

Opportunity Cost Calculator

MIC Special Session
Opportunity Cost
Calculator Issue
May 23, 2017

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PJM Operating Agreement

- **Schedule 2(a) - Two types of limitations may result in opportunity costs**
 - **“energy or environmental limitations imposed on the generating unit by Applicable Laws and Regulations (as defined in the PJM Tariff)”**
 - **“limited number of starts or available run hours resulting from (i) the physical equipment limitations of the unit, for up to one year, due to original equipment manufacturer recommendations or insurance carrier restrictions, or (ii) a fuel supply limitation, for up to one year, resulting from an event of Catastrophic Force Majeure”**

PJM Operating Agreement

- **Schedule (a) – Opportunity Cost Calculation**

“... unit-specific Energy Market Opportunity Costs are calculated by forecasting Locational Marginal Prices based on future contract prices for electricity using PJM Western Hub forward prices, taking into account historical variability and basis differentials for the bus at which the generating unit is located for the prior three year period immediately preceding the relevant compliance period, and subtract therefrom the forecasted costs to generate energy at the bus at which the generating unit is located, as specified in more detail in PJM Manual 15. If the difference between the forecasted Locational Marginal Prices and forecasted costs to generate energy is negative, the resulting Energy Market Opportunity Cost shall be zero.”

PJM Manual 15

- **Calculation of expected hourly LMPs**
 - **Monthly forward prices for the PJM Western Hub**
 - **To reflect locational and hourly differences, hourly basis differentials and hourly volatility scalars are calculated using the most recent three years of LMP data**

PJM Manual 15

- **Calculation of expected fuel costs**
 - **Daily delivered fuel price forecasts**
 - **Fuel monthly forward prices and/or contract fuel prices, and transportation costs applicable to specific unit are converted to daily prices using the most recent three years of data**

PJM Manual 15

- **Unit offers consistent with Manual 15 cost-based short run marginal energy cost, no load cost, and start-up cost**
- **Participant supplies heat rate, variable O&M, projected fuel delivery charges and parameters including notification time, minimum run time and minimum down time**

PJM Manual 15 - Calculation

- **Optimization and Adder Determination**
 - **Margins equal net revenue (LMP minus offer)**
 - **Compute margins for blocks of hours with run time durations corresponding to the minimum run time, up to twice the minimum run time**
 - **Compute the average margin for each block of hours**
 - **Sort the average block margin values from highest to lowest**
 - **OC adder is equal to the average block margin corresponding to the first or lowest block that would be foregone if the unit ran currently**

MMU OCC Constraint Definition

- **The MMU obtains a copy of the documentation that defines the output restriction.**
- **In the case of an environmental limitation, Market Participants provide the Market Monitor with a copy of the permit that typically specifies the limits on NO_x, SO₂, CO₂, or CO**
- **For physical equipment limitations, Market Participants provide the Market Monitor with documentation from the equipment manufacturer or insurance carrier**

MMU OCC Constraint Definition

- **Market Participants supply MMU with emissions rates and current emissions levels**
- **MMU confirms inputs**
- **MMU checks back with Market Participants to compare actual emissions rates and levels**

MMU OCC Constraint Definition

- **Example Environmental Permit:**
 - **NO_x limit, 100 Tons/Yr**
 - **SO₂ limit, 5 Tons/Yr**
 - **CO₂ limit, 80 Tons/Yr**
 - **Limits enforced on rolling 12 months basis**
- **Thirty-six (36) constraints needed to model 3 restrictions on 12 month rolling basis**
- **Constraints must be enforced simultaneously**

MMU OCC Unit Offers

- **For units that offer in excess of short run marginal cost as defined in Manual 15, and are not subject to mitigation in the PJM energy dispatch, the MMU includes a margin equal to the adder actually used by the unit in its offers**
- **Reflecting the actual offer behavior of the unit results in run hours consistent with actual run hours.**

MMU OCC Unit Offers

- **Use of an offer that is too low will overestimate expected generation and overestimate the opportunity cost adder**
- **Use of an offer that is too high will underestimate expected generation and underestimate the opportunity cost adder**



MMU OCC Optimization

- **Mixed Integer Programming (MIP) Optimization**
 - **Objective is to dispatch the unit based on forward power and fuel curves to maximize net revenue subject to the environmental or fuel limits, whether calendar year or rolling periods**
 - **Operational flexibility between economic minimum and economic maximum**
 - **Unit parameters are binding:**
 - **Start costs**
 - **Minimum run time and minimum down time**

MMU OCC Optimization

- **Three step algorithm for each forecast scenario**
 - **Step 1: Optimize w/o environmental/equipment limitation constraints**
 - **Step 2: Optimize with environmental/equipment limitation constraints**
 - **If the objective function value in Step 2 is less than the objective function value in Step 1, then continue to Step 3; otherwise OCC Adder = 0**
 - **Step 3: Determine the earliest compliance period that is binding in Step 2, and restrict the run time hours for that compliance period to be 1 hour less than the previous solution. Resolve the optimization**

MMU OCC Optimization Example

- **If running the OC Calculator on July 7 and limitations are enforced on a 12 month rolling basis, the first compliance period ends on July 31, the 2nd compliance period ends on August 31, etc.**
- **For Step 3, identify the compliance period with earliest end date that corresponds to a binding constraint in Step 2, reduce the run hours by one, then resolve the optimization**

MMU OCC Optimization

- **Marginal hourly opportunity cost is equal the decrease in the objective function (total margin) from the restriction to one less hour of operation**
- **The OC adder is the average of the three marginal hourly opportunity cost values**
- **The three values are based on the three optimization scenarios from the three calendar years of LMP and fuel price history used to develop the hourly LMP and daily fuel price scalars**

Possible Differences with PJM Approach

- **MMU models rolling constraints precisely**
- **MMU MIP optimization versus brute force block methodology**
- **MMU models unit flexibility that allows generation at economic minimum or economic maximum**
- **MMU uses actual offer behavior**
- **MMU includes all unit parameters, e.g. minimum down time constraint**
- **PJM does not check individual unit input details provided by participants or evaluate the opportunity cost adder results**

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