PI World 2019 Lab

Using AF to Analyze Asset Performance

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1. Introduction

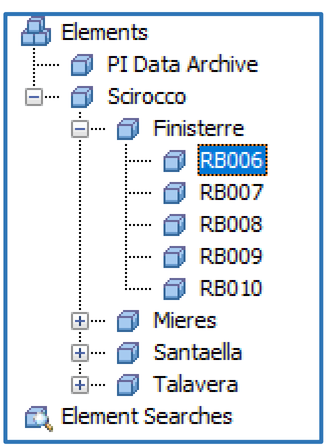
1.1 Overview of Lab

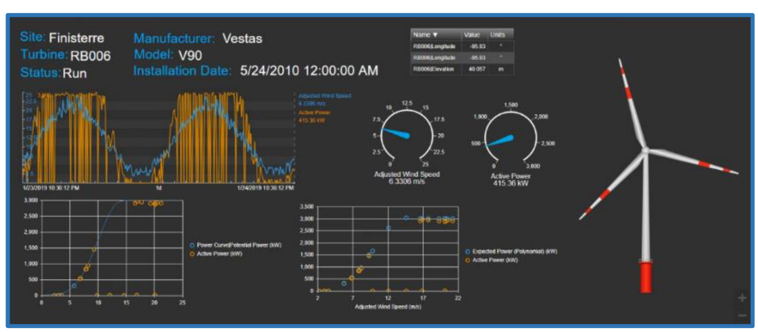
Calculation of and immediate feedback on wind turbine performance is an important part of maximizing revenue from wind generation assets. Waiting for a daily or monthly rundown of performance of a wind farm can cost thousands of dollars of lost production each day. Common causes of deviations from the 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

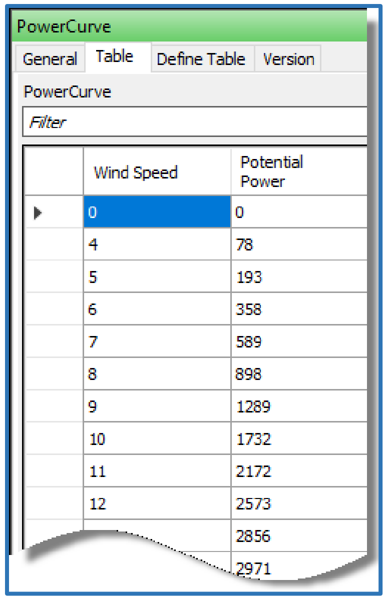
- Find the **Turbine Template** and identify the **Attributes** that will have the **Table Lookup** data reference
- Identify the columns in each **Table** and which ones apply to each **Attribute**
- Assign the **Table Lookup** data reference to each of these **Attributes** and create the **Settings** 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.



Tip

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

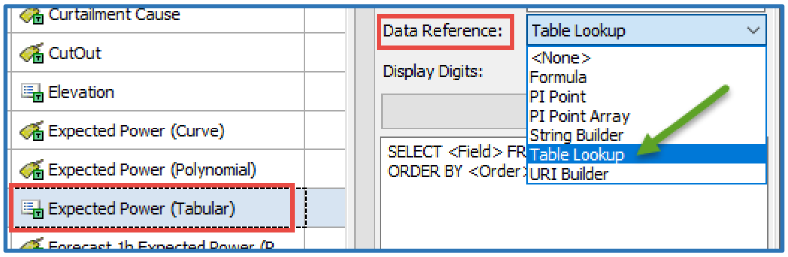
Step 2: Create Attribute and Assign Table Lookup Data Reference

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

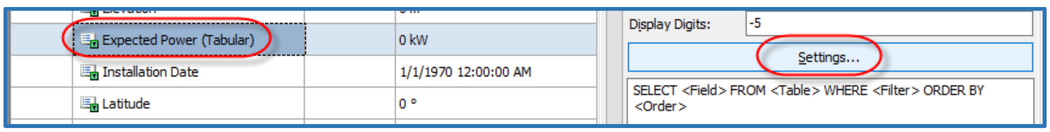
For the **Default UOM** a simple way to find the unit of measure is to highlight the **<None>** and then start typing **kilow** (or **kW**).
You will see the intellisense showing you the available matching units of measure. From the matching list, select **kilowatt**

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

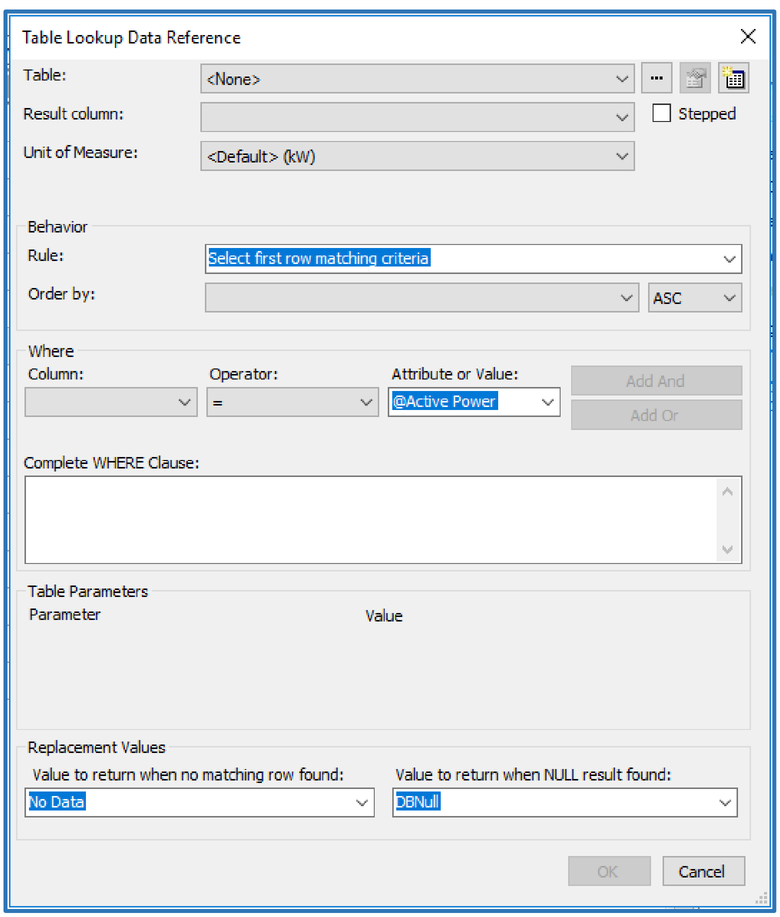


Step 3: Enter Settings for the Table Lookup Data Reference

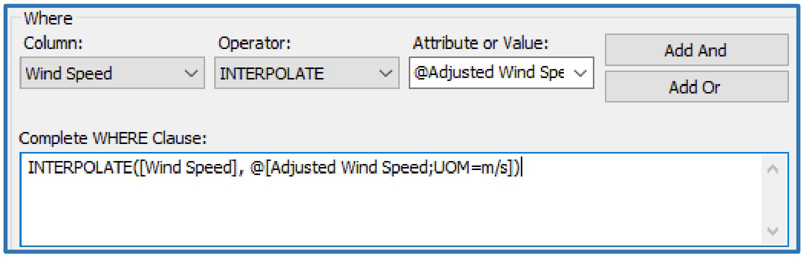
1. First we will create the **Settings** for the **Attribute Expected Power (Tabular)** since that is the only one that will get data from the **Table PowerCurve**. We have simplified this for the lab and only have one power curve that will be used for all the turbines, in reality each **different turbine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



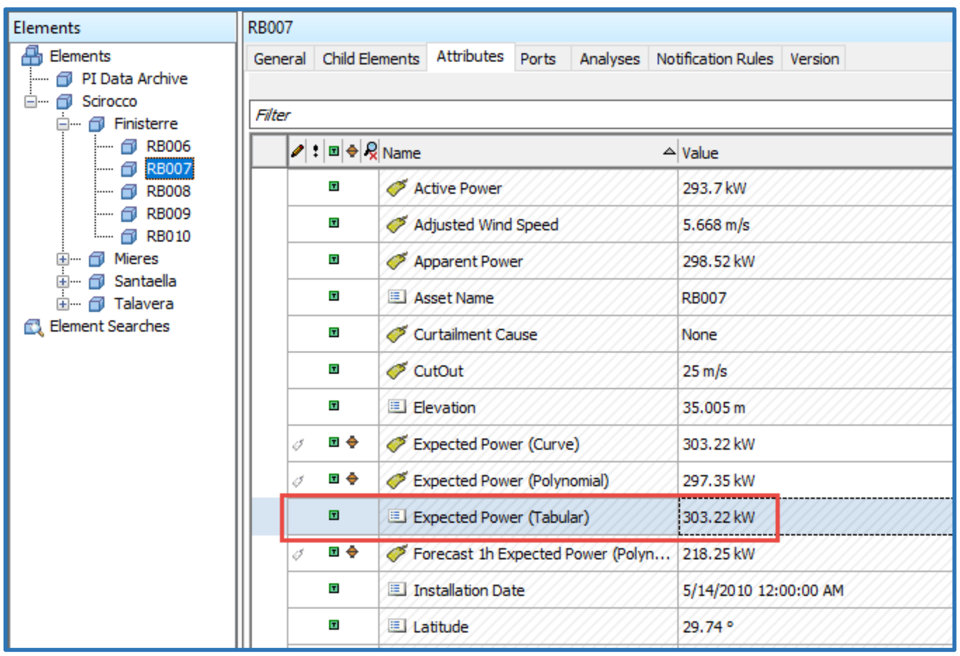
2. You should see the following dialog pop up.



3. 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.



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.



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.

✓ 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

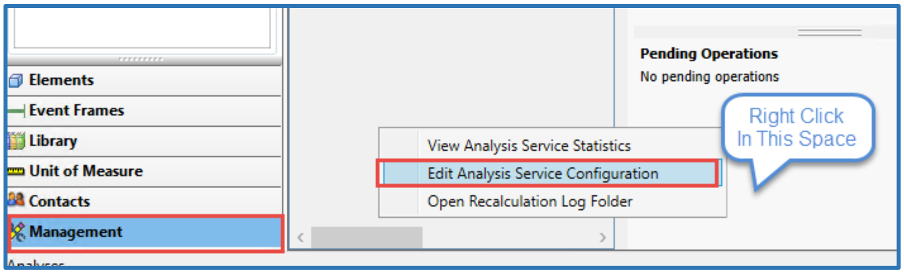
- Set Analysis Tag Naming default
- Create the Expected Power analysis template

3.3 Step by Step Explanation of this Lab Section

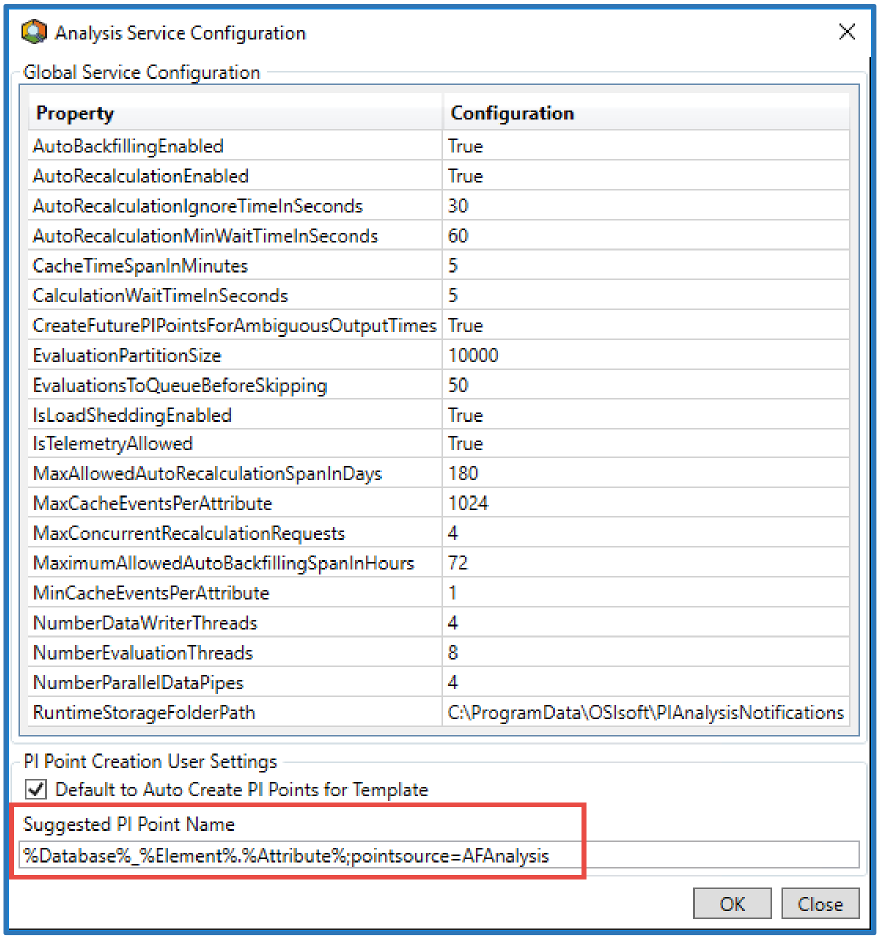
Step 1: Set Suggested PI Point Name Default for Analysis Generated Attributes (i.e. via mapping)

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.



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.



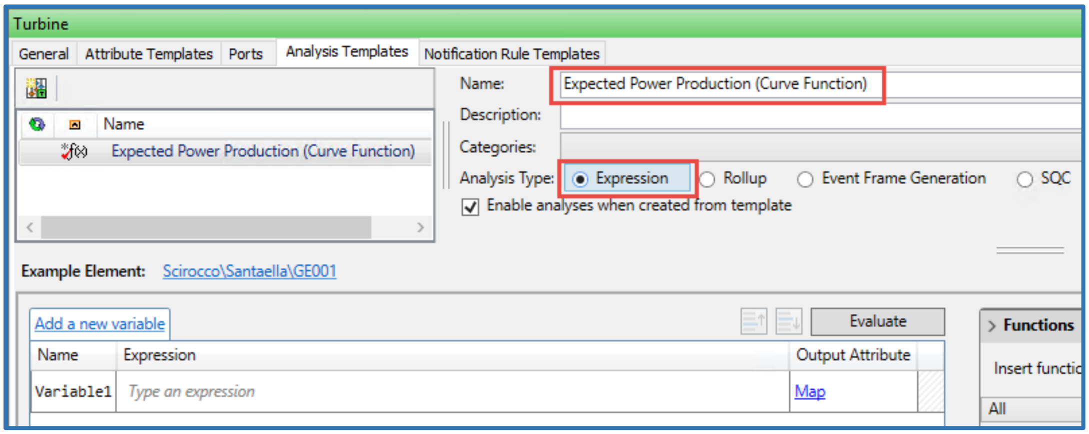
✓

Best Practice

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.

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)



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).**

✓ Best Practice	Name analysis variables rather than leaving at Variable1, Variable2… This improves readability and better code definition when used in subsequent expressions.

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

Tip	The Curve function calculates a best fit curve for a given set of data points (x,y pairs) provided. An x value is passed along with the data pairs and a corresponding y value is returned based on the curve fit. The syntax is as follows: **`Curve( x, (x1,y1) (x2,y2) … (xn,yn) )`**

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

✓ Best Practice	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.

9. Remember to comment your code.

Tip	Both **** and ***** work to begin a comment.

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**.

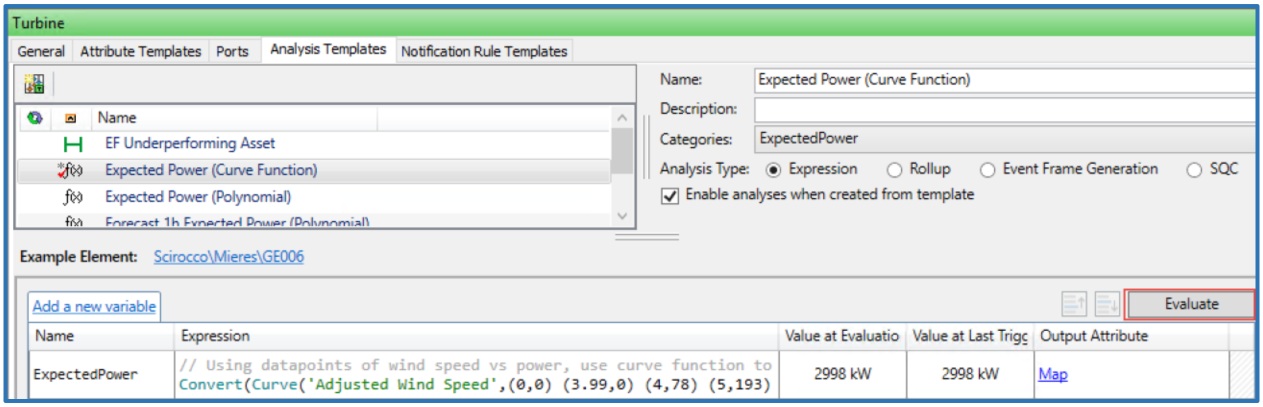
✓ Best Practice	Always deliberately evaluate the scheduling plan for each analysis. Triggering analyses more often than needed, especially those with downstream dependencies, can tax the Analysis Service.

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.

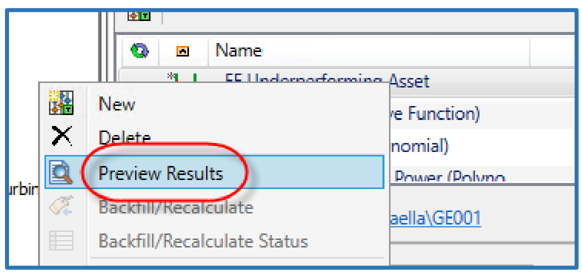
Variable	Expression	Output Attribute
ExpectedPower	`// Using data points of wind speed vs power, use curve function to return an Expected Power for a given Wind Speed. Convert function explicitly assigns UOM to calculation results. //` `Convert(Curve('Adjusted Wind Speed', (0,0) (3.99,0) (4,78) (5,193) (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")`	Expected Power (Curve)

Step 3: Test the expression

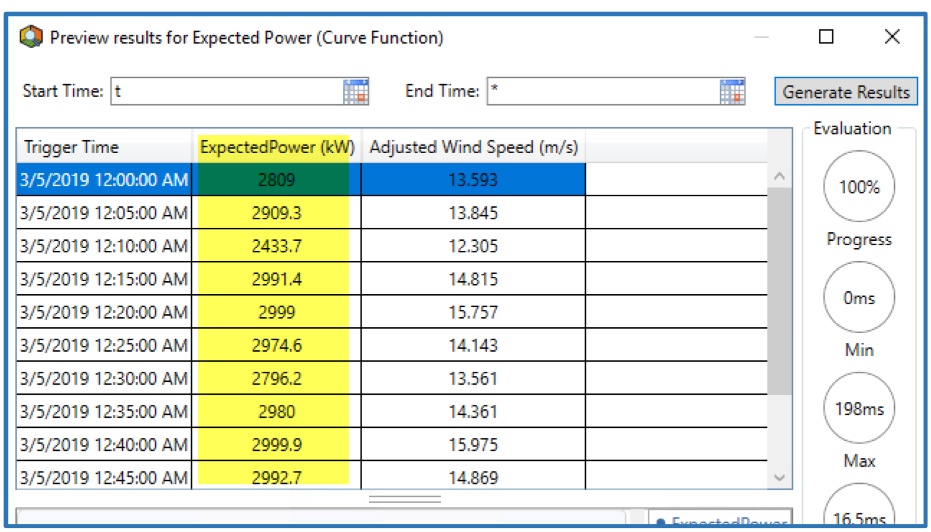
1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click **Evaluate** to make sure you have no syntax errors. You should see values next to each of the variables and no error messages in the Status bar.



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.

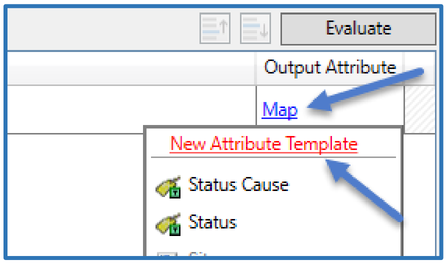


3. In the pop up window click on the Generate Results button. You should see something like the picture below.

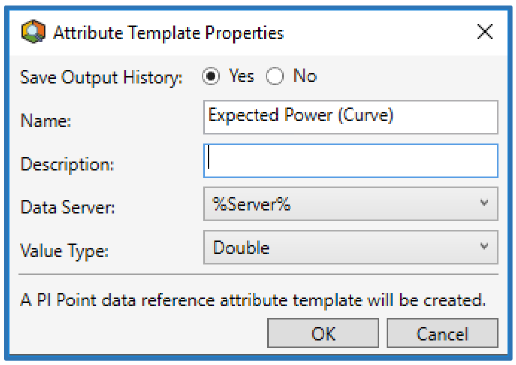


Step 4: Map the analysis result to an attribute

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

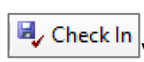


2. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.



✓ Best Practice	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  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.

Tip	Not only do categories help organize attributes in PSE, they do as well for PI Vision.

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**
2. Create a **New Analysis called "Expected Power (Polynomial)"** (right click or select the  icon)
3. Create a variable called **AdjustedWindSpeedVar**

✓ Best Practice	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

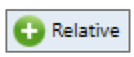
6. Since we fit our curve to a 6^{th} order polynomial, Our expression will use the following equation:

$$y = C_0 + C_1x + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5 + C_6x^6$$

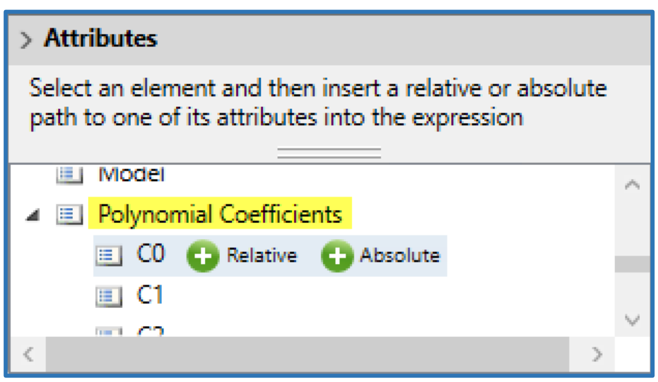
where y is the Expected Power and x is the Adjusted Wind Speed

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:

$$y = C_0x^0 + C_1x^1 + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5 + C_6x^6$$

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

to add it to the expression.



9. Multiply the C0 coefficient by `AdjustedWindSpeedVar` raised to the 0^{th} power (i.e. multiplying C0 by 1). By multiplying by the 0^{th} 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_6x^6

Polynomial

```
// 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
```

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.

Tip

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

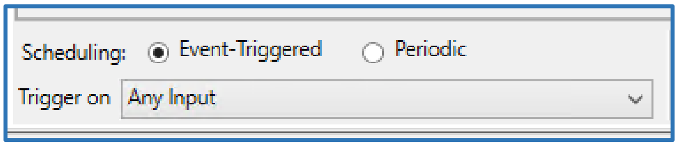
Output

```
//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_Power'
else if AdjustedWindSpeedVar>='Polynomial Coefficients|HighWind_Limit'
   then 'Polynomial Coefficients|HighWind_Power'
else 'Polynomial Coefficients|HighWind_Power' ,"kW")
```

Best Practice

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.

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



Best Practice

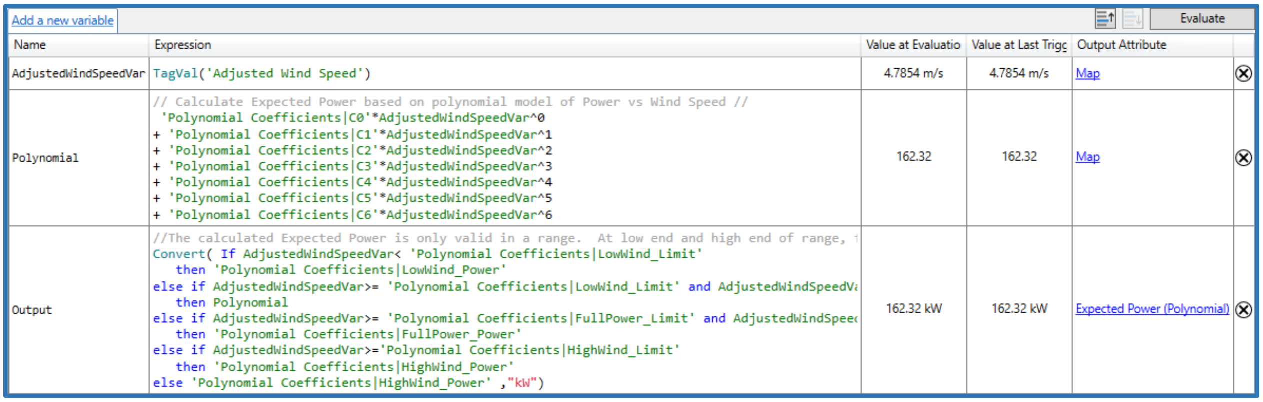
Always deliberately evaluate the scheduling plan for each analysis. Triggering analyses more often than needed, especially those with downstream dependencies, can tax the Analysis Service.

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.

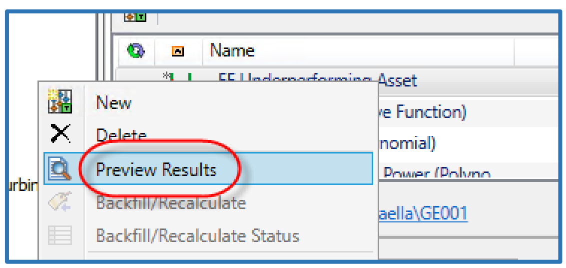
<table>
<tr><th>Variable</th><th>Expression</th></tr>
<tr><td>AdjustedWindSpeedVar</td><td>TagVal('Adjusted Wind Speed')</td></tr>
<tr><td>Polynomial</td><td>// Calculate Expected Power based on polynomial model of Power vs Wind Speed //
‘Polynomial Coefficients|C0'*AdjustedWindSpeedVar^0
+ ‘Polynomial 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</td></tr>
<tr><td>Output</td><td>//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 if AdjustedWindSpeedVar>= 'Polynomial Coefficients|LowWind_Limit' and AdjustedWindSpeedVar< 'Polynomial Coefficients|FullPower_Limit'
then Polynomial
else if AdjustedWindSpeedVar>= 'Polynomial Coefficients|FullPower_Limit' and AdjustedWindSpeedVar< 'Polynomial Coefficients|HighWind_Limit'
then 'Polynomial Coefficients|FullPower_Power'
else if AdjustedWindSpeedVar>='Polynomial Coefficients|HighWind_Limit'
then 'Polynomial Coefficients|HighWind_Power'
else 'Polynomial Coefficients|HighWind_Power' ,"kW")</td></tr>
</table>

Step 2: Test the expression

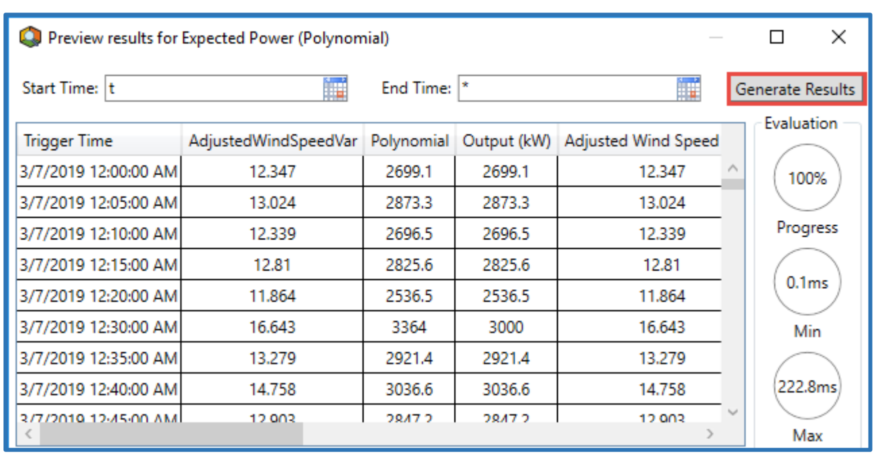
1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click Evaluate to make sure you have no syntax errors. You should see values next to each of the variables and no error messages in the Status bar.



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 (Polynomial) and select Preview Results.

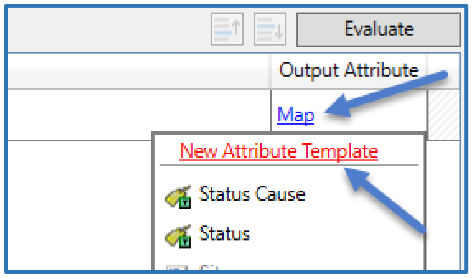


3. In the pop up window click on the Generate Results button. You should see something like the picture below, though the numbers may not match exactly as wind speed is variable.

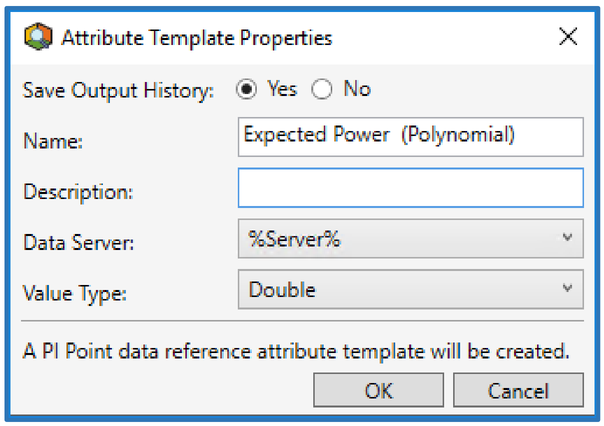


Step 3: Map Expected Power output to an attribute

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

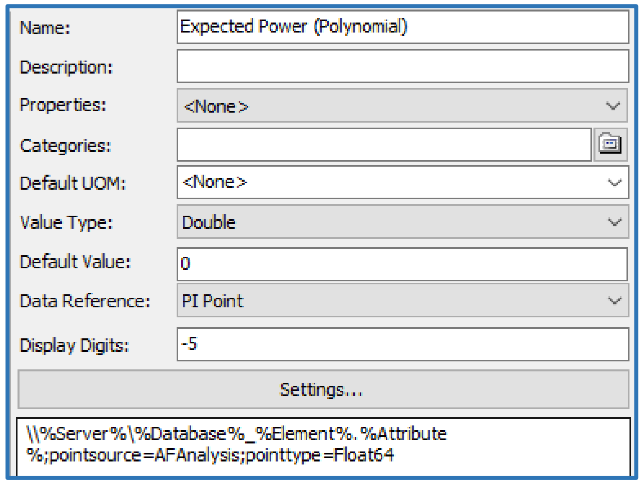


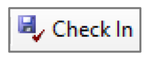
2. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.



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



4. Once you are happy with the PI Point configuration,  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.

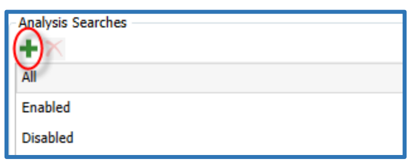
5.2 Tasks

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

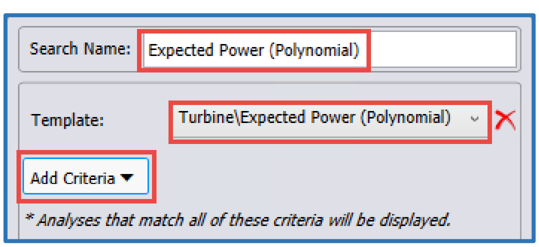
5.3 Step by Step Explanation of this Lab Section

Step 1: Create Filter

1. 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.

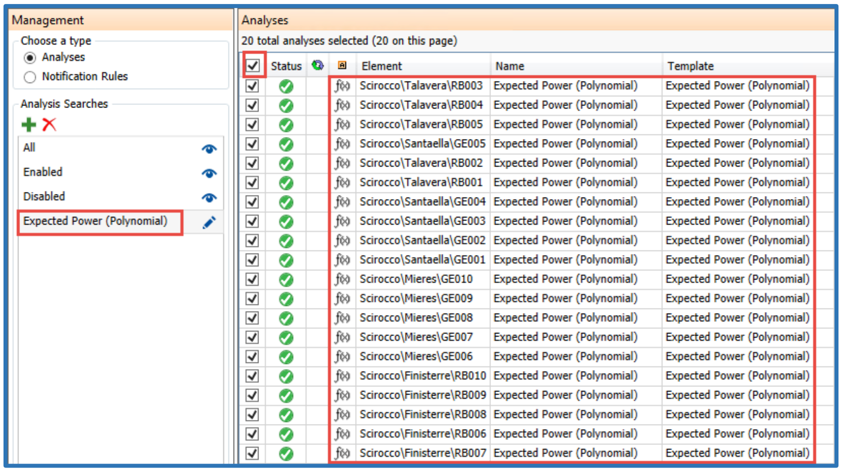


2. In the dialog that shows up, enter Expected Power (Polynomial) in the Search Name field. Then click on the Add Criteria combo-box and select Template. The Template field combo-box appears. Click this combo-box and select Turbine\Expected Power (Polynomial). Click the OK button.

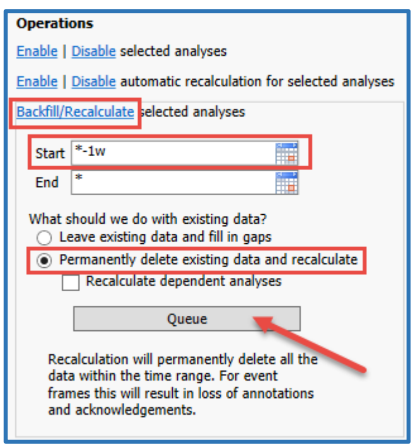


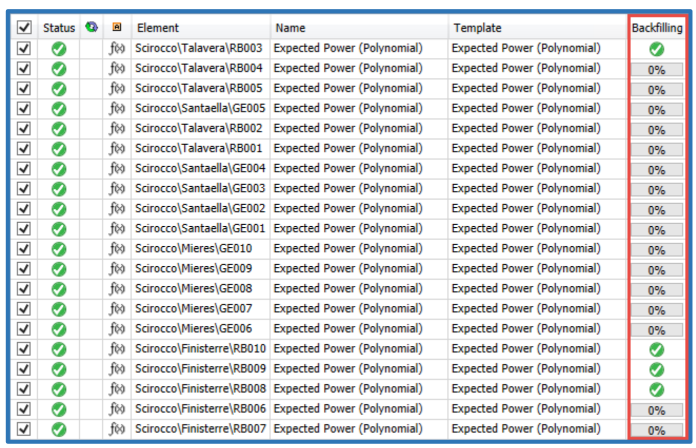
Step 2: Backfill Analyses

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.



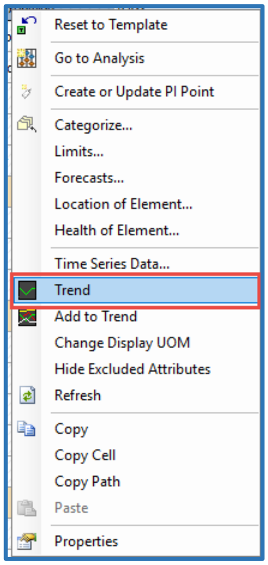
2. To backfill the events click on Backfill/Recalculate in the right pane under Operations. The Start and End fields appear. Change the start time to "*-1w", we will backfill for the last week. Click the radio button: "Permanently delete existing data and recalculate" and the click the Queue button.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

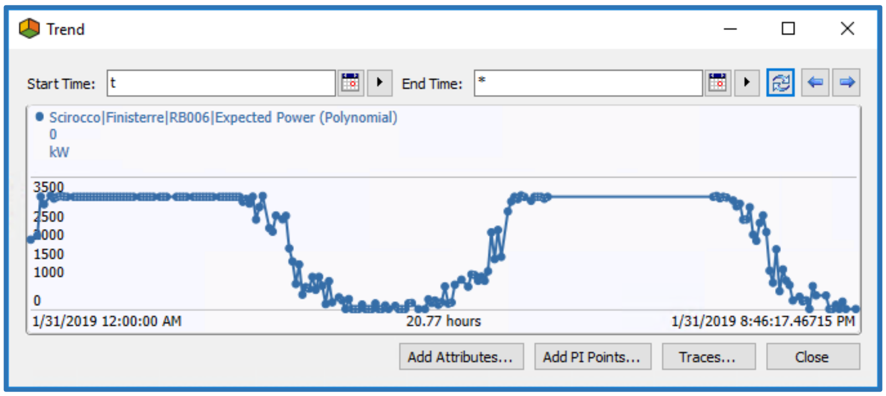




Step 3: Repeat for Other Analyses by Updating the Template Criteria in Step 1

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.

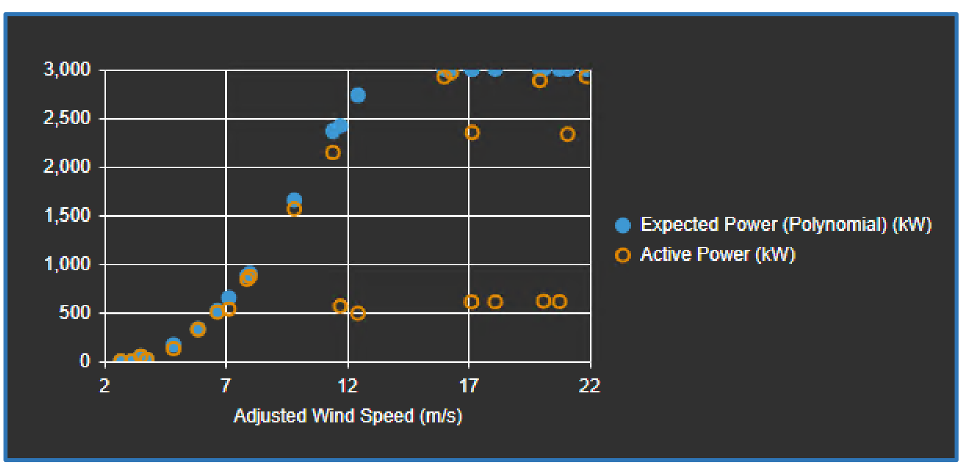
6.2 Tasks

- 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

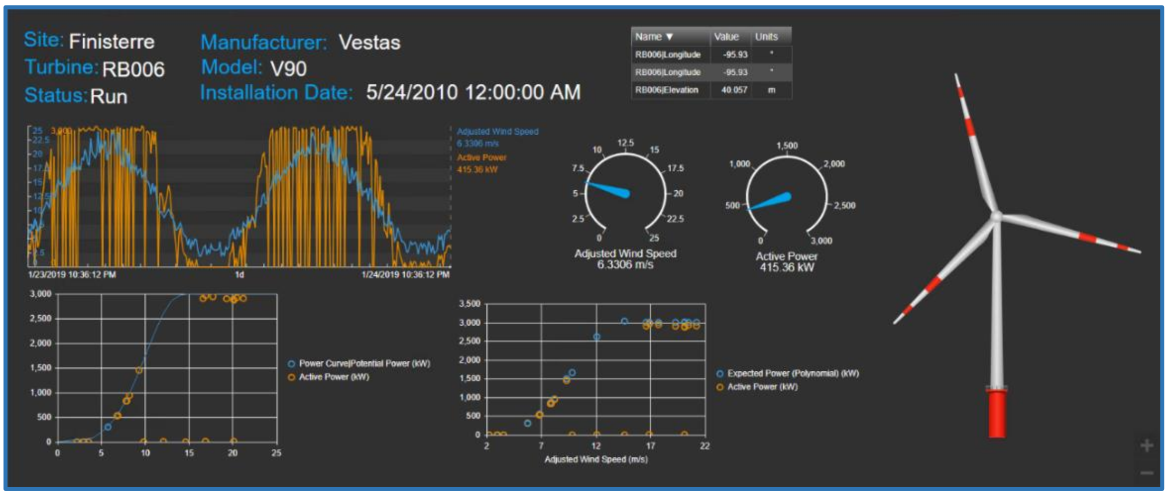
Step 1: Create Polynomial Expected Power XY Plot

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. Table: Longitude, Latitude, Elevation
   b. Trend: Active Power, Adjusted Wind Speed
   c. Radial 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. 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 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.

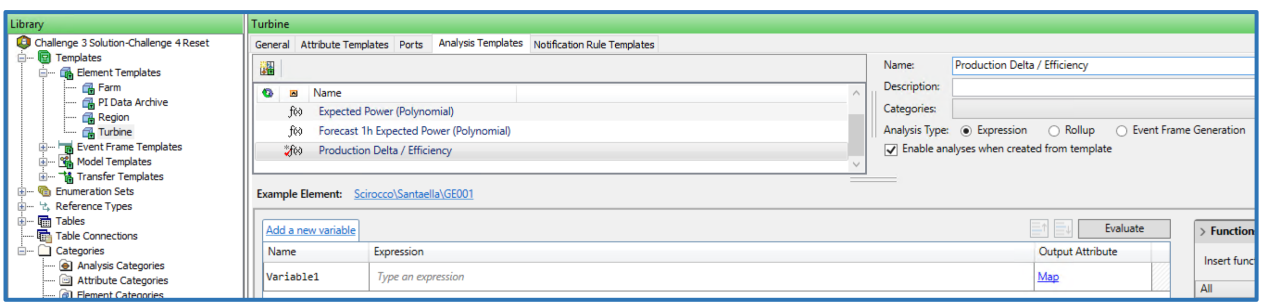
7.2 Tasks

- 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**



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

> Tip
>
> 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:

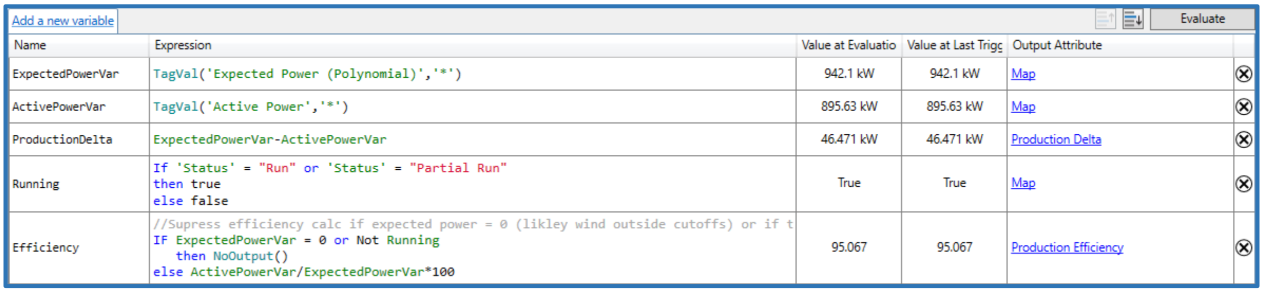
Name	Expression	Output Attribute
ExpectedPowerVar	`TagVal('Expected Power (Polynomial)','*')`	Map
ActivePowerVar	`TagVal('Active Power','*')`	Map
ProductionDelta	`ExpectedPowerVar-ActivePowerVar`	Production Delta

Running	`If 'Status' = "Run" or 'Status' = "Partial Run"`
	`then true`
	`else false`
		Map

Efficiency	`//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`
		Production Efficiency

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 | Evaluate

Name	Expression	Value at Evaluatio	Value at Last Trigg	Output Attribute
ExpectedPowerVar	TagVal('Expected Power (Polynomial)','*')	942.1 kW	942.1 kW	Map
ActivePowerVar	TagVal('Active Power','*')	895.63 kW	895.63 kW	Map
ProductionDelta	ExpectedPowerVar-ActivePowerVar	46.471 kW	46.471 kW	Production Delta
Running	If 'Status' = "Run" or 'Status' = "Partial Run" then true else false	True	True	Map
Efficiency	//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	95.067	95.067	Production Efficiency

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.

✓ Best Practice	For the purposes of this lab, Event Triggered is appropriate (small number of assets with low frequency data). It is important to ensure you use the proper scheduling each time you create an analysis to ensure optimal performance of your system.

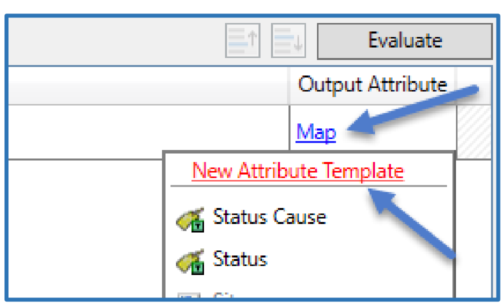
13. Don't forget to **Check In** the analysis after testing is complete!

14. After **Check In**, review a couple of actual turbines to ensure the analyses are operating properly.

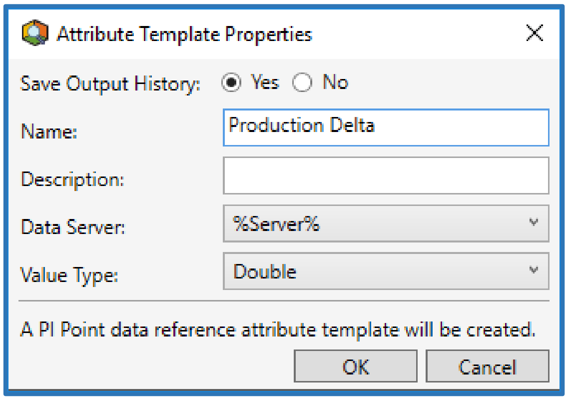
Step 2: Map Production Delta and Efficiency outputs to attributes

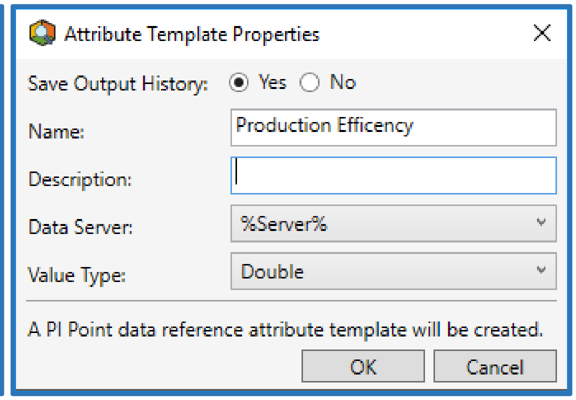
1. Map the ProductionDelta and Efficiency outputs each to their own attribute following the instructions below

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.



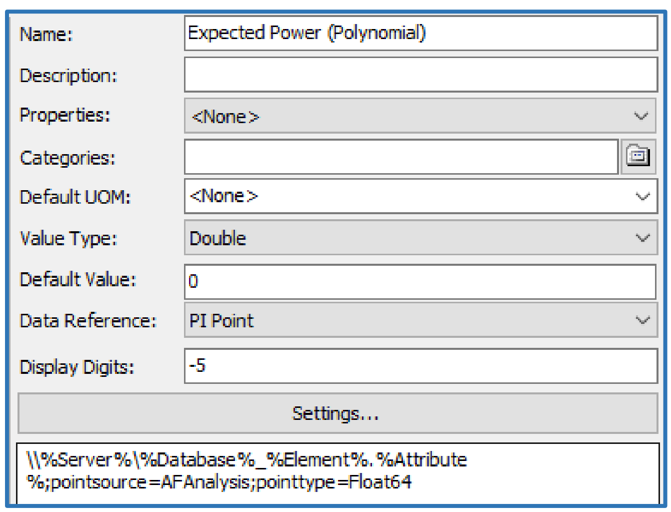


✓

Best Practice

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.)



5. Once you are happy with the PI Point configuration, 

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.

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.

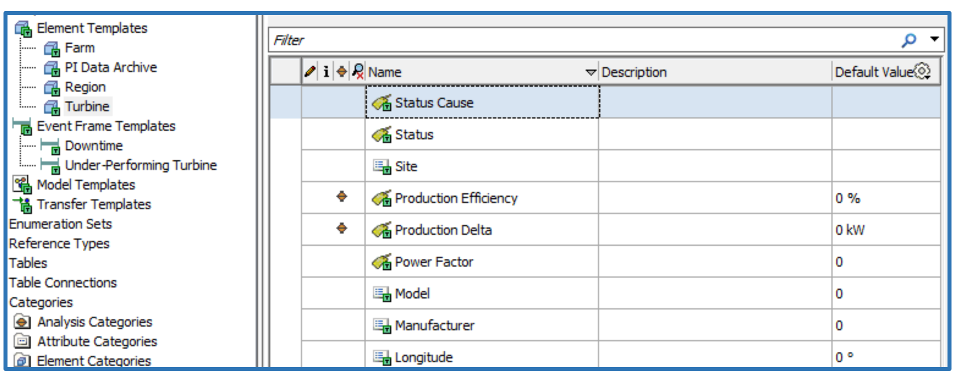
8.2 Tasks

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

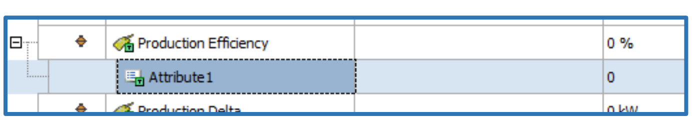
8.3 Step by Step Explanation of this Lab Section

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

1. 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.

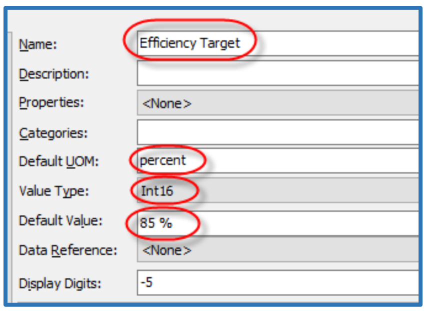


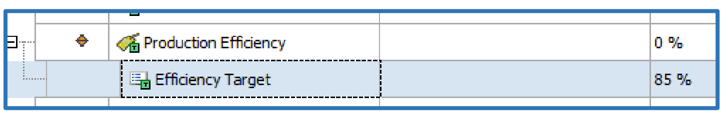
2. Right-click on the Attribute **Production Efficiency** and select **New Child Attribute Template**. This creates an Attribute below **Production Efficiency**.



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%

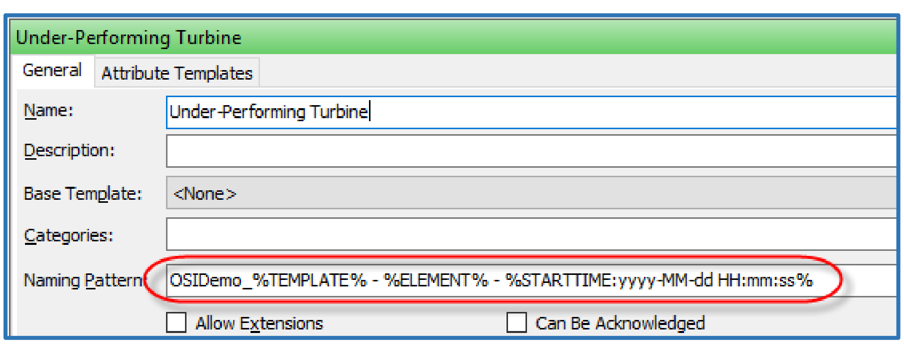


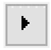


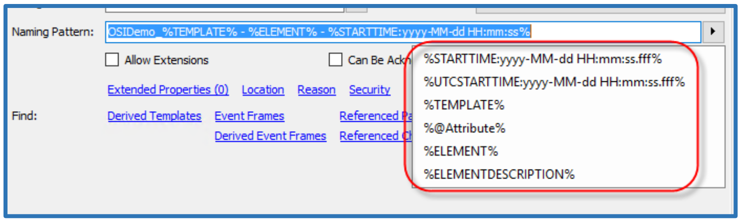
4. It is a good idea to create a naming pattern for these events so that we can recognize them in amongst all the other events. Select the **Under-Performing Turbine** Template under **Event Frame Templates**. In the **Naming Pattern** field enter the following text. Then 

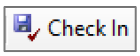
your work.

5. OSIDemo_%TEMPLATE% - %ELEMENT% - %STARTTIME:yyyy-MM-dd HH:mm:ss%



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.

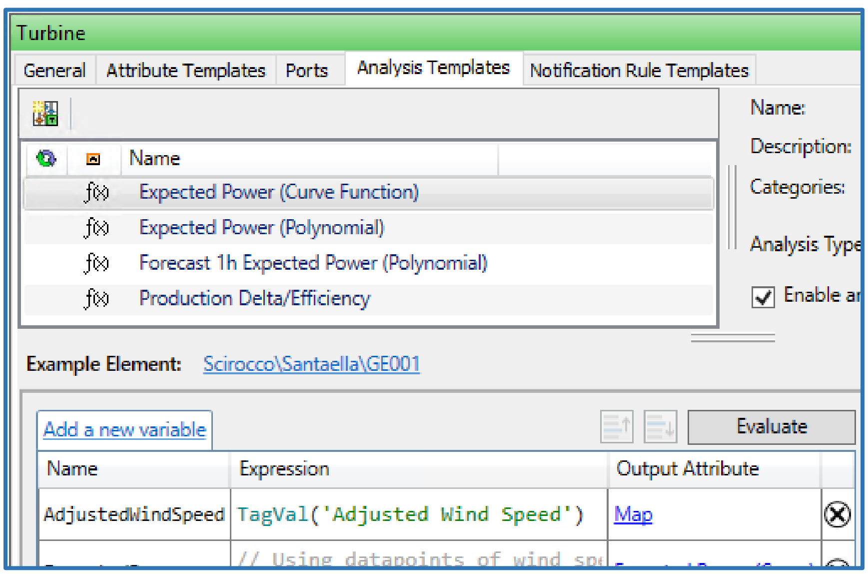


7. 

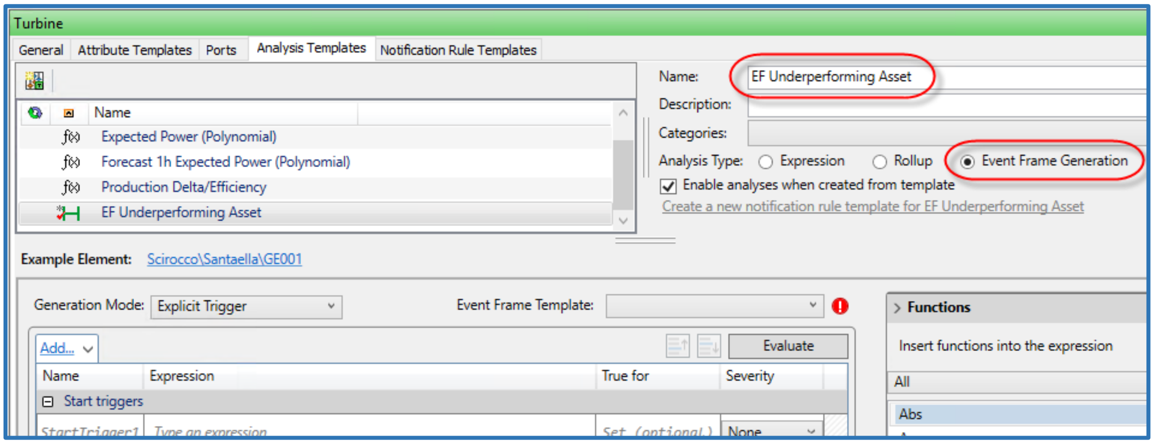
your work.

Step 2: Create Event Frame Expression

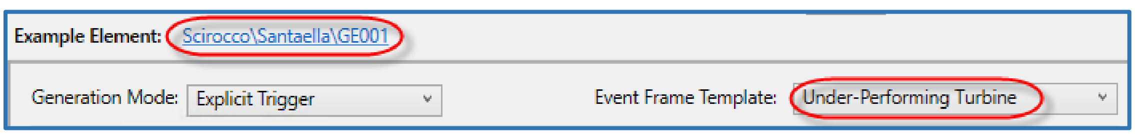
1. Navigate to the **Turbine** Template and Click on the **Analyses** tab in the center pane. You should see the following.



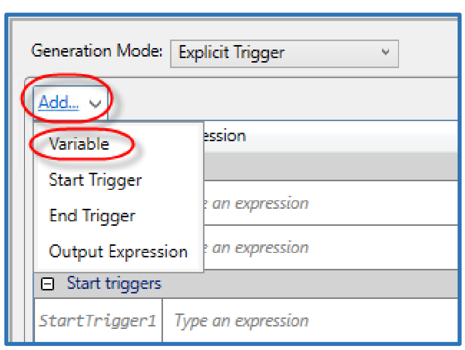
2. Click the  symbol and then select the **Event Frame Generation** radio-button. Then change the Name to **EF Underperforming Asset.**

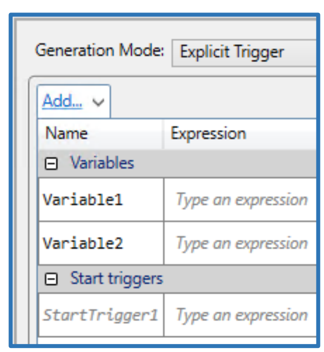


3. If **Example Element** shows Select an example element, then click it and select an element from the pop-up dialog that shows **all** the elements that are derived from the **Turbine** template. Then click the **Event Frame Template** combo-box and select **Under-Performing Turbine**.

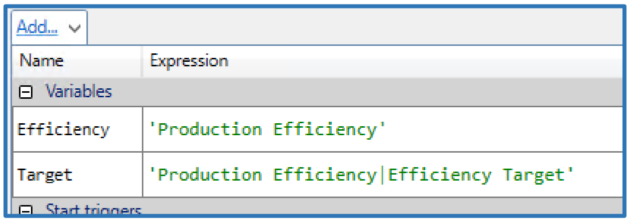


4. Below **Generation Mode** click on the  and select **Variable**. Do this one more time to create a second variable.



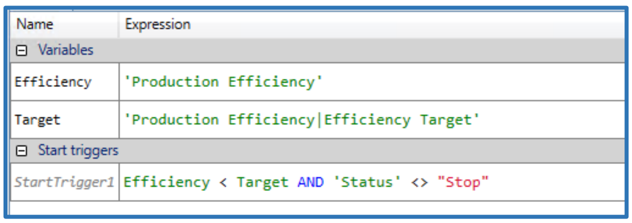


5. Click on Variable1 and type Efficiency. Click on Variable2 and type Target. Then for **Variable1** type `'Production Efficiency'` and for **Variable2** type `'Production Efficiency|Efficiency Target'`. Note: The intellisense does not recognize **Child-Attributes**, so you need to type the whole of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



6. For the **Start Trigger** type the following expression.

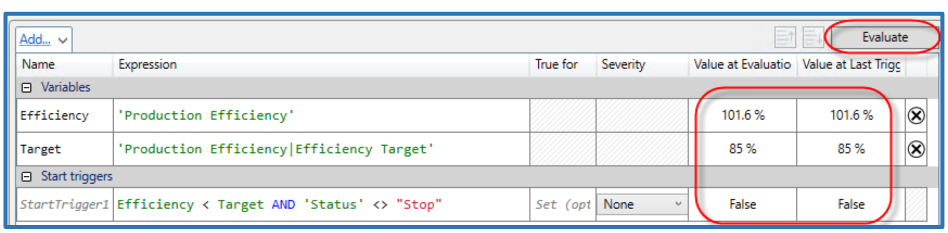
7. Efficiency < Target AND 'Status' <> "Stop"



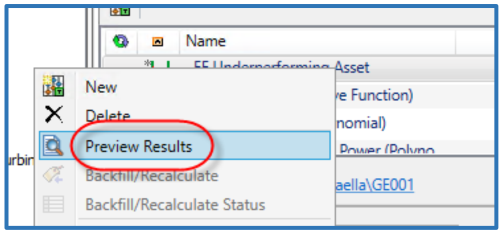
8. Note: A common mistake is to start typing the quote **'** and then **Efficiency**, typing the quote is for **Attributes** only. In this case, `Efficiency` is the Variable you defined in item 5 above. For **Variables**, do not type the quote. The same goes for `Target` in the expression.

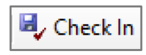
Step 3: Test the Event Frame Expression

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.

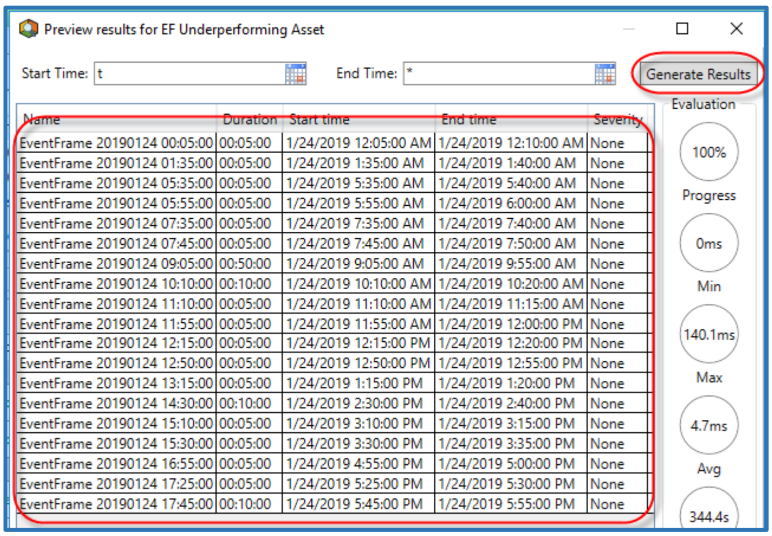


2. To check the logic it is always a good idea to preview the results before implementing the analyses. Right-click on the expression **EF Underperforming Asset** and select **Preview Results**.



3. 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 

your work.

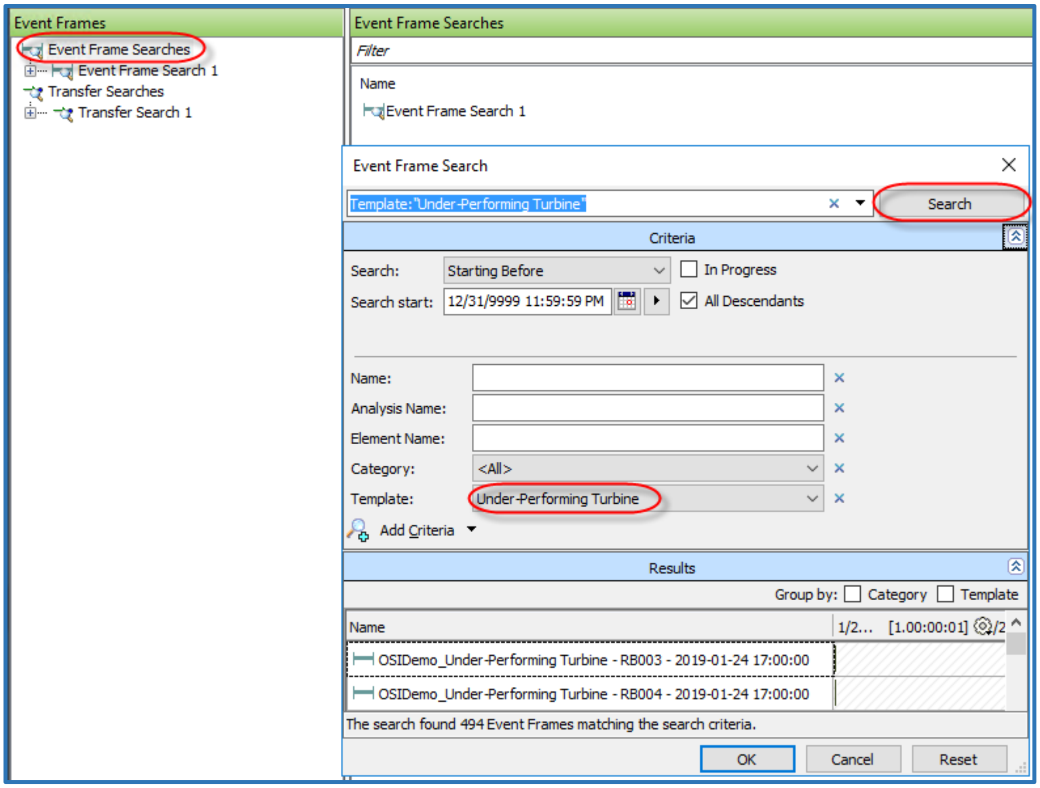


Name	Duration	Start time	End time	Severity
EventFrame 20190124 00:05:00	00:05:00	1/24/2019 12:05:00 AM	1/24/2019 12:10:00 AM	None
EventFrame 20190124 01:35:00	00:05:00	1/24/2019 1:35:00 AM	1/24/2019 1:40:00 AM	None
EventFrame 20190124 05:35:00	00:05:00	1/24/2019 5:35:00 AM	1/24/2019 5:40:00 AM	None
EventFrame 20190124 05:55:00	00:05:00	1/24/2019 5:55:00 AM	1/24/2019 6:00:00 AM	None
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
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
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
EventFrame 20190124 12:15:00	00:05:00	1/24/2019 12:15:00 PM	1/24/2019 12:20:00 PM	None
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
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
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
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

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.

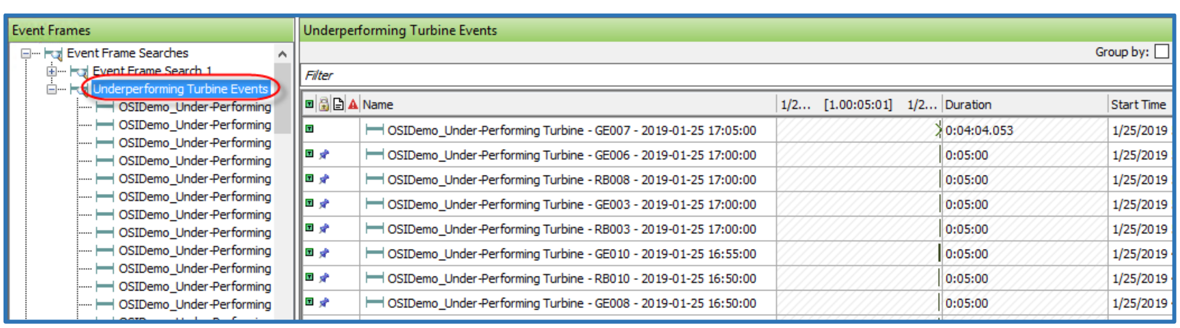
2. When the backfilling finishes navigate to the **Event Frames**. Right-click on **Event Frame Searches** and select **New Search**. In the dialog that pops up click on the **Template** combo-box and select **Under-Performing Turbine**. Then click the **Search** button. You should see something like 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.



Tip

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.



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

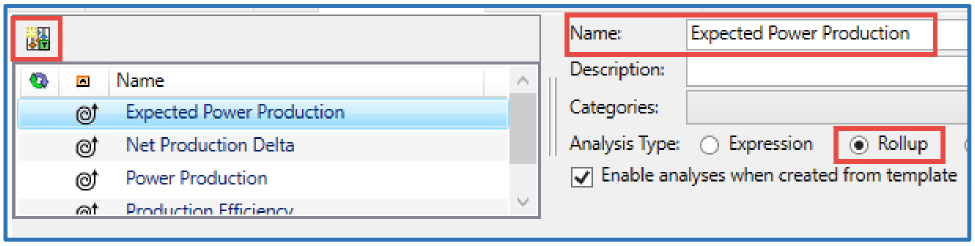
You haven't done rollups before, so you decide to review the content on my.OSIsoft.com and the OSIsoft learning Channel. You learn that:

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…

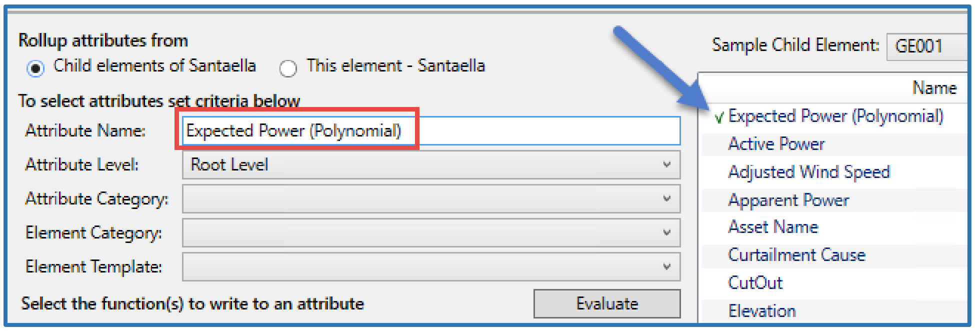
   Mapping of outputs work the same as expression analyses

Step 2: Build the Farm rollup for Expected Power Production

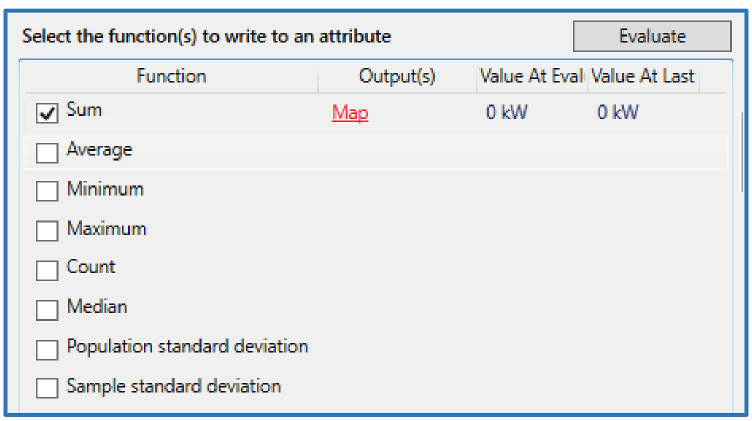
1. Expected Power Production
2. Using the element template Farm, add **a new analysis** of type **rollup**. Name it **Expected Power Production**.



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.



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



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

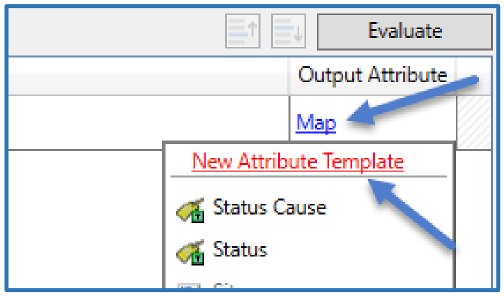
✓

Best Practice

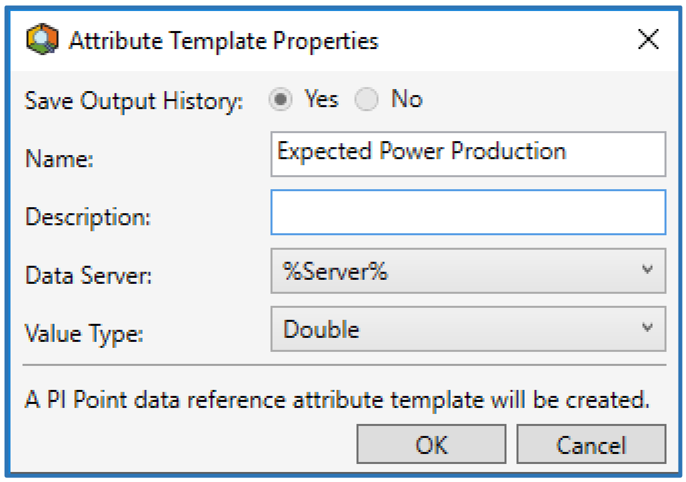
Always deliberately evaluate the scheduling plan for each analysis. Triggering analyses more often than needed, especially those with downstream dependencies, can tax the Analysis Service. In this case, while it may make “sense” to event trigger as a new turbine power is recorded, if the data is not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



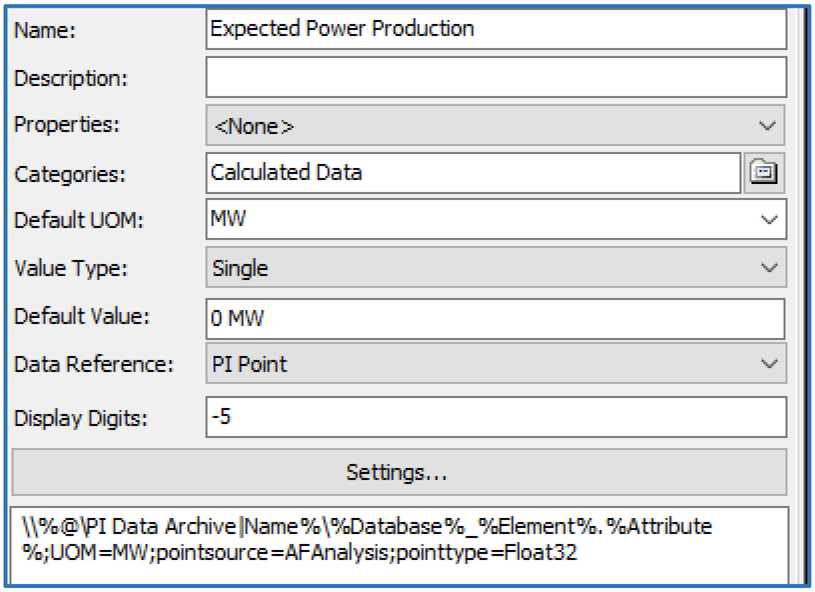
5. Note, rollup analysis types do not allow the option for not saving the output history.



✓ Best Practice

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.

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



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

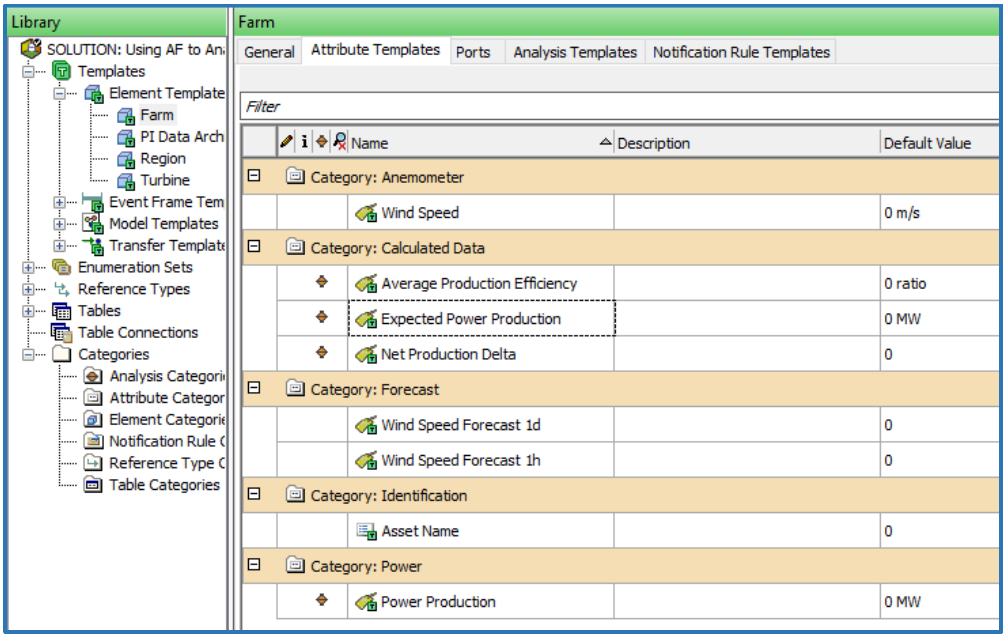
1. As a reminder, the CEO requested aggregations also for **Net Production Delta**, and **Production Efficiency** at the Farm level as well as all of these items at the **Region** level.
2. Use the table below as a reference along with Step 2 above to create the remaining analyses.

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

1. 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.

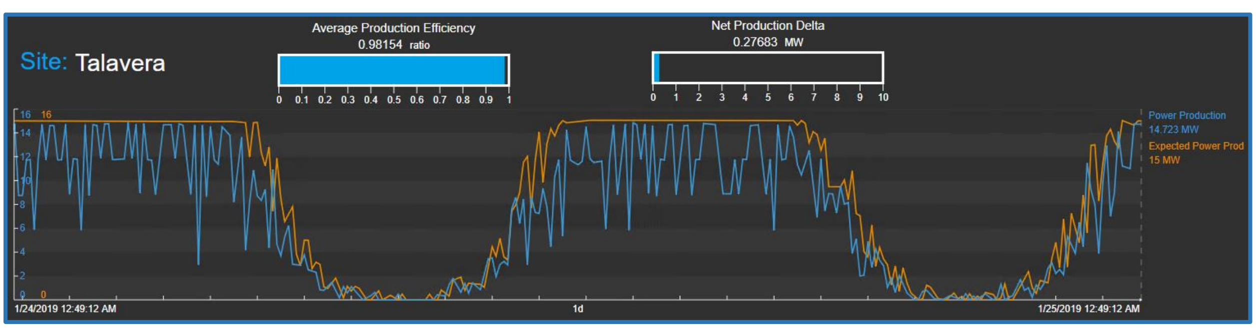
10.2 Tasks

- 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

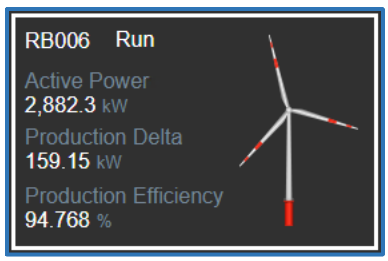
1. Open Google Chrome and navigate to PI Vision at https://pisrv01/pivision/ . Once at the PI Vision homepage, click on the New Display option at the top. New Display.
2. Navigate on the Asset sidebar and select a Site. Then add the following information about the Site to the display:
3. Trend: Power Production, Expected Power Production
4. 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



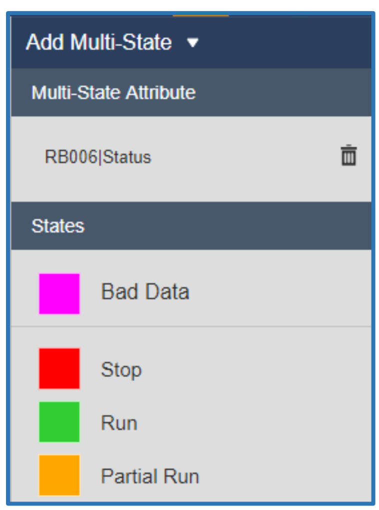
8. Now we can create a collection of Turbine assets to show relevant information about each turbine at the site. Navigate down from the current site you are on and select a Wind Turbine. Add the following information to the display
9. Value: Asset Name, Active Power, Production Delta, Production Efficiency

Tip	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.

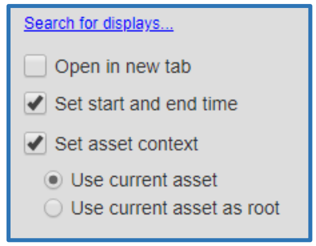
10. Change to the Symbol Library on the left hand side and add a Wind Turbine graphic.
11. Enclose all this in a Rectangle. Format this shape in the right click window to have no fill and Send it to Back with the Arrange options



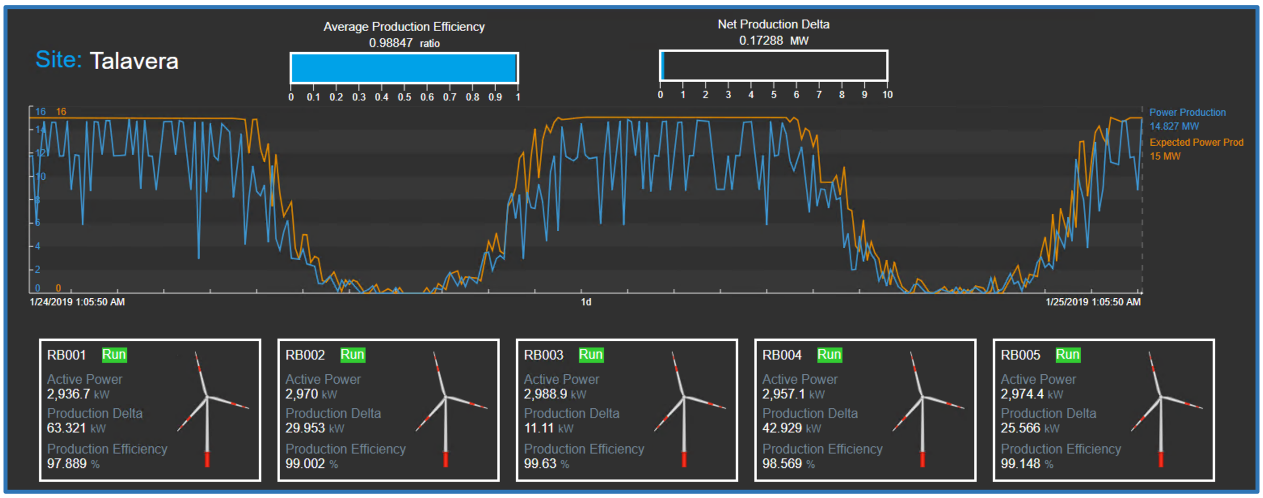
12. Right Click the Status value object and Configure Multistate. Use the following color scheme:



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



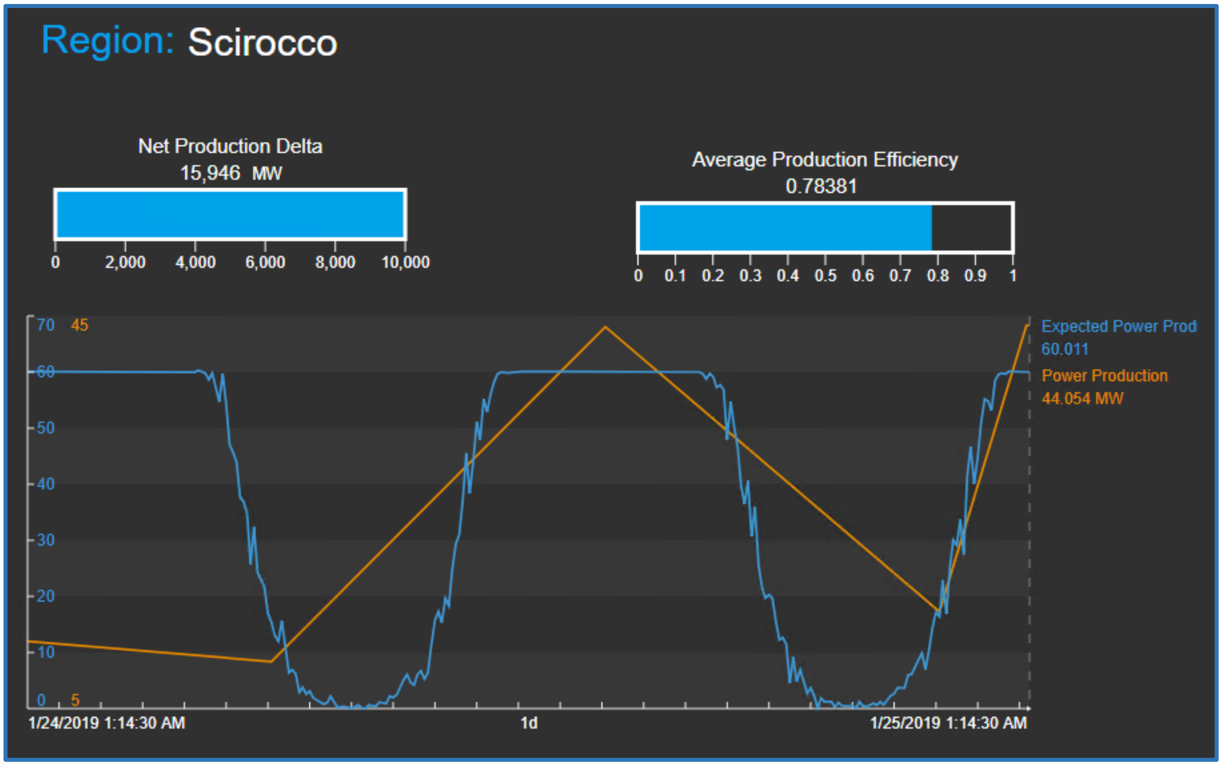
16. Now click and drag your mouse over all the objects we have made and with a right click Group Symbols. Then right click again and Convert to Collection.



17. Save this display as Site Dashboard

Step 2: Create a Region dashboard

1. Click on the New Display option at the top. New 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. 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

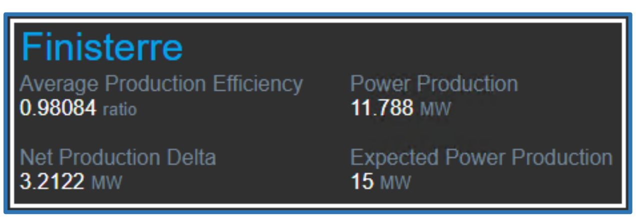


8. Now we can create a collection of Site assets to show relevant information about each site at the site. Navigate down from the current Region you are on and select a Site. Add the following information to the display

9. 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

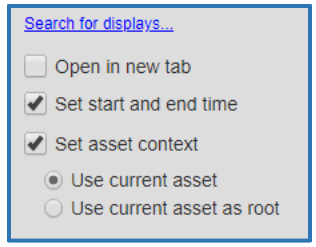
11. Enclose all this in a Rectangle. Format this shape in the right click window to have no fill and Send it to Back with the Arrange options



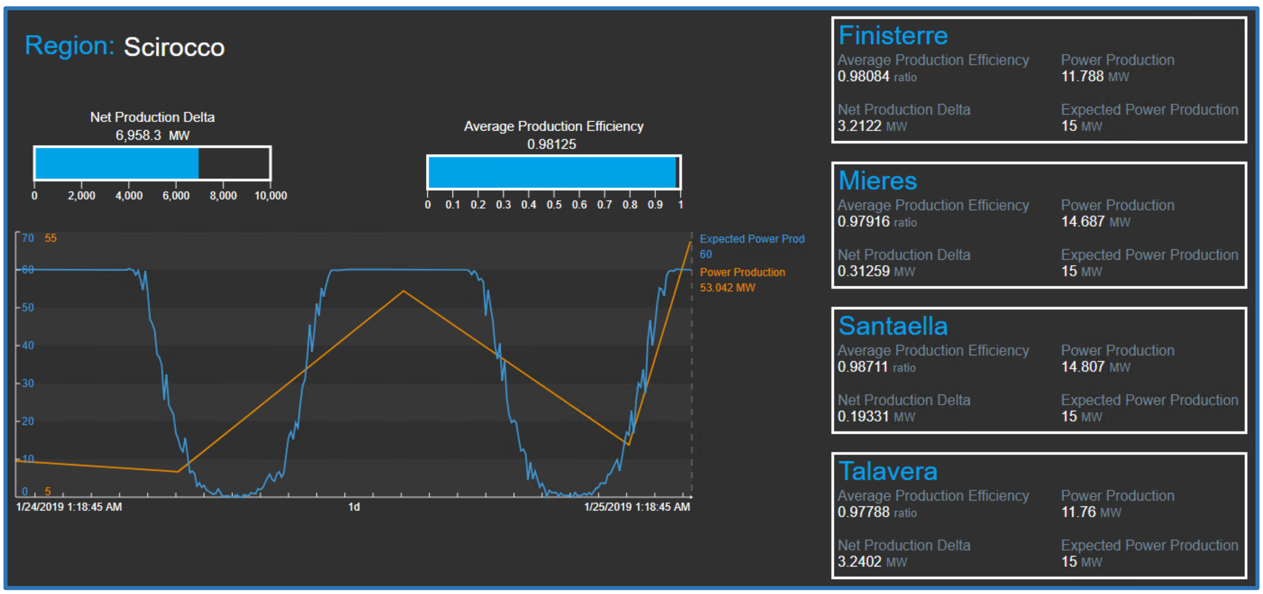
12. Right click the Site Name symbol and choose to Add Navigation Link.

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.

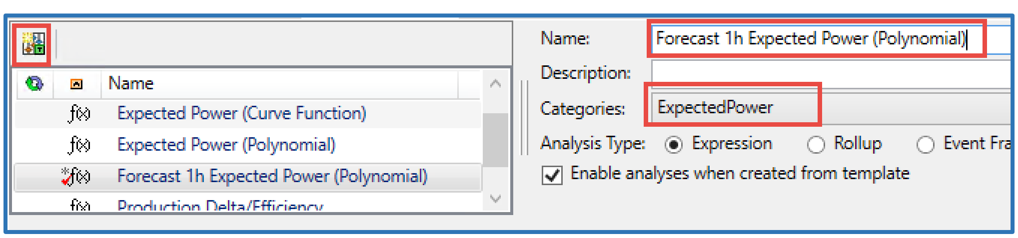
11.3 Step by Step Explanation of this Lab Section

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.

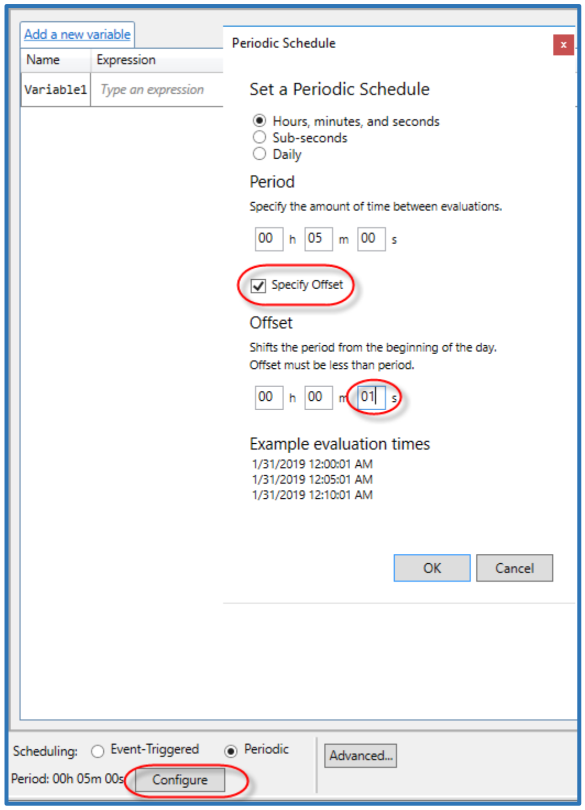
Step 1: Add Analysis to Turbine Template and Set Schedule and Future Output

1. 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.

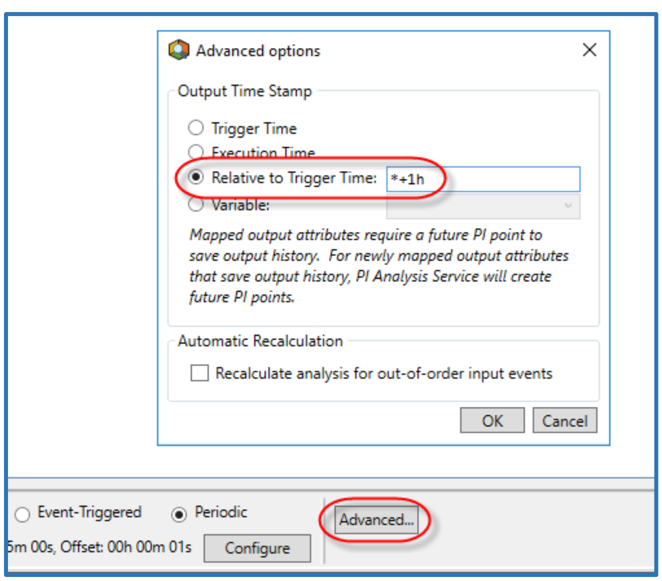
2. Click the symbol to create a new analysis. In the **Name** field enter the text **Forecast 1h Expected Power (Polynomial)**.



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.



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.



Step 2: Fill in Expected Power Polynomial Analysis

1. Create a variable called **AdjustedWindSpeedVar**

✓ Best Practice	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.

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.

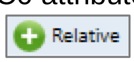
4. Since we fit our curve to a 6th order polynomial, Our expression will use the following equation:

$$y = C_0 + C_1x + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5 + C_6x^6$$

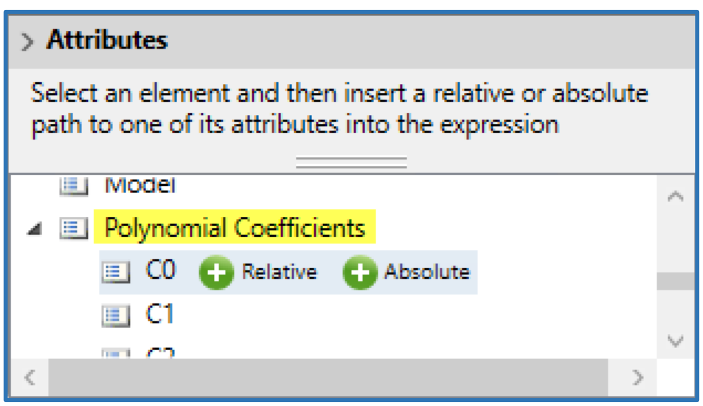
   where y is the Expected Power and x is the Adjusted Wind Speed

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

$$y = C_0x^0 + C_1x^1 + C_2x^2 + C_3x^3 + C_4x^4 + C_5x^5 + C_6x^6$$

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

to add it to the expression.



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_6x^6

Polynomial	// 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

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.

Tip

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

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

Output	//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_Power'
	else if AdjustedWindSpeedVar>='Polynomial Coefficients|HighWind_Limit'
	   then 'Polynomial Coefficients|HighWind_Power'
	else 'Polynomial Coefficients|HighWind_Power' ,"kW")

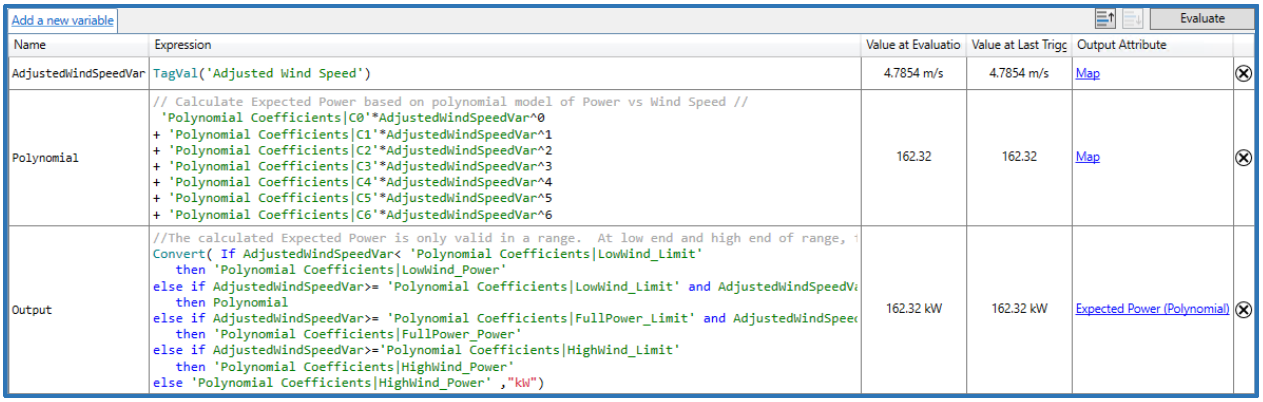
✓

Best Practice

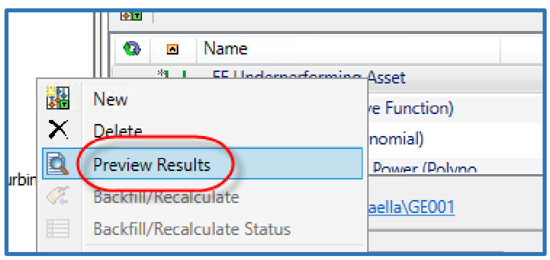
Analyses do not provide UOM of variable expressions where calculations or functions are involved. It is a best practice to use the **Convert** function inside the analyses to properly apply a unit of measure.

Step 3: Test the expression

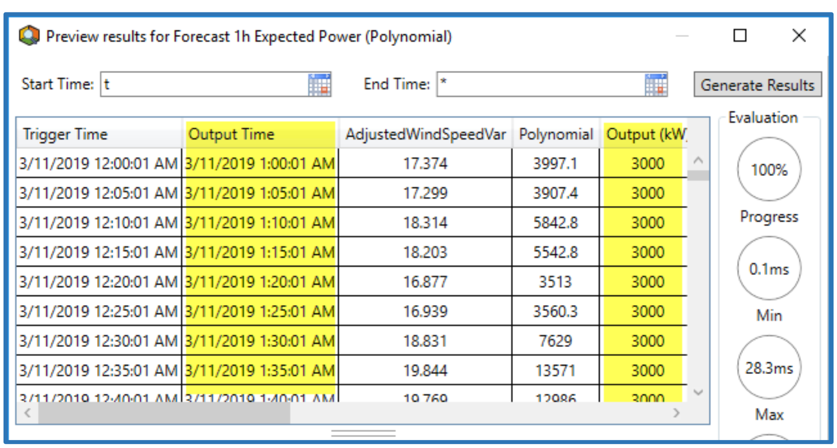
1. Do not check in yet. This is a common mistake, because the analyses will attempt to start for all the turbines. Click Evaluate to make sure you have no syntax errors. You should see values next to each of the variables and no error messages in the Status bar.



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.

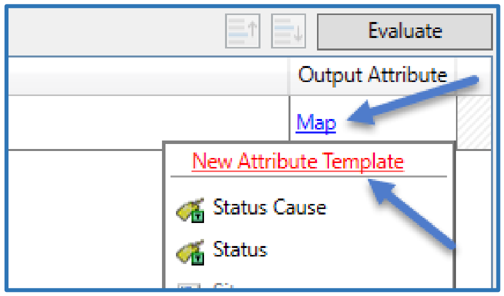


3. In the pop up window click on the Generate Results button. You should see something like the picture below.

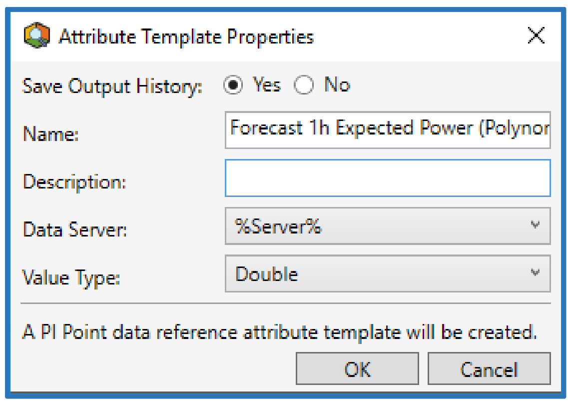


Step 4: Map Expected Power output to an attribute

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

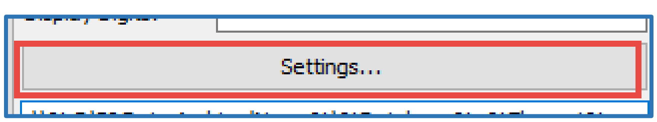


2. In this case we would like to historize the results, so ensure the **Save Output History** radio button is checked Yes.

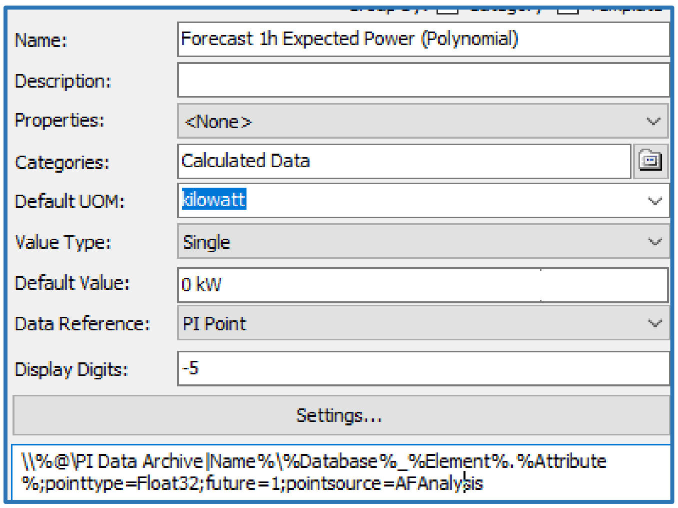


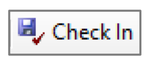
> ✓
> Best Practice
>
> It is a best practice to use the New Attribute Template option for outputs of analyses. There are a couple advantages over creating it "manually" on an element template. First, the Data Reference is automatically set. Secondly, the naming standards created in Challenge 1B are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



5. Once you are happy with the PI Point configuration,  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.

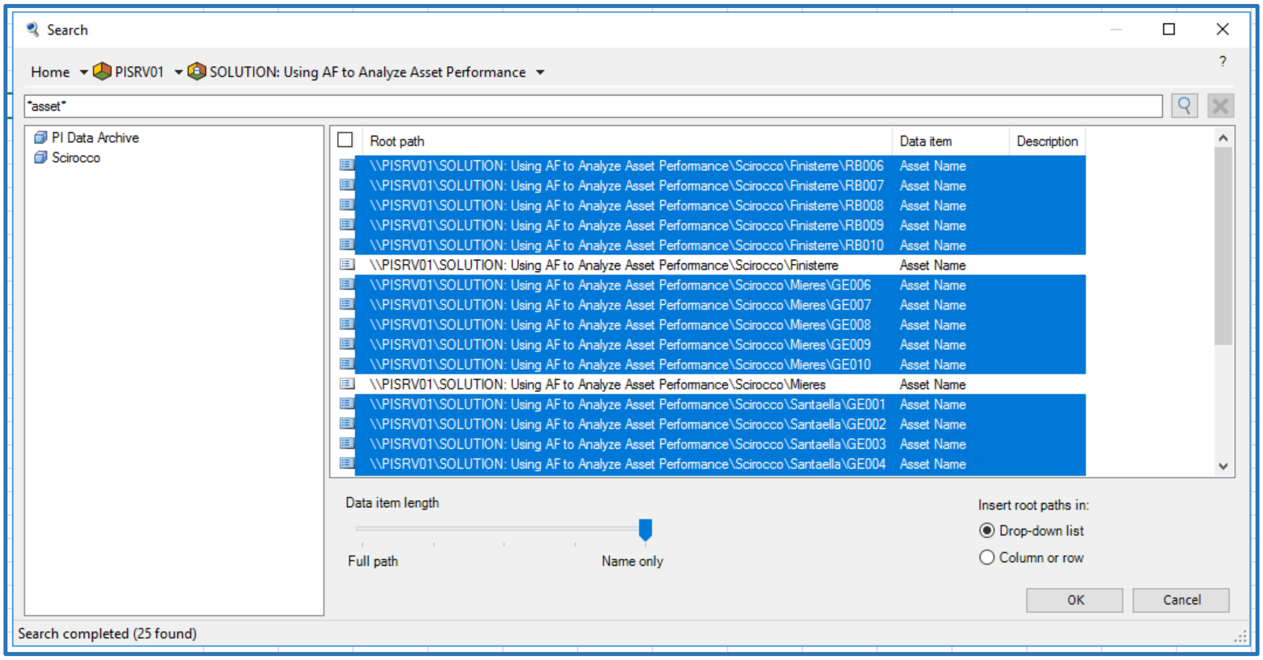
12.2 Tasks

- 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

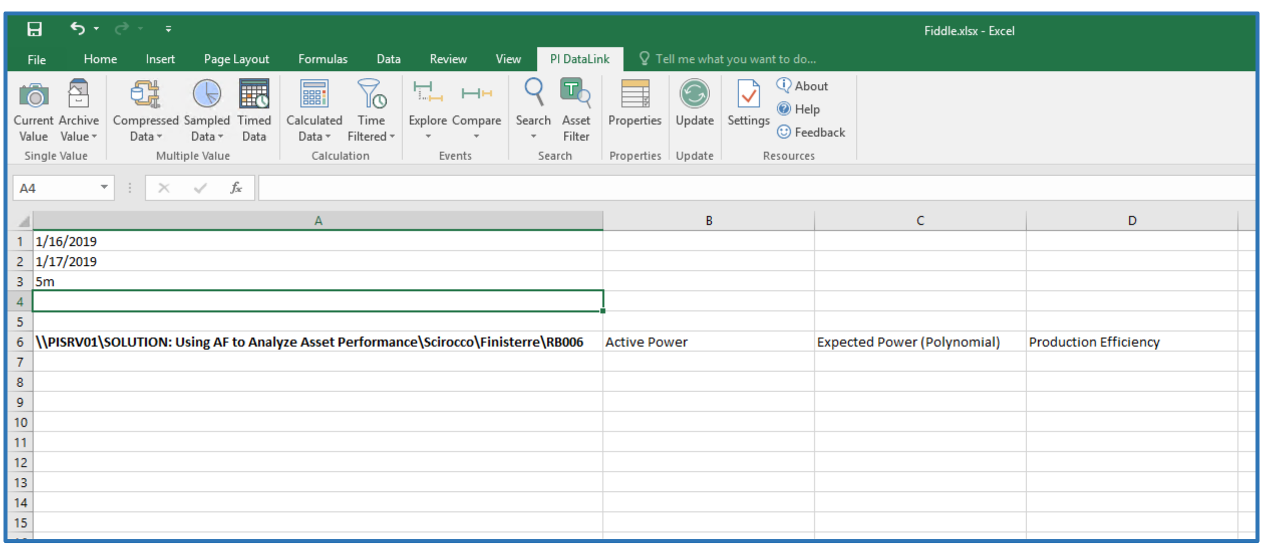
1. Create the Root path that determines which turbine you will create the report for.
2. Open Excel and start in cell A6 (you are starting in A6 to give room for cells to define the report and do run up calculations). Expand the width of column A to about 80
3. In the **PI DataLink** tab, click on **Search** 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.



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

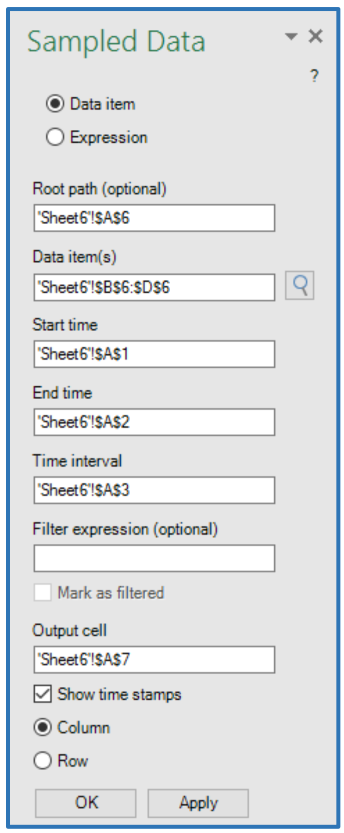
Step 2: Choose the attributes and the time range you would like to have data pulled into Excel

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:

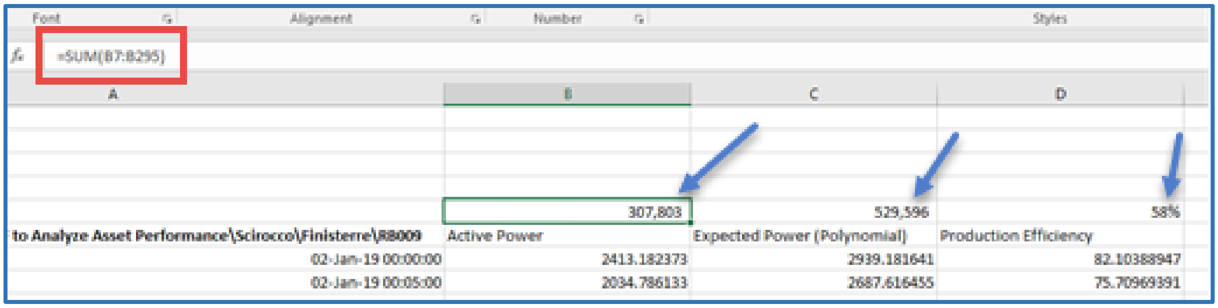


Step 3: Choose the type of data you want to pull into the spreadsheet

1. 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.



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.



11. 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

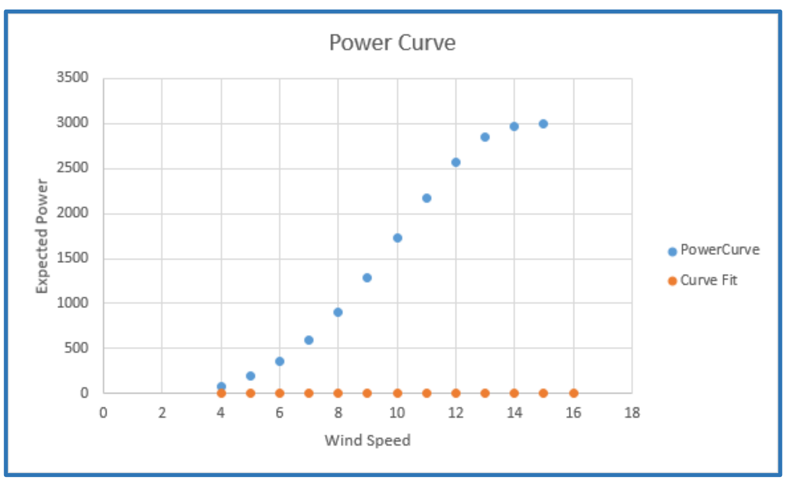
- Define the logic for the generation of low efficiency events and implement in the Turbine Template
- Test and backfill the events

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

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

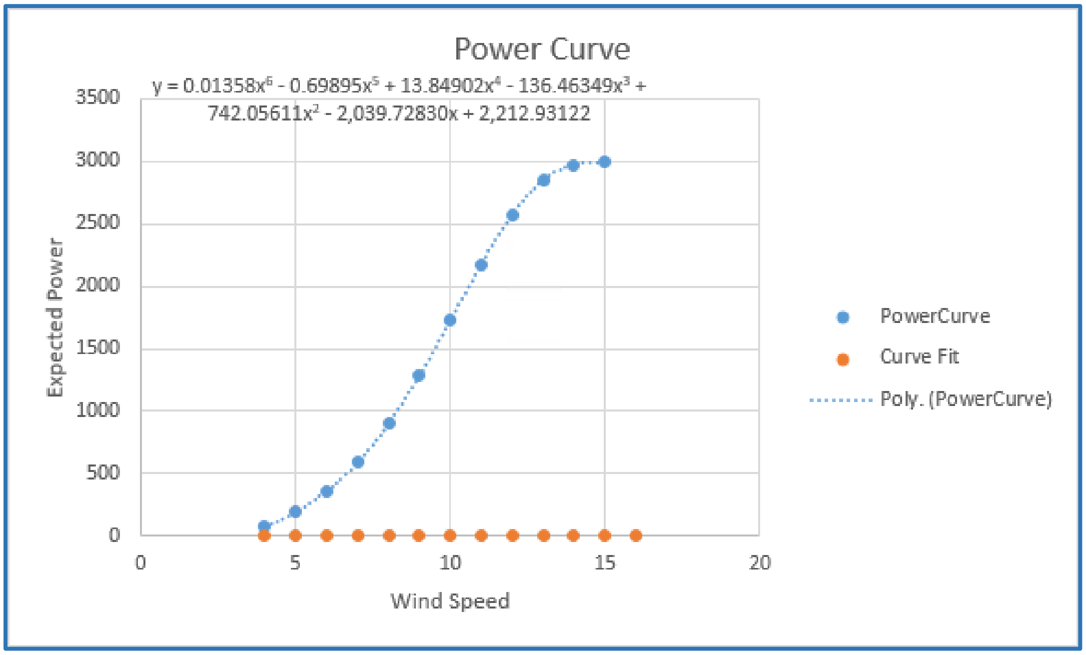
1. Open Challenge 1C_Fitting Performance Curve.xlsx from the shared drive located on the desktop.
2. Save the file with your initials to the desktop, example: ABC_Challenge 1C_Fitting Performance Curve.xlsx
3. Using PI System Explorer, navigate to the PowerCurve table and copy the contents to the spreadsheet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

Wind Speed	Expected Power
0	0
4	78
5	193
6	358
7	589
8	898
9	1289
10	1732
11	2172
12	2573
13	2856
14	2971
15	2996
16	3000
17	3000
18	3000
19	3000
25	3000
26	0
100	0



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



8. 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 PI 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

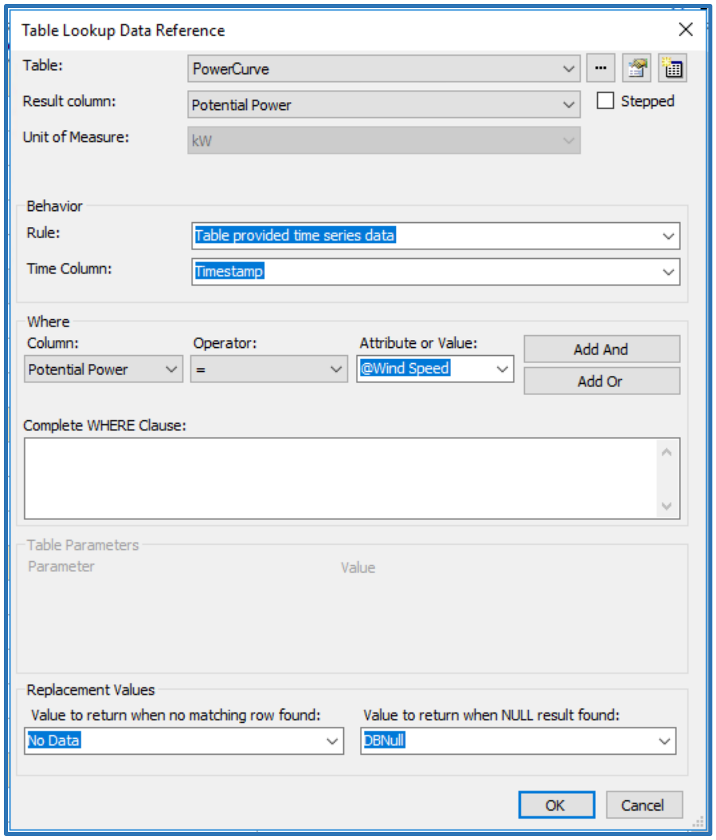
- Create Attributes to facilitate plotting Power Curve on PI Vision XY Plot
- Plot Power Curve and Live data on PI Vision XY Plot

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 KB01580. 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.



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>	Double	
Potential Power	kilowatt	Double	SELECT [Potential Power] FROM PowerCurve;TC=Timestamp
Wind Speed	meter per second	Double	SELECT [Wind Speed] FROM PowerCurve;TC=Timestamp

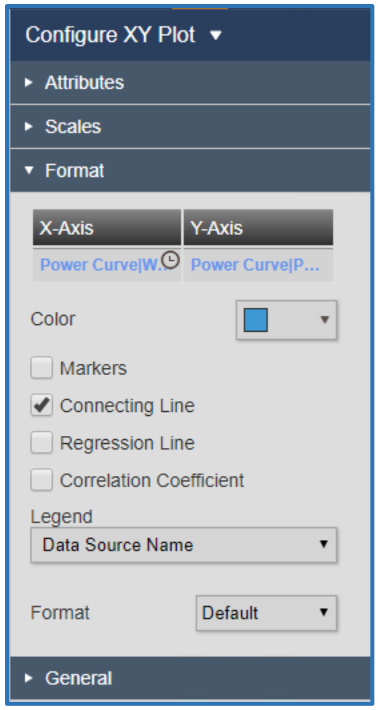
Step 2: Create Power Curve XY Plot

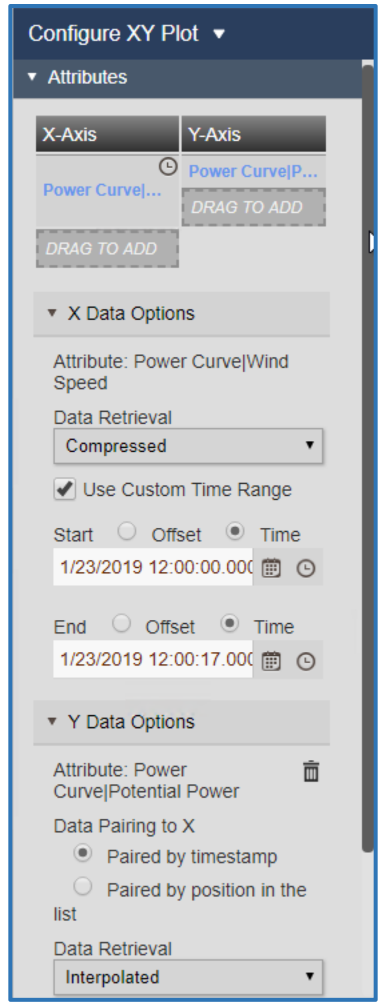
For this step we will be continuing to follow the instructions from KB01580. Now that we have the attributes configured for the static curve we will use Vision to plot it.

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.

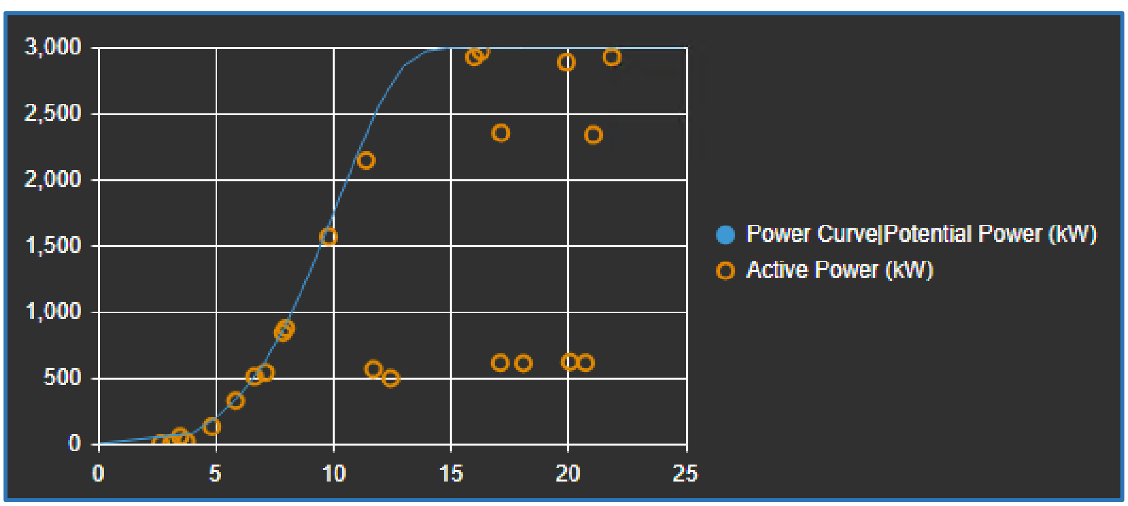
2. In the Assets sidebar navigate to any site and select any wind turbine. Find the attributes (Potential Power and Wind Speed) that you just created. Ensure the XY plot option is selected on the top left and then drag the Wind Speed to the main display. Then drag the Potential Power attribute onto the 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 deselect Markers
8. Now add a second set of data to compare the live data with Power Curve. With the Configure XY Plot sidebar open 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

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