

PJM Generator Verification Test Correction Calculations

Temperature and Relative Humidity Correction
Calculations and Example: Combustion Turbines

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Combustion Turbine Temperature and Relative Humidity Corrections

Combustion Turbine ISO Rating

In order to correct a combustion turbine's output for ambient conditions we must first determine the ISO rating of the unit. The International Organization of Standards (ISO) ensures all combustion turbine power ratings are measured at a standard set of given parameters and each combustion turbine has an ISO rating. These parameters are:

- 15 Degrees Celsius (59 Degrees Fahrenheit)
- 60% Relative Humidity
- Zero Elevation (sea level)
- Standard Atmospheric Pressure (at sea level)

These ratings should be corrected to net ratings for the unit where it has been installed. Station service, auxiliary use and other plant or unit-related power use should be subtracted from the rating so that the ISO rating is a net rating. If auxiliary consumption varies with power output, this too, must be taken into account.

Combustion Turbine Reference for this Document

For the purposes of this document we shall use a combustion turbine with an ISO Rating of 100 MW. Combustion turbines have power output that is inversely proportional to their inlet air temperature. Each combustion turbine has a manufacturer's performance curve that shows this temperature-power output relationship. Each combustion turbine should also have a set of curves, correction tables or formulae that can be used to produce a family of power output curves for relative humidity at the specific site elevation. Also, for the purposes of this document, we will assume the combustion turbine used in the calculations, is situated at sea level. We will also assume that the slope of the temperature-power output curve is -0.3 MW per degree F and the slope of the relative humidity-power curve is +0.1 MW per degree F.

Combustion Turbine PJM Rating

In order to arrive at the PJM Rating for the combustion turbine, the dates and times of the last fifteen PJM summer peaks must be known. The PJM Peak History is updated semi-annually and can be found at this link: <http://www.pjm.com/~media/planning/res-adeq/pjm-peak-hour-history.ashx>. The PJM rating is simply the power output of the combustion turbine at the site average ambient conditions coincident with the last fifteen years' PJM summer peaks. If weather history for the combustion turbine site is unavailable, weather data from a nearby town, city or weather station can be used. Once site temperatures and relative humidity are established, they can be blended into the data history. For the purposes of this document the table of temperature and relative humidity data on the next page will be used (Table 1).

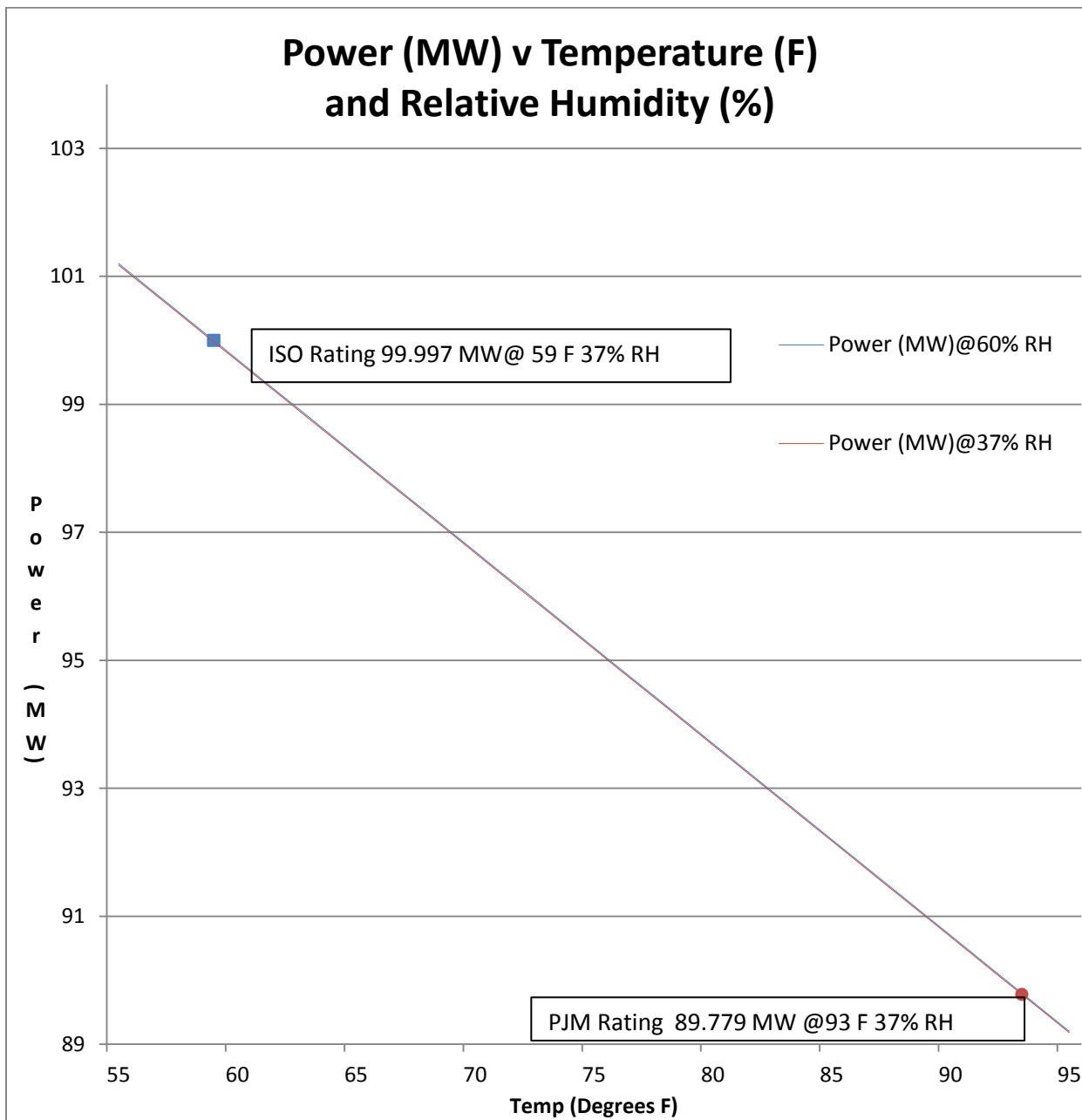
The PJM Rating is also the ICAP value to be filed with RPM and determined in accordance with PJM Manual 21 and the PJM Reliability Assurance Agreement (RAA), Schedule 9.C. Simply put, the ICAP value is a proxy for the expected capability at the time of future PJM peaks. Historical ambient conditions are to be used to determine this proxy value. Also, adjustments must be made for auxiliary consumption if it varies with output and/or ambient conditions experienced at the times of the PJM peaks.

Table 1

PJM Summer Peak Date and Time (EPT)	Site Temperature Degrees F	Site Relative Humidity Per Cent
8/11/16 16:00	95	35
7/28/15 17:00	93	38
6/17/14 18:00	92	39
7/18/13 17:00	97	30
7/17/12 17:00	90	42
7/21/11 17:00	90	45
7/7/10 17:00	91	44
8/10/09 17:00	92	38
6/9/08 17:00	92	37
8/8/07 17:00	94	39
8/2/06 17:00	95	32
7/27/05 16:00	93	31
8/3/04 17:00	95	35
8/22/03 16:00	95	36
8/14/02 16:00	91	34
15 Year Average	93	37

The PJM rating can be determined now that we have a fifteen year average temperature and relative humidity. Figure 1 shows the power curve at the ISO Rating adjusted to 37% Relative Humidity (99.977 MW @59°F) over a temperature span of 40°F and also shows the PJM Rating 89.779 MW @ 93°F/37%RH over the same temperature span. Each curve can be determined by the equation: $Power @ Temp_F @ RH_{\%} = Power_{ISO} - 0.3 * (T_F - 59) + 0.1 * (RH_{\%} - 60)$. Please note that adding corrections for relative humidity do not only change the calculations of the correction, but the PJM rating should be recalculated since the relative humidity can cause the PJM rating to change (albeit slightly). In this example we will correct for both temperature and relative humidity. Please note that the two curves are so close that a graphical demonstration as in the temperature only correction document cannot be reasonably performed. Also, keep in mind that the relationships in these correction examples are not necessarily linear, but are shown to be linear for simplification purposes.

Figure 1



Combustion Turbine Verification Test

PJM Manual 21 mandates that a combustion turbine generator be tested during the summer period (June 1st through August 31st) if the unit participates in the PJM capacity markets. A generator with Capacity Interconnection Rights (CIRs) must test to its CIR level once every three summers. This test must be performed for one contiguous hour and corrected for ambient conditions. For this example we will only correct for temperature.

Assume the verification test was performed when the local plant site temperature was 80°F and the relative humidity was 75% and the output over that one hour period was 88.0 MW.

Using the equation in the previous section, the expected power output at 80°F and 75% relative humidity can be determined. The process should render 93.714 MW.

Resultant Correction for Temperature and Relative Humidity

The correction can now be determined since we know the expected output at 80°F and the actual output at 80°F. The correction is simply the actual output at 80°F/75%RH less the expected output at 80°F/37%RH, or 88.0 MW less 93.714 MW or -5.714 MW. The correction is then added to the claimed installed capacity or ICAP value of 89.8 MW. Hence the corrected net test capability, as shown in Table 2, is 89.8 MW plus -5.714 MW or 84.086 MW.

Table 2

Quantity	MW
Actual output at 80°F/75%RH	88.0
Less expected output at 80°F/37%RH	-93.714
Equals Correction for Temperature	-5.714
Plus Claimed Installed Capacity or ICAP value	89.8
Net Corrected Test Capability	84.086

As you can see, corrections for relative humidity are rather small compared to temperature corrections. As combustion turbines get larger it may become necessary to correct for relative humidity. Of course, if combustion turbine inlet cooling is added it is imperative to correct for both inlet temperature and humidity, since inlet cooling is frequently evaporative based and the humidity corrections become important. Also, barometric pressure plays a part in how well these systems perform and should also be considered when correcting for these conditions. It is important to remember, if a correction is rendered for any set of parameters, the PJM rated installed capacity must also be calculated based on the same set of parameters and all future corrections must use the same set of correction parameters.

In the next document for combustion turbine corrections we will discuss combustion turbine inlet evaporative cooling.