Production Delta	0 kw

3. In the right hand pane enter the values shown in the table below for the corresponding text. The result should look like the figure below. For simplicity use the fixed value of 85% as the **Default Value**. Note: A tip, for the **Default UOM** a simple way to find the unit of measure is to highlight the **<None>** and then start typing "**pe**", you will see the intellisense showing you the available units. Select the **percent**, there you go much easier.

Text	Value
Name	Efficiency Target
Default UOM	Percent
Value Type	Int16
Default Value	85%

_	
Name:	(Efficiency Target)
Description:	
Properties:	<none></none>
Categories:	
Default <u>U</u> OM:	percent
Value Type:	Int16
Default Value:	85 %
Data <u>R</u> eference:	<none></none>
Display Digits:	-5

		-	
3	🔶 🍝 Production Efficiency		0 %
		🔄 Efficiency Target	85 %

- 4. It is a good idea to create a naming pattern for these events so that we can recognize them in amongst all the other events. Select the Under-Performing Turbine Template under Event Frame Templates. In the Naming Pattern field enter the following text. Then
 Check In your work.
- 5. OSIDemo_%TEMPLATE% %ELEMENT% %STARTTIME:yyyy-MM-dd HH:mm:ss%

Under-Performi	ng Turbine							
General Attrib	emplates							
Name: Under-Performing Turbine								
Description:								
Base Template:	<none></none>							
Categories:								
Naming Pattern	OSIDemo_%TEMPLATE% - %ELEMENT% - %STARTTIME:yyyy-MM-dd HH:mm:ss%							
	Allow Extensions							

6. Note: If you click on in the **Naming Pattern** field an example list of substitution syntaxes displays. You can click on these to save you typing and making mistakes in the syntax.



7. Check In your work.

Step 2: Create Event Frame Expression

1. Navigate to the **Turbine** Template and Click on the **Analyses** tab in the center pane. You should see the following.

Turbine										
General	A	ttribute Templ	lates	Ports	Analysis Templat	es Notifi	cation Rule Ter	nplates	;	
									Name:	
6	-	Name							Descrip	tion:
f⊗ Expected Power (Curve Function)									Categories:	
fte Expected Power (Polynomial)								-11		
fix Eorecast 1h Expected Power (Polynomial)								Analysis Type		
	f⊗	Production	n Delta	/Efficier	ncy				✓ Enable a	
Exampl	le El	ement: <u>Sci</u>	rocco	Santael	la\GE001					
Add a	a ne	w variable						E	valuate	
Nam	e		Expr	ession			Output A	ttribut	e	
Adju	ste	dWindSpeed	Tag\	/al <mark>('</mark> A	djusted Wind	Speed') <u>Map</u>			\otimes
			// ι	Jsing	datapoints o	f wind	spt -	_		

2. Click the symbol and then select the Event Frame Generation radio-button. Then change the Name to EF Underperforming Asset.

Turk	oine								
Gen	eral A	Attribute Te	mplates Por	s Analysis Templat	Notification Rule Templates				
	fixi fixi fixi	Name Expecte Forecas	ed Power (Poly at 1h Expected	rnomial) I Power (Polynomial)		Name: Descript Categori Analysis	EF Underperform	Rollu	p • Event Frame Generation
Exa	ہر H mple f	EF Und	erperforming Scirocco\San	Asset aella\GE001		Create a	a new notification rule te	emplate for	EF Underperforming Asset
0	Generat	tion Mode:	Explicit Trig	ger v	Event Frame Template:		× 🌖	> Fu	nctions
	Add	~					U Evaluate	Inse	rt functions into the expression
	Name		Expression			True for	Severity	All	
	😑 Sta	art triggers						Abs	
	Start	Triager1	Type on exp	ression		Set (ontional	None ~	1.00	

 If Example Element shows <u>Select an example element</u>, then click it and select an element from the pop-up dialog that shows all the elements that are derived from the Turbine template. Then click the Event Frame Template combo-box and select Under-Performing Turbine.

Example Element: Scirocco\Santaella\GE001	
Generation Mode: Explicit Trigger v	Event Frame Template: Under-Performing Turbine v

4. Below **Generation Mode** click on the Add... v and select **Variable**. Do this one more time to create a second variable.



 Click on Variable1 and type Efficiency. Click on Variable2 and type Target. Then for Variable1 type 'Production Efficiency' and for Variable2 type 'Production Efficiency |Efficiency Target'. Note: The intellisense does not recognize Child-Attributes, so you need to type the whole of |Efficiency Target' manually or select the Efficiency Target child attribute from the Attributes Pane.

Add V					
Name Expression					
Variables					
Efficiency	'Production Efficiency'				
Target	'Production Efficiency Efficiency Target'				
Start triggers					

- 6. For the **Start Trigger** type the following expression.
- 7. Efficiency < Target AND 'Status' <> "Stop"

Name	Expression
Variables	
Efficiency	'Production Efficiency'
Target	'Production Efficiency Efficiency Target'
 Start triggers 	
StartTrigger1	Efficiency < Target AND 'Status' <> "Stop"

8. Note: A common mistake is to start typing the quote ' and then **Efficiency**, typing the quote is for **Attributes** only. In this case, Efficiency is the Variable you defined in item 5 above. For **Variables**, do not type the quote. The same goes for Target in the expression.

Step 3: Test the Event Frame Expression

1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click **Evaluate** to make sure you have no syntax errors. You should see values next to the variables and the start trigger and no error messages in the Status bar.

ſ	Add V								
	Name	Expression	Value at Evaluatio	Value at Last Trig	99				
	Variables								
	Efficiency	'Production Efficiency'			101.6 %	101.6 %	\otimes		
	Target	'Production Efficiency Efficiency Target'			85 %	85 %	۲		
	 Start triggers 								
	StartTrigger1	Efficiency < Target AND 'Status' <> "Stop"	Set (opt	None ~	False	False			

 To check the logic it is always a good idea to preview the results before implementing the analyses. Right-click on the expression EF Underperforming Asset and select Preview Results.

		(9)]	
		🚯 🖪 Name	
		*1 EE Undernorforming	Asset
		New	re Function)
	X	Delete	nomial)
urbin	<u>a</u> (Preview Results	Power (Polyno
	<i>7</i>	Backhill/Recalculate	aella\GE001
		Backfill/Recalculate Status	

 In the pop up window click on the Generate Results button. You should see something like the picture below. If everything looks good click the Close button and Check In your work.

Q Preview results for EF Underp	performing	g Asset			o x
Start Time: t		End Time: *			Generate Results
Mame	Duration	Start time	End time	Severity	Evaluation
EventFrame 20190124 00:05:00	00:05:00	1/24/2019 12:05:00 AM	1/24/2019 12:10:00 AM	None	
EventFrame 20190124 01:35:00	00:05:00	1/24/2019 1:35:00 AM	1/24/2019 1:40:00 AM	None	(100%)
EventFrame 20190124 05:35:00	00:05:00	1/24/2019 5:35:00 AM	1/24/2019 5:40:00 AM	None	\sim
EventFrame 20190124 05:55:00	00:05:00	1/24/2019 5:55:00 AM	1/24/2019 6:00:00 AM	None	Progress
EventFrame 20190124 07:35:00	00:05:00	1/24/2019 7:35:00 AM	1/24/2019 7:40:00 AM	None	
EventFrame 20190124 07:45:00	00:05:00	1/24/2019 7:45:00 AM	1/24/2019 7:50:00 AM	None	(0ms)
EventFrame 20190124 09:05:00 (00:50:00	1/24/2019 9:05:00 AM	1/24/2019 9:55:00 AM	None	
EventFrame 20190124 10:10:00 (00:10:00	1/24/2019 10:10:00 AM	1/24/2019 10:20:00 AM	None	Min
EventFrame 20190124 11:10:00 (00:05:00	1/24/2019 11:10:00 AM	1/24/2019 11:15:00 AM	None	
EventFrame 20190124 11:55:00 (00:05:00	1/24/2019 11:55:00 AM	1/24/2019 12:00:00 PM	None	(140.1
EventFrame 20190124 12:15:00 (00:05:00	1/24/2019 12:15:00 PM	1/24/2019 12:20:00 PM	None	(140.1ms)
EventFrame 20190124 12:50:00 (00:05:00	1/24/2019 12:50:00 PM	1/24/2019 12:55:00 PM	None	
EventFrame 20190124 13:15:00 (00:05:00	1/24/2019 1:15:00 PM	1/24/2019 1:20:00 PM	None	Max
EventFrame 20190124 14:30:00 (00:10:00	1/24/2019 2:30:00 PM	1/24/2019 2:40:00 PM	None	
EventFrame 20190124 15:10:00 (00:05:00	1/24/2019 3:10:00 PM	1/24/2019 3:15:00 PM	None	(4.7ms)
EventFrame 20190124 15:30:00 (00:05:00	1/24/2019 3:30:00 PM	1/24/2019 3:35:00 PM	None	
EventFrame 20190124 16:55:00 (00:05:00	1/24/2019 4:55:00 PM	1/24/2019 5:00:00 PM	None	Avg
EventFrame 20190124 17:25:00 (00:05:00	1/24/2019 5:25:00 PM	1/24/2019 5:30:00 PM	None	
EventFrame 20190124 17:45:00 (00:10:00	1/24/2019 5:45:00 PM	1/24/2019 5:55:00 PM	None	(
				_	344.45

Step 4: Create two weeks of history and view results

- 1. Follow the steps in Challenge 1D: Backfill Analyses to Provide Two Weeks of Data to backfill the data for the new analysis.
- 2. When the backfilling finishes navigate to the Event Frames. Right-click on Event Frame Searches and select New Search. In the dialog that pops up click on the Template combobox and select Under-Performing Turbine. Then click the Search button. You should see something like the example below. To select all the resulting event frames do not click inside the Results table and try to select them. Just click the OK button, by default all of the results are selected.

Event Frames	Event Frame Searches						
Event Frame Searches	Filter						
	Name						
🗄 👾 🔫 Transfer Search 1	For Event Frame Search 1						
	Event Frame Search	×					
	Template:"Under-Performing Turbine"	× 🔻 🖉 Search					
	Criteria	8					
	Search: Starting Before V In Progress						
	Search start: 12/31/9999 11:59:59 PM 🛗 🕨 🗹 All Descendants						
	Name:	×					
	Analysis Name:	×					
	Element Name:	×					
	Category: <all> ~</all>	×					
	Template: Under-Performing Turbine V	×					
	💫 Add <u>C</u> riteria 🔻						
	Results	۲					
	Group b	y: Category Template					
	Name	1/2 [1.00:00:01] @/2 ^					
	H OSIDemo_Under-Performing Turbine - RB003 - 2019-01-24 17:00:00						
	OSIDemo_Under-Performing Turbine - RB004 - 2019-01-24 17:00:00						
	The search found 494 Event Frames matching the search criteria.						
	ОК	Cancel Reset					
	10 10						

You can navigate to the **Event Frames** section by using **Ctrl-2** key combination.

3. Right-click the search you just created and select **Rename**. Enter **Underperforming Turbine Events**. This way if you have more than one search you know which one refers to what. Your task is complete.

Tip

Event Frames	Underpe	rforming Turbine Events			
Event Frame Searches	Filter				Group by:
	• 🗟 🖻 🖌	Name	1/2 [1.00:05:01] 1/2	Duration	Start Time
OSIDemo_Under-Performing		OSIDemo_Under-Performing Turbine - GE007 - 2019-01-25 17:05:00		0:04:04.053	1/25/2019
OSIDemo_Under-Performing OSIDemo_Under-Performing	E 📌	CSIDemo_Under-Performing Turbine - GE006 - 2019-01-25 17:00:00		0:05:00	1/25/2019
OSIDemo_Under-Performing	* 🖈	CSIDemo_Under-Performing Turbine - RB008 - 2019-01-25 17:00:00		0:05:00	1/25/2019
OSIDemo_Under-Performing	*	OSIDemo_Under-Performing Turbine - GE003 - 2019-01-25 17:00:00		0:05:00	1/25/2019
OSIDemo_Under-Performing	*	OSIDemo_Under-Performing Turbine - RB003 - 2019-01-25 17:00:00		0:05:00	1/25/2019
OSIDemo_Under-Performing	* ۵	OSIDemo_Under-Performing Turbine - GE010 - 2019-01-25 16:55:00		0:05:00	1/25/2019
OSIDemo_Under-Performing	*	OSIDemo_Under-Performing Turbine - RB010 - 2019-01-25 16:50:00		0:05:00	1/25/2019
OSIDemo_Under-Performing	x	OSIDemo_Under-Performing Turbine - GE008 - 2019-01-25 16:50:00		0:05:00	1/25/2019 ·

9. Optional: Challenge 5: Rollups

9.1 Objective of Activity

Now that you've established good metrics around each of the turbines the CEO is asking for a dashboard that provides all of the information at a farm and region level. Since all of the needed data is visible in AF, you realize it is a simple task to create rollups to aggregate the turbine data.

The CEO would like the values to be updated on a 5-minute frequency.

9.2 Tasks

- Create analysis template rollups on the element farm template for **Expected Power Production**, **Net Production Delta**, **Power Production**, and **Production Efficiency.** For **Expected Power Production**, use the polynomial calculation.
- Create analysis template rollups on the element region template for Expected Power Production, Net Production Delta, and Production Efficiency

9.3 Step by Step Explanation of this Lab Section

Step 1: Understanding rollups

You haven't done rollups before, so you decide to review the content on my.OSIsoft.com and the OSIsoft learning Channel. You learn that:

- 1. Rollups gather data based on a search criteria.
- 2. Most commonly a rollup is aggregating data to a parent from all of its children.
- 3. Rollups have a built in list of calculations to choose from such as sum, average, etc...

Mapping of outputs work the same as expression analyses

Step 2: Build the Farm rollup for Expected Power Production

- 1. Expected Power Production
- 2. Using the element template Farm, add **a new analysis** of type **rollup**. Name it **Expected Power Production**.

				Name:	Expected Power P	roduction	
٥		Name	~	 Description:			
	ø	Expected Power Production		Categories:			
	Ø	Net Production Delta		Analysis Type:	\bigcirc Expression	Rollup	(
	ø	Power Production		✓ Enable ana	alyses when created	d from templat	te
	at	Production Efficiency	~				

3. Fill in the criteria such that the attribute **Expected Power (Polynomial)** is found for Child elements. There are several criteria options name, categories, etc... **Attribute Name** is most appropriate here. Note the green check mark that appears next to attributes which match the filter criteria.

Rollup attributes fro	m of Santaella 🔿 This element - Santaella		Sample Child Element: GE001			
To select attributes s	To select attributes set criteria below					
Attribute Name:	Expected Power (Polynomial)		✓ Expected Power (Polynomial)			
And Boarde Harrier		_	Active Power			
Attribute Level:	Root Level	*	Adjusted Wind Speed			
Attribute Category:		~	Apparent Power			
Element Category:		~	Asset Name			
Element Template		~	Curtailment Cause			
element remplater			CutOut			
Select the function(s	s) to write to an attribute Evaluate		Elevation			

4. Select the appropriate aggregate function by checking the box. In this case, select **Sum**.

Select the function(s) to write to an	Evaluate		
Function	Output(s)	Value At Eva	Value At Last
✓ Sum	<u>Map</u>	0 kW	0 kW
Average			
Minimum			
Maximum			
Count			
Median			
Population standard deviation			
Sample standard deviation			

5. Set the **Scheduling** to accommodate the requested 5 minute update frequency is required.

Best Practice

Always deliberately evaluate the scheduling plan for each analysis. Triggering analyses more often than needed, especially those with downstream dependencies, can tax the Analysis Service. In this case, while it may make "sense" to event trigger as a new turbine power is recorded, if the data is not needed that often, there are unneeded calculation cycles.

This is a common occurrence when setting event triggered analyses and the trigger is field measurement with a very high frequency. If analyses are overscheduled, high performance impact may occur.

4. Use the **Map** link and **New Attribute Template** to create a new attribute template for the output.



5. Note, rollup analysis types do not allow the option for not saving the output history.

Q Attribute Template Properties X			
Save Output History:	● Yes ◯ No		
Name:	Expected Power Production		
Description:			
Data Server:	%Server% v	,	
Value Type:	Double v	,	
A PI Point data referen	ce attribute template will be created.		

It is a best practice to use the New Attribute Template option for outputs of analyses. There are a couple advantages over creating it "manually" on an element template. First, the Data Reference is automatically set. Secondly, the naming standards created in Step 1 are implemented.

Best Practice

6. Return to the attributes tab and verify the configuration of your PI Point (i.e. tag name, point source, etc.)

<none></none>	\sim				
Calculated Data					
MM.	~				
Single	\sim				
) MW					
PI Point	\sim				
5					
Settings					
\\%@\PI Data Archive Name%\%Database%_%Element%.%Attribute %;UOM=MW;pointsource=AFAnalysis;pointtype=Float32					
	Calculated Data IW Single IMW PI Point 5 Settings re [Name%\%Database%_%Element%.%Attribute purce=AFAnalysis;pointtype=Float32				

7. Once you are happy with the PI Point configuration, Check In your changes

Step 3: Create rollups for the remaining Farm aggregations and Region aggregations

- 1. As a reminder, the CEO requested aggregations also for **Net Production Delta**, and **Production Efficiency** at the Farm level as well as all of these items at the **Region** level.
- 2. Use the table below as a reference along with Step 2 above to create the remaining analyses.

Element Template	Analysis	Function	Output Attribute
Farm	Net Production Delta	Sum	Net Production Delta
Farm	Production Efficiency	Average	Average Production Efficiency
Region	Expected Power Production	Sum	Expected Power Production
Region	Net Production Delta	Sum	Net Production Delta
Region	Production Efficiency	Average	Average Production Efficiency

Step 4: Add Attribute Categories

- Add categories for all the new rollup results on the Farm and Region element templates. You may want to reuse the Calculated Data category or create a new one such as Aggregation
- 2. Add categories for all the new rollup results on the Region element template



Step 5: Create two weeks of history

1. Follow the steps in Challenge 1D: Backfill Analyses to Provide Two Weeks of Data to backfill the data for the new analysis.

10. Optional: Challenge 6: PI Vision Displays for Farm and Region

10.1 Objective of Activity

In this activity you will create a PI Vision Display that show the Rollup data you developed in the previous section. Specifically you will use Collections and Navigation Links to show all assets at a Farm/Region and be able to drill down to find more detail.

10.2 Tasks

- Create a Site dashboard with Rollup information and Turbine Collections
- Create a Region dashboard with Rollup information and Site Collections

10.3 Step by Step Explanation of this Lab Section

Step 1: Create a Site dashboard

- 1. Open Google Chrome and navigate to PI Vision at https://pisrv01/pivision/ . Once at the PI Vision homepage, click on the New Display option at the top. New Display.
- 2. Navigate on the Asset sidebar and select a Site. Then add the following information about the Site to the display:
- 3. I Trend: Power Production, Expected Power Production
- 4. Im Horizontal Gauge: Average Production Efficiency, Net Production Delta
- 5. Note: If the scales are not as desired you can correct them by right clicking the gauge and then Format Gauge. Also you can change the Label to just show the attribute name as well
- 6. 💷 Value: Asset Name
- 7. Text Labels: Asset Name



- 8. Now we can create a collection of Turbine assets to show relevant information about each turbine at the site. Navigate down from the current site you are on and select a Wind Turbine. Add the following information to the display
- 9. I Value: Asset Name, Active Power, Production Delta, Production Efficiency



- 10. Change to the Symbol Library 🕕 on the left hand side and add a Wind Turbine graphic.
- 11. Enclose all this in a Rectangle. Format this shape in the right click window to have no fill and Send it to Back with the Arrange options



12. Right Click the Status value object and Configure Multistate. Use the following color scheme:



- 13. Right click the Turbine symbol and choose to Add Navigation Link.
- 14. Click "Search for displays..." and search for the Turbine Details display you saved earlier
- 15. Once you have found the Turbine Details display, ensure the options selected match those below



16. Now click and drag your mouse over all the objects we have made and with a right click Group Symbols. Then right click again and Convert to Collection.



17. Save this display as Site Dashboard

Step 2: Create a Region dashboard

- 1. Click on the New Display option at the top. Over Display.
- 2. Navigate on the Asset sidebar and select a Region (in this case there is only one: Scirocco). Then add the following information about the Site to the display:
- 3. Trend: Power Production, Expected Power Production
- 4. Im Horizontal Gauge: Average Production Efficiency, Net Production Delta
- 5. Note: If the scales are not as desired you can correct them by right clicking the gauge and then Format Gauge. Also you can change the Label to just show the attribute name as well
- 6. 💷 Value: Asset Name
- 7. II Text Labels: Asset Name



- 8. Now we can create a collection of Site assets to show relevant information about each site at the site. Navigate down from the current Region you are on and select a Site. Add the following information to the display
- 9. I Value: Asset Name, Power Production, Net Production Delta, Average Production Efficiency, Expected Power Production
- 10. Note: If you want all Value objects to come in with the same formatting you can copy and paste the correctly formatted Value objects and simply drag and drop new attributes over the copies to update the data item
- 11. Enclose all this in a Rectangle. Format this shape in the right click window to have no fill and Send it to Back with the Arrange options



- 12. Right click the Site Name symbol and choose to Add Navigation Link.
- 13. Click "Search for displays..." and search for the Site Dashboard display you saved earlier

14. Once you have found the Site Dashboard display, ensure the options selected match those below



15. Now click and drag your mouse over all the objects we have made and with a right click Group Symbols. Then right click again and Convert to Collection



16. Save your display as Region Dashboard.

11. Optional: Challenge 7: Forecasted Power

11.1 Objective of Activity

As an engineer at the Wind Farm you need to have the ability to forecast the power that the wind farm would be expected to generate, so that you know if you can meet the forecasted demand. You have the forecasted wind for each region in a PI Tag and you will use this together with the power curve to calculate the forecasted power that will be should be generated.

11.2 Tasks

- Add an Attribute for the forecast expected power to the Turbine Template.
- Map this new Attribute to a PI Tag.
- Create the **Analysis** to calculate power generated based on the forecasted wind speed.
- Validate the calculation and backfill.

11.3 Step by Step Explanation of this Lab Section

This challenge is very similar to Challenge 1C: Use a Polynomial Fit to Model the Power Curve. The exception is related to the times that the data are queried for and written out to. In fact, you could copy the analysis from the previous challenge and simply apply the time based changes described in this section.

Step 1: Add Analysis to Turbine Template and Set Schedule and Future Output

- Navigate to the Library section in the PI System Explorer (PSE). You should be in the Turbine template, if not click on Turbine under the Element Templates tree in the left pane. Then click on the Analysis Templates tab in the center pane. Note: Remember, you can navigate to the Library section by using Ctrl-3 key combination.
- 2. Click the symbol to create a new analysis. In the **Name** field enter the text **Forecast 1h Expected Power (Polynomial)**.

Ī]	Name:	Forecast 1h Expected	Power (Polynomial)	
ľ	0		Name	~	1.	Description:			
		ſ⊗	Expected Power (Curve Function)	-	Ш	Categories:	ExpectedPower		
		f⊗	Expected Power (Polynomial)		U	Analysis Type:	Expression O	Rollup O Event	Fra
		% {⊗	Forecast 1h Expected Power (Polynomial)		L	🖌 Enable and	alyses when created fro	m template	
L		fish	Production Delta/Efficiency	\sim					

3. At the bottom of the window, set the scheduling to **Periodic** and click the **Configure** button. Check the **Specify Offset** check-box; leave **5 minutes** as the period and enter **1 second** for the offset. Then click the **OK** button.

Add a new y	variable	Periodic Schedule			
Name	Expression				
Variable1	Type an expression	Set a Periodic Schedule			
		 Hours, minutes, and seconds Sub-seconds Daily 			
		Period			
		Specify the amount of time between evaluations.			
		00 h 05 m 00 s			
		Specify Offset			
		Offset			
		Shifts the period from the beginning of the day. Offset must be less than period.			
		00 h 00 m 01 s			
		Example evaluation times 1/31/2019 12:00:01 AM 1/31/2019 12:05:01 AM 1/31/2019 12:10:01 AM			
		OK Cancel			
Scheduling: Period: 00h 05	cheduling: O Event-Triggered Periodic Advanced Advanced				

4. Click the **Advanced** button and in the pop up dialog select the **Relative to Trigger Time** radio button. Enter ***+1h** in the field and click the **OK** button. Remember that we want to write the forecast one hour ahead.

	Q Advanced options X
	Output Time Stamp
	Trigger Time Execution Time Relative to Trigger Time: Variable: Manned output attributes require a future PI point to
	save output history. For newly mapped output attributes that save output history, PI Analysis Service will create future PI points.
	Automatic Recalculation
	Recalculate analysis for out-of-order input events
	OK Cancel
 Event-Triggered 5m 00s, Offset: 00h 00n 	Periodic Advanced
 Event-Triggered 5m 00s, Offset: 00h 00n 	Periodic Advanced n 01s Configure

Step 2: Fill in Expected Power Polynomial Analysis

1. Create a variable called AdjustedWindSpeedVar



2. In this expression, we want to grab the current tag value of the Adjusted Wind Speed attribute so we can save it to use in the subsequent expressions.

```
AdjustedWindSpeedVar PrevVal('...\Wind Speed Forecast 1h','*+1h')
```

- 3. Create a new variable called **Polynomial**, this variable is the real "guts" of this analysis.
- 4. Since we fit our curve to a 6th order polynomial, Our expression will use the following equation:

 $y = C_0 + C_1 x + C_2 x^2 + C_3 x^3 + C_4 x^4 + C_5 x^5 + C_6 x^6$

where y is the Expected Power and x is the Adjusted Wind Speed

5. To make the expression a bit easier to follow and troubleshoot (as well as repeatable), we will actually type in following this equation:

 $y = C_0 x^0 + C_1 x^1 + C_2 x^2 + C_3 x^3 + C_4 x^4 + C_5 x^5 + C_6 x^6$

 Begin by navigating to the C0 attribute from the Attributes Panel on the bottom right side of the analysis pane. Choose Image: Choose ">"</a href="#">Image: Choose "</a href="#">

>	Attr	ibutes					
Se p	elect ath t	an elem o one of	ent and then its attributes	n insert a rela s into the exp	tive or absol pression	ute	
		Model					\sim
4	=	Polynom	nial Coefficie	nts			
		🗉 C0	🕂 Relative	🔁 Absolute			
		🗉 C1					
		- CO					\sim
<						>	

7. Multiply the C0 coefficient by AdjustedWindSpeedVar raised to the 0th power (i.e. multiplying C0 by 1). By multiplying by the 0th power now, this makes the expression reproducible:

'Polynomial Coefficients|C0'*AdjustedWindSpeedVar^0

8. Copy and paste the first line with a + in between then change the 0's to 1's:

'Polynomial Coefficients|C0'*AdjustedWindSpeedVar^0 + 'Polynomial Coefficients|C1'*AdjustedWindSpeedVar^1

9. Repeat Step 10 until you have put in expressions through $C_6 x^6$

Polynomial	<pre>// Calculate Expected Power based on polynomial model 'Polynomial Coefficients C0'*AdjustedWindSpeedVar^0 + 'Polynomial Coefficients C1'*AdjustedWindSpeedVar^1 + 'Polynomial Coefficients C2'*AdjustedWindSpeedVar^2 + 'Polynomial Coefficients C3'*AdjustedWindSpeedVar^3 + 'Polynomial Coefficients C4'*AdjustedWindSpeedVar^4 + 'Polynomial Coefficients C5'*AdjustedWindSpeedVar^5 + 'Polynomial Coefficients C6'*AdjustedWindSpeedVar^6</pre>
------------	--

10. Don't forget to add comments to your expression to describe what is happening, as well as line breaks to help make the expression more readable.



- 11. Add one last variable, Output
- 12. This expression will check which range we are in (Low, In Range, High or Fault) then assign the appropriate value for the Expected Power using IF THEN ELSE Statements



Step 3: Test the expression

1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click Evaluate to make sure you have no syntax errors. You should see values next to each of the variables and no error messages in the Status bar.

Add a new variable				Evalu	iate
Name	Expression	Value at Evaluatio	Value at Last Trigg	Output Attribute	
AdjustedWindSpeedVar	TagVal('Adjusted Wind Speed')	4.7854 m/s	4.7854 m/s	Map	⊗
Polynomial	<pre>// Calculate Expected Power based on polynomial model of Power vs Wind Speed // 'Polynomial Coefficients[C1*AdjustedWindSpeedVar^0 + 'Polynomial Coefficients[C1*AdjustedWindSpeedVar^1 + 'Polynomial Coefficients[C2*AdjustedWindSpeedVar^3 + 'Polynomial Coefficients[C4*AdjustedWindSpeedVar^4 + 'Polynomial Coefficients[C5*AdjustedWindSpeedVar^6 + 'Polynomial Coefficients[C5*AdjustedWindSpeedVar^6 + 'Polynomial Coefficients[C5*AdjustedWindSpeedVar^6</pre>	162.32	162.32	Мар	8
Output	<pre>//The calculated Expected Power is only valid in a range. At low end and high end of range, 1 Convert(If AdjustedWindSpeedVar< 'Polynomial Coefficients LowWind_Limit' then 'Polynomial Coefficients LowWind_Dewer' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients LowWind_Limit' and AdjustedWindSpeedVa then Polynomial coefficients FullPower_Power' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HighWind_Limit' then 'Polynomial Coefficients FullPower' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HighWind_Limit' then 'Polynomial Coefficients HighWind_Power' else if AdjustedWindSpeedVar>= 'Polynomial Coefficients HighWind_Limit' then 'Polynomial Coefficients HighWind_Power' else 'Polynomial Coefficients HighWind_Power' else 'Polynomial Coefficients HighWind_Power'</pre>	162.32 kW	162.32 kW	Expected Power (Polyno	nial) 🛞

2. To check the logic it is always a good idea to preview the results before implementing the analyses. Right-click on the expression Forecast 1h Expected Power (Polynomial) and select Preview Results.

		💿 🖻 Name	
	-	*1 EE Undernorforming	Asset
		New	re Function)
	X	Delete	nomial)
rebie	Q (Preview Results	Power (Polyno
Indiri	<i>7</i> .	Backfill/Recalculate	aella\GE001
		Backfill/Recalculate Status	

3. In the pop up window click on the Generate Results button. You should see something like the picture below.

Q Preview results for F	orecast 1h Expected Po	wer (Polynomial)			
Start Time: t		End Time: *			Generate Results
Trigger Time	Output Time	AdjustedWindSpeedVar	Polynomial	Output (kW	Evaluation
3/11/2019 12:00:01 AM	3/11/2019 1:00:01 AM	17.374	3997.1	3000	^ (100%)
3/11/2019 12:05:01 AM	3/11/2019 1:05:01 AM	17.299	3907.4	3000	
3/11/2019 12:10:01 AM	3/11/2019 1:10:01 AM	18.314	5842.8	3000	Progress
3/11/2019 12:15:01 AM	3/11/2019 1:15:01 AM	18.203	5542.8	3000	
3/11/2019 12:20:01 AM	3/11/2019 1:20:01 AM	16.877	3513	3000	0.1ms
3/11/2019 12:25:01 AM	3/11/2019 1:25:01 AM	16.939	3560.3	3000	Min
3/11/2019 12:30:01 AM	3/11/2019 1:30:01 AM	18.831	7629	3000	
3/11/2019 12:35:01 AM	3/11/2019 1:35:01 AM	19.844	13571	3000	(28.3ms)
3/11/2010 12-40-01 AM	3/11/2010 1-40-01 AM	10 760	12026	3000	~ <u>·</u>
				>	Max

Step 4: Map Expected Power output to an attribute

Best Practice

1. Use the **Map** link and **New Attribute Template** to create a new attribute template for the output.



2. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.

Attribute Template Properties ×						
Save Output History:	● Yes ○ No					
Name:	Forecast 1h Expected Power (Polynor					
Description:						
Data Server:	%Server% v					
Value Type:	Double v					
A PI Point data referen	ce attribute template will be created.					
	OK Cancel					

It is a best practice to use the New Attribute Template option for outputs of analyses. There are a couple advantages over creating it "manually" on an element template. First, the Data Reference is automatically set. Secondly, the naming standards created in Challenge 1B are implemented.

3. Most analyses write to a historical tag. However, since we are using future data, we need the output to be a Future Tag. Navigate to the attributes tab and select the Forecast 1h Expected Power (Polynomial) attribute template and open the settings window.



4. We will use AF to create the tags for the forecasted power. To do this, click the Tag

Creation check-box and then lick the *m* next to the **Tag Creation** field. Scroll down to the **future** field and enter a **value of 1** (to indicate it is a future tag). Then, click the **OK** button and then click the **OK** button on the settings dialog.

The settings should look as shown below. You can copy the text below and paste it in the field under the **Settings** button. **Note:** You can edit the text in the field under the **Settings** button directly, you do not need to use the dialog boxes.

Name:	Forecast 1h Expected Power (Polynomial)								
Description:									
Properties:	<none></none>	~							
Categories:	Calculated Data								
Default UOM:	kilowatt	~							
Value Type:	Single	~							
Default Value:	0 kW								
Data Reference:	PI Point	~							
Display Digits:	-5								
	Settings								
\\%@\PI Data Aro %;pointtype=Floa	chive Name%\%Database%_%Element%.%Attribute at32;future=1;pointsource=AFAnaly§is								

5. Once you are happy with the PI Point configuration, Check In your changes

Step 5: Create two weeks of history

1. Follow the steps in Challenge 1D: Backfill Analyses to Provide Two Weeks of Data to backfill the data for the new analysis.

12. Optional: Challenge 8: Create a Report with DataLink in Excel

12.1 Objective of Activity

We have now created a number of analyses, on a turbine level, rolled them up to the site and fleet level, created Event Frames for normal operation, and viewed all of this within the Vision tool.

What if you want a report? This optional section is included in the appendix to show you how reports can be generated within Excel. This will show one type of report – by turbine. Learn this and you will be able to do many kinds of reports using the power of AF within the Excel DataLink add-in.

Note the task below is outlined in greater detail in the PI DataLink User Guide.

12.2 Tasks

- Determine whether you want to be pulling data on a fleet, a site, or an individual turbine basis and create a pull down based on that choice.
- Choose the attribute(s) and time range you want the data for.
- Pull data into Excel and use the power of Excel to do reporting.

12.3 Step by Step Explanation of this Lab Section

Step 1: Create the Root Path Pull-Down

- 1. Create the Root path that determines which turbine you will create the report for.
- 2. Open Excel and start in cell A6 (you are starting in A6 to give room for cells to define the report and do run up calculations). Expand the width of column A to about 80
- 3. In the **PI DataLink** tab, click on **Search** to find all of the turbines
- 4. At the top of the search window, choose the correct database (in this case the "SOLUTION" database).
- 5. In the search criteria box, type *asset*
- 6. Click on the magnifying glass and the list of items with the name "Asset Name" comes up. Choose all of the individual turbines.
- 7. Slide the **Data item length** slider all the way over to **Name Only**. Click OK. See screen shot below.

🔍 Search					Х
Home 👻 🕩 PISRV01 👻 🖨 SOLUTION: Using A	F to Analyze Asset Performance 🔻				?
"asset"				Q	×
PI Data Archive	Root path	Data item	Description		^
	VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Finistere\RB006 VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Finistere\RB007 VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Finistere\RB009 VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Finistere VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Mieres\GE006 VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Mieres\GE008 VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Mieres\GE001 VPISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Sartaela\GE001 VPISRV01\SOLUTION: Usin	Asset Name Asset Name			
	\/PISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Santaella\GE003 \/PISRV01\SOLUTION: Using AF to Analyze Asset Performance\Scirocco\Santaella\GE004	Asset Name Asset Name			~
	Data item length	I	Insert root paths in:		
	Full eath Name only		Drop-down list Column or row		
	run paur indine only		ОК	Cancel	
Search completed (25 found)					

8. You now have a pulldown with all of the individual turbines in cell A6. (Delete the Asset Name that has populated cell A7.)

Step 2: Choose the attributes and the time range you would like to have data pulled into Excel

- 1. Choose turbine attributes that you would like to see data for put them in cells B6...C6...D6...etc.
- 2. Choose the date range and data frequency in cells A1, A2, A3. Your sheet should look something like this:

H	5 • d	÷ ÷												Fiddle.xlsx	- Excel		
File	Home	Insert	Page Layout	Formulas	Data	Revie	w V	iew Pl	DataLir	nk ♀⊤	ell me wha	t you want to do.					
Current A Value Single	Archive Value *	mpressed Data ~ Multi	Sampled Timed Data * Data ple Value	Calculated Data ~ Calcula	Time Filtered +	Explore C	Compare nts	Search	Asset Filter ch	Properties Properties	Update Update	Settings () Ab () He () Fee Resource	out lp edback s				
A4		•	V JX														
				A							В			С		D	
1 1/16	/2019																
2 1/17	/2019																
3 5m																	
4																	
5																	
6 \\PI	SRV01\SOL	UTION: U	Ising AF to Anal	yze Asset P	erformar	nce\Sciroo	co\Fini	sterre\RB	006	Active Po	wer		Expecte	ed Power (Polynom	ial)	Production Efficiency	
7			0														
8																	
9																	_
10																	
11																	
12																	_
12																	
14																	_
14																	
15																	

Step 3: Choose the type of data you want to pull into the spreadsheet

- On the PI DataLink tab choose Sampled Data. There are many other ways of pulling data – Averages, totals, min/max, etc... See the PI DataLink User Guide for the full range of ways of pulling data. Now fill the Sampled data pane that popped up.
- 2. Root path should be cell A6 (just click on cell A6 to populate the Root path box).
- 3. **Data item(s)** is cell B6...D6. (Again click on the three boxes to populate the Data item(s) box.)
- 4. Start time / End time / Time interval = A1 / A2 / A3
- 5. Output cell = A7
- 6. **Show time stamps** = yes (checked). Column should be chosen. See screenshot below for the proper setup after you have done this.

Sampled Data
2011112100 20100
 Data item
Root path (optional)
'Sheet6'!\$A\$6
Data item(s)
'Sheet6'!\$B\$6:\$D\$6
Start time
'Sheet6'!\$A\$1
End time
'Sheet6'!\$A\$2
Time interval
'Sheet6'!\$A\$3
Filter expression (optional)
Mark as filtered
Output cell
'Sheet6'!\$A\$7
Show time stamps
 Column
◯ Row
OK Apply

- 7. Click OK (or Apply) and the data for the day will be pulled into your spreadsheet.
- 8. You can now use the pulldown in cell A6 to pick a different turbine. The sheet will automatically update with data from the new turbine.
- 9. You can also change the date range in cells A1 and A2 to pull data from a different date.
- 10. You can use the power of Excel to sum up the power and calculate daily efficiency.

Font 1 Alignment	G Number	G		Styles
/* =SUM(87:8295) A	8		c	D
			/	
		-		· •
		307,803	529,596	58%
to Analyze Asset Performance\Scirocco\Finisterre\R8009	Active Power	Ex	(pected Power (Polynomial)	Production Efficiency
02-Jan-19 00:00:0	2	413.182373	2939.181641	82.10388947
02-Jan-19 00:05:00	2	034.786133	2687.616455	75.70969391

- In this example we pulled data and did totals and run-up calculations for an individual turbine. If you change the selection in step 1. b. iii. You can change the pull down to have the four different sites and pull data on a site basis rather than a turbine basis.
- 12. The possibilities and power of using Excel in combination with the PI DataLink are endless! Experiment and have fun!

Appendix A. Standard Tag Naming

Standardized tag naming – Wind turbines lend themselves very well to standardized tag naming conventions. For example: Active Power (real time generation) for a wind turbine could be designated as:

BB.WTGXX.Active Power where:

BB = the site designation (Buffalo Bear wind farm, in this case)

XX = the wind turbine number 01 – 99 (if kore than 100, use three characters here)

In this manner the same tag naming convention can be utilized to denote the generation for every wind turbine at a particular site, or in a fleet with multiple sites.

Substitution Parameters – If a standardized tag naming convention is utilized, substitution parameters can be leveraged to significantly reduce the amount of time it takes to

Appendix B. Fit Expected Power Table to Polynomial Curve

B.1. Objective of Activity

As an engineer at the Wind Farm you want to monitor the turbine efficiency and identify which turbines are running below 85% and for how long. You also want to eliminate fluctuations to the efficiency that may cause events of a duration of less than 5 minutes.

B.2. Tasks

- Define the logic for the generation of low efficiency events and implement in the Turbine Template
- Test and backfill the events

B.3. Step by Step Explanation of this Lab Section

Step 1: Use Microsoft Excel Plot to Fit data to Polynomial Trend line

- 1. Open Challenge 1C_Fitting Performance Curve.xlsx from the shared drive located on the desktop.
- 2. Save the file with your initials to the desktop, example: ABC_Challenge 1C_Fitting Performance Curve.xlsx
- 3. Using PI System Explorer, navigate to the PowerCurve table and copy the contents to the spreadsheet (Cells marked in Green). Verify the curve on the Chart (Blue Curve)



4. Add a trend line to the Chart for the PowerCurve series

- 5. Select the trend line and update the trend line options:
 - a. Polynomial 6th Order
 - b. Display Equation on Chart
- 6. Select the trend line Equation from the chart to update the formatting. You can Open the formatting window by double clicking the trend line or right click and select format.
- 7. Change the Number Category to Number, with 5 decimal places



- Copy the coefficients to the cells below the chart to verify the fit of the curve (Orange Curve). If the polynomial coefficients are entered correctly, the orange curve should be very close to the blue curve on the graph
- 9. Save your Excel file, we will use the coefficients in a moment back in PI System Explorer

Appendix C. XY Plot in Pl Vision

C.1. Objective of Activity

In this activity you will create a PI Vision Display that uses the Power Curves. Specifically you will use the XY Plot to compare plot a consistent curve versus real time data.

C.2. Tasks

- Create Attributes to facilitate plotting Power Curve on PI Vision XY Plot
- Plot Power Curve and Live data on PI Vision XY Plot

C.3. Step by Step Explanation of this Lab Section

Step 1: Create Power Curve Attributes for XY Plot

For this step we will be following the instructions from <u>KB01580</u>. Since we already have the AF Table created, we will start with the Attribute configuration. Note in the table that we have assigned an arbitrary time to each row. This is so that in our XY Plot we can use this time to correlate the values to plot a static curve. Our goal in this step is to create two Attributes which we can use to plot a static Power Curve on the XY Plot.

- 1. In PSE navigate to the Turbine Template and create a **New Attribute Template** called **"Power Curve"**.
- 2. Underneath the new Power Curve Attribute, create **two New Child Attribute Templates** called **"Potential Power"** and **"Wind Speed"** both the **Table Lookup Data Reference**.
- 3. Each of these Child Attributes should be configured to retrieve their respective column in the Power Curve table. Use the Table provided time series data Rule and specify the column called "Timestamp" as the Time Column.

Appendix

Table Lookup Data Refe	rence	×
Table:	PowerCurve	~ 🗝 🚰 🛅
Result column:	Potential Power	Stepped
Unit of Measure:	kW	\sim
Behavior		
Rule:	Table provided time series data	~
Time Column:	Timestamp	~
Where		
Column:	Operator: Attribute or Value:	Add And
Potential Power 🗸 🗸	= v @Wind Speed v	
Table Parameters		
Parameter	Value	
Replacement Values Value to return when no <u>No Data</u>	matching row found: Value to return when NULL	. result found:

4. Assign UOMs to the Potential Power and Wind Speed attributes of kW and m/s respectively. Once completed your attributes should like so.

		Power Curve	<none></none>	Double	
		E Potential Power	kilowatt	Double	SELECT [Potential Power] FROM PowerCurve;TC=Timestamp
		🖷 Wind Speed	meter per second	Double	SELECT [Wind Speed] FROM PowerCurve;TC=Timestamp

Step 2: Create Power Curve XY Plot

For this step we will be continuing to follow the instructions from <u>KB01580</u>. Now that we have the attributes configured for the static curve we will use Vision to plot it.

- 1. Open Google Chrome and navigate to PI Vision at https://pisrv01/pivision/. Once at the PI Vision homepage, click on the New Display option at the top. New Display.
- 2. In the Assets sidebar navigate to any site and select any wind turbine. Find the attributes (Potential Power and Wind Speed) that you just created. Ensure the XY plot option is selected on the top left and then drag the Wind Speed to the main display. Then drag the Potential Power attribute onto the newly created XY Plot.

- 3. Once the two items are in the XY Plot the Configure XY Plot sidebar should open on the right hand side. Make the following changes:
- 4. Under X Data Options set the Data Retrieval to be Compressed
- 5. Select Use Custom Time Range and set the Start and End Time to 1/23/19 12:00:00 AM and 1/23/19 12:00:17:00 AM respectively. Remember this was the arbitrary time used in the AF Table to correlate the values in our static Power Curve.
- 6. Ensure Y Data Options are set to Data Pairing to X as Paired by timestamp and Data Retrieval is set to Interpolated
- 7. Under Format select Connecting Line and
- Now add a second set of data to compare the second set of data to Power Curve. With the Configure XY Plot si complete the following:
- 9. Find the Adjusted Wind Speed attribute and drag it to the new X-Axis slot
- 10. Find the Active Power attribute and drag it to corresponding Y-Axis spot

Config

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Configure XY Plot 🔻	Configure XY Plot 🔻		
Attributes	▼ Attributes		
Scales	X-Axis Y-Axis		
r Format	Power Curvel		
X-Axis Y-Axis Power Curve]W. Power Curve]P	DRAG TO ADD		
Color 📃 🔻	 X Data Options 		
Markers	Attribute: Power Curve Wind Speed		
Connecting Line	Data Retrieval		
Regression Line	Compressed •		
Correlation Coefficient	✓ Use Custom Time Range		
Legend	Start 🔾 Offset 🖲 Time		
	1/23/2019 12:00:00.000 📋 🕒		
Format Default •	End Offset		
General	1/23/2019 12:00:17.000 📋 🕒		
	 Y Data Options 		
and deselect Markers	Attribute: Power 💼 Curve Potential Power		
are the live data with	Data Pairing to X		
ot sidebar open	 Paired by timestamp 		
·	 Paired by position in the list 		

Data Retrieval Interpolated





Save the Date!

OSIsoft PI World Users Conference in Gothenburg, Sweden. September 16-19, 2019. Register your interest now to receive updates and notification early bird registration opening.

https://pages.osisoft.com/UC-EMEA-Q3-19-PIWorldGBG-

<u>RegisterYourInterest_RegisterYourInterest-LP.html?_qa=2.20661553.86037572.1539782043-591736536.1533567354</u>

