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Performance Equations

GADS Wind Training Module 19

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RELIABILITY | ACCOUNTABILITY

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Equation Overview

- There are a large number (106) of Performance Equations listed in Appendix E of the Wind DRI
- All the equations are patterned after the equations in the conventional Data Reporting Instructions (DRI)
- The large number of equations is the result of many different customer needs
- The purpose of the indicators is to demonstrate how NERC may calculate indicators and to provide a standard for the industry
- All the equations can be calculated using the data supplied in the Performance record
- There is no requirement to provide GADS with any equation results

There are 106 Performance Equations in the DRI and none of the equations are part of required reporting. If NERC publishes any consolidated data, the equations in the DRI will be used. Most companies will only use 3-4 of these equations which will vary depending on customer needs

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Equation Sets

- As shown below, there are 4 sets of equations each having 2 sections (Resource and Equipment)
- A plant operator will most like use Set 3 - Equipment equations of which there are 12.
- Equations are identified – 3.B.5 = Set 3, Without OMC, Equipment, Equation 5 = Equivalent Forced Outage Factor. Resource = A and Equipment = B

Appendix E – Equations

Four different sets of performance equations are listed. A description of these sections is below.

1. **Resource and Equipment Calculations** – These equations calculate the individual resource and equipment performance by turbine sub-group(s) that have similar turbine capacities. These equations also include OMC hours.
2. **Pooled Resource and Equipment Calculations** – These equations pool the resource and equipment performance of sub-groups into collections of sub-groups, groups, or plants. These equations also include OMC hours. These equations are not weighted and should only be used for pooling data with turbines of the same turbine capacity.
3. **Resource and Equipment Calculations without OMC Hours** – These equations calculate the individual resource and equipment performance by turbine sub-group(s) that have the same, or very similar, turbine capacities. These equations do not include OMC hours.
4. **Multi-Resource and -Equipment Calculations without OMC Hours** – These equations pool the resource and equipment performance of sub-groups into collections of sub-groups, groups, or plants. These equations do not include OMC hours. These equations are not weighted and should only be used for pooling data with turbines of the same turbine capacity.

The equations are divided into 4 sets. Each set is further divided into 2 sub-sets (Resource and Equipment). Most plant operators will use equations from Set 3 Equipment sub-set. Those interested in the plants ability to deliver power will probably use Set 1 Resource sub-set.

Resource VS. Equipment

- Each equation set contains 2 types of indicators, Resource and Equipment.
- Resource Equations (A)
  - Used by planners to estimate loads
  - Indicate the plants ability to deliver power
  - Difficult for the plant to influence
  - Lack of resource (RUTH) is considered lack of fuel and is classified as a forced outage
- Equipment Equations (B)
  - Used by O&M as indicators of plant performance
  - Indicates the reliability of the plant's equipment
  - Management has a large impact on these indicators
  - Lack of resource (RUTH), is considered normal for this technology
  - RUTH is classified as Available hours in these calculations

Resource equations consider RUTH as a lack of fuel issue and are forced events. In a conventional type plant the output can be dialed in to what is needed. For a wind plant the resource varies, so the maximum output will vary minute by minute depending on the resource. For planning and delivering power these conditions need to be taken into account.

Equipment equations indicate how well the equipment is managed and the equipment performs. For these equations RUTH is considered available hours. Management has no influence over the resource and therefore it is not considered forced.

Equation Set 1

Equation Set 1 – Resource and Equipment

- 15 equations were originally selected from the conventional DRI that could apply to Wind (“A” equations)
- On the resource side RUTH would be considered lack of fuel and a forced outage

1.A.5. Resource Equivalent Forced Outage Factor (REFOF)
% of period that the plant was forced off line. Including low and high winds.

$$REFOF = \frac{(FTH + EFDTH + RUTH)}{ACTH} \times 100$$

1.B.5. Equipment Equivalent Forced Outage Factor (EEFOF)
% of period that the WTG equipment was forced off line. Excluding RUTH.

$$EEFOF = \frac{(FTH + EFDTH)}{ACTH} \times 100$$

Equation set 1 treats all FO, MO and PO the same there is no adjustment for OMC events. Transmission, off-takers and balancing authorities are most likely to use the Resource (Type A) as these equations truly reflect the plants ability to deliver power.

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Equation Set 2

Equation Set 2 – Pooled Resource and Equipment

- This set of data provides a very generic way of roll-up data
- Only turbines of similar system capacities should use this method
- No weighting is involved
- Discussion – Are all hours equal

2.A.5. Pooled Resource Equivalent Forced Outage Factor (PREFOF)

% of period that the plant was forced off line. Including low and high winds.

$$PREFOF = \frac{\sum(FTH + EFDTH + RUTH)}{\sum ACTH} \times 100$$

2.B.5. Pooled Equipment Equivalent Forced Outage Factor (PEEFOF)

% of period that the WTG equipment was forced off line. Excluding Ruth.

$$PEEFOF = \frac{\sum(FTH + EFDTH)}{\sum ACTH} \times 100$$

Equation set 2 is identical to set 1 except they are pooling equations. These equations only have value when pooling Sub-groups with the same Turbine System capacity. There is no weighting involved when using these equations.

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Equation Set 3

Equation Set 3 – Resource and Equipment without OMC Hours

- There are 12 equations in this set
- OMC Hours are removed from the equations
- For the plant operator, these will be the most likely used equations
- The "B" equations define what the operator is in control of and can have an impact

3.A.5. OMC Resource Equivalent Forced Outage Factor (XREFOF)
% of period that the plant was forced off line. Including low and high wind.

$$XREFOF = \frac{[((FTH + EFDTH) - (oFTH + oEFDTH)) + RUTH]}{ACTH} \times 100$$

3.B.5. OMC Equipment Equivalent Forced Outage Factor (XEEFOF)
% of period that the WTG equipment was forced off line. Excluding RUTH.

$$XEEFOF = \frac{[(FTH + EFDTH) - (oFTH + oEFDTH)]}{ACTH} \times 100$$

Equation set 3 removes OMC from the formula. The Equipment (B) equations would most likely be used by plant managers to monitor key equipment performance indicators. These are equations that plant management can be held accountable for.

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Equation Set 4

Equation Set 4 – Pooled Resource and Equipment without OMC

- Same set of cautions when using these pooling equations as with Set 2
- A weighted pool will give you a better result and will be discussed in a later module

4.A.5. Pooled OMC Resource Equivalent Forced Outage Factor (PXREFOF)
% of period that the plant was forced off line. Including low and high winds.

$$PXREFOF = \frac{\sum[(FTH + EFDTH) - (oFTH + oEFDTH) + RUTH]}{\sum ACTH} \times 100$$

4.B.5. Pooled OMC Equipment Equivalent Forced Outage Factor (PXEEFOF)
% of period that the WTG equipment was forced off line. Excluding RUTH.

$$PXEEFOF = \frac{\sum[(FTH + EFDTH) - (oFTH + oEFDTH)]}{\sum ACTH} \times 100$$

Set 4 is just pooling calculations using set 3 equations.

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Derates

Just a few words about the standard equations and derates

- Each equation with a derate has the term “Equivalent” in its name. As an example the equation below = “OMC Equipment Equivalent Forced Outage Factor”
- Derate calculations produce equivalent hours
- If you are not calculating derates (optional), the derate terms become zero and have no impact on the results
- Also, since there are no derates, there are no equivalent hours and the equation name could be called “OMC Equipment Forced Outage Factor”

3.B.5. OMC Equipment Equivalent Forced Outage Factor (XEEFOF)

% of period that the WTG equipment was forced off line. Excluding RUTH.

$$XEEFOF = \frac{[(FTH + EFDTH) - (oFTH + oEFDTH)]}{ACTH} \times 100$$

Equivalent hours are calculated hours. In reality, 2 or more issues are occurring at the same time and calculating equivalents is a way to separate and allocate the time correctly.

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