PJM Reference Model Development for Analysis of the EPA's Final Clean Power Plan Rule

Introduction and Purpose

On August 3, 2015 the U.S. Environmental Protection Agency released its final Clean Power Plan rule for reducing greenhouse gas emissions in the form of carbon dioxide from existing fossil-fueled electric generating units. On October 16, 2015 the Organization of PJM States, which represents state utility regulators in the region served by PJM, requested that PJM analyze the potential economic impacts of the EPA's Clean Power Plan Final Rule. PJM then intends to use the outputs from the economic analysis to examine the potential reliability impacts, if any, of the Clean Power Plan.

PJM's role in performing analysis on the final Clean Power Plan is as an independent source of expert electric power industry information. PJM's primary focus is on reliability, followed by the operation of efficient and non-discriminatory markets, and hence, PJM is neutral concerning the fuel-type, age, size and technology used by resources to provide energy and reliability services,. PJM does not advocate particular energy or environmental policies and is not forecasting market outcomes in this analysis. The outcomes of the scenarios/sensitivities are dependent upon the underlying assumptions and are designed to examine a potential state of the PJM market driven by fuel price assumptions, federal and state policy assumptions and resource capital costs.

In the proposed rule analysis, PJM performed scenario-based analysis to understand the impacts of fuel prices, and changes in the generation mix on compliance with the some rate-based, but primarily mass-based compliance paths. For the final rule, OPSI requested that PJM develop an economic baseline (reference case) representing PJM market outcomes absent the Clean Power Plan before studying the various compliance pathways articulated by the EPA in the final rule. In addition to the reference case, PJM also performed sensitivities to the reference case, including adopting lower natural gas prices based on a separate proprietary vendor forecast and achieving state Renewable Portfolio Standards. This document provides a closer view of the resource entry/exit modeling framework employed by PJM to respond to the OPSI request.

PJM Entry/Exit Modeling

Generation entry/exit decisions are affected by many factors including public policy, regulations and market drivers such as fuel prices, demand growth, and technology costs and efficiencies. Most long-term modeling tools are designed to perform integrated resource planning-type analysis in a regulated, vertically integrated utility environment where a portfolio of assets is optimized to minimize overall costs, subject to reserve margin constraints.

As an independent entity and operator of wholesale power markets, it is inappropriate and unnecessary for PJM to perform integrated resource planning studies. However, in its role in providing reliability and non-discriminatory open access to transmission, PJM does study and coordinate resource retirements and new generation interconnection requests to participate in the PJM wholesale market. With over 60,000 megawatts of gas-fired generation, 15,000

MW of wind generation, and 3,600 MW of solar currently in the interconnection queue[1], performing an economic or reliability study can be challenging because of the probability of a significant amount of projects cancelling or delaying in-service dates. Moreover, future retirements are often unknown as the PJM Tariff only requires that resources provide a 90-day notice prior to deactivation. Therefore, when studying the future transmission needs of the system, PJM's planning process uses established criteria for retaining existing resources, such as known deactivation notices, and including resources within the models based on "steel in the ground" and interconnection queue study status.

To evaluate a period longer than five years in a policy study exercise can be challenging because of the difficulty of determining which existing resources will retire and which new resources to add to maintain resource adequacy. The challenge lies in the uncertainty of which existing resources will eventually retire and which resources in the interconnection queue will eventually go into commercial operation as such decisions are related to future policies and market conditions.

To address these uncertainties from a competitive, wholesale market standpoint for the purposes of modeling, PJM utilized Plexos (R) Integrated Energy Model to perform a 20-year, simultaneous optimization of the energy market, capacity and renewable energy credit markets. While PJM does not administer the renewable energy credit markets, it was important to evaluate them within the simulation given they are key drivers of renewable interconnections and a key component of EPA's articulated "Best System of Emissions Reductions" in the final Clean Power Plan. There are other factors that will influence generation development including out-of-market bilateral contracts, but the energy market, capacity and renewable energy credit markets provide the primary market signals that drive utility-scale generation development within the PJM region.

Energy Market

Like all optimization models, Plexos' objective is to minimize overall costs to serve energy. Because of the long-term study horizon, the approach to dispatching resources is different from the typical chronological, security constrained unit commitment and economic dispatch approach. A chronological dispatch approach enforces more detailed unit operational constraints.

In Plexos, PJM is dispatching resources based on a load duration curve approach, which basically equates to isolating segments of the annual load curve and economically stacking resources to serve the system's energy needs with a very simple representation of the transmission system as described below. Given PJM's size, and the number of resource decisions over the study horizon (2018-2037), this is a necessary simplification given current computing capabilities both at PJM and in the industry. PJM selected a minimum number of segments for all years to satisfy several objectives: (1) minimize the error in representing the hourly load shape, (2) produce similar market prices and dispatch as would be developed through chronological dispatch, and (3) reduce computational run time. Plexos does not perform any resource aggregation or use "representative resources" to represent a class of resource types like

[1] State of the Market Report, Table 12-5 Queue Capacity by LDA, control zone and fuel (MW): At December 31,2015 http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2015/2015-som-pjm-volume2-sec12.pdf

other software packages for existing or new resources. Each specific and unique resource is modeled and dispatched based on its own fuel, variable operations and maintenance, and emissions costs which can be location specific. As PJM continues to work through the remainder of the analysis – the evaluation of the compliance pathways – improvements to this approach may become apparent. PJM will implement any improvements identified into the reference model for analysis results provided in May 2016.

Capacity Market

PJM also is using Plexos to simultaneously clear the Reliability Pricing Model Capacity Market over 20 years using the same variable resource requirement curve parameters as used in the Reliability Pricing Model Base Residual Auction. This is a feature that PJM has worked with the vendor to develop specifically for PJM. In the model, the decision to enter or exit the market for thermal resources, therefore, is based on a long-term expectation of clearing the capacity market and earning enough revenues in the energy market to cover the variable production costs to produce energy plus going-forward costs inclusive of pre-specified hurdle rate of return on capital investment. New resources must also be able to cover their annual build costs based on a capital recovery factor. PJM recognizes that its member, generation-owning companies have different risk profiles, hurdle rates of return, and timing considerations for generation investment and retirement decisions. However, in the model, the near term viewpoint carries greater weight for all generators simply based on discounting future cash flows. At any time in the study horizon (2018-2037) resources can enter/exit the market. In the reference model, because there aren't price or cost-based fluctuations due to new regulations or fuel prices, most of the unit retirements occur in the beginning of the study period, whereas new entry is volatile over the study horizon as a function of capacity and energy demand and prices.

Transmission

Transmission is a key factor in deciding to bring in new generation resources and also to retire them. Existing resources in constrained delivery areas can extend their economic and reliability value until new transmission is built. The period of time it takes to build new transmission upgrades can also bridge to a future in which fundamental market conditions are more favorable for their continued operation.

Transmission limitations are not represented in the 20-year model. Therefore, the additional congestion payments potentially earned are not reflected. At the same time, similar resources located in other parts of the system that contribute to congestion costs are not modeled as having to make a congestion payment. While it may be reasonable to assume that the PJM Regional Transmission Expansion Process addresses transmission congestion reflecting model assumptions, PJM is working with the Plexos vendor, Energy Exemplar, to determine whether there are opportunities to improve the model's robustness to account for the congestion effect on resource entry and exit decisions.

Renewable Energy Credit Market

While PJM does not administer the trading markets for Renewable Energy Certificates, developing a modeling representation for these markets was fundamental to studying the state Renewable Energy Portfolio Standards. Some states (Maryland, District of Columbia, Delaware, New Jersey, Pennsylvania, Ohio and Illinois) have

mandatory RPS targets enforceable through alternative compliance payment penalties. The alternative compliance payment effectively establishes a ceiling on the clearing price of RECs in those states.

Within the aforementioned states, there are also specific requirements for solar resources. Because of the requirements, PJM needed to study individual state Solar Renewable Energy Credit markets in addition to a single REC market in which all renewable portfolio standard qualifying resources can participate in trading regardless if they are receiving SRECs. By having a state SREC price, the model will build solar resources in state. The SREC prices reported in the PJM reference case and sensitivities are therefore the weighted average prices of SRECs across all states with solar carve-outs.

The model assumes it is not necessary to build non-solar resources within a state to meet a state's RPS requirement because of their broad geographic eligibility requirements and this simplifies modeling computation. Therefore, the model assumes only a PJM-wide REC trading market to capture price signals. By assuming trading, the alternative compliance payments established by one state may not lead to a sudden change in the total renewable energy added to the system. The level of the alternative compliance penalties will impact resource investment decisions in the model because in some instances, it could be cheaper to pay the penalty than to invest in new resources. The price of RECs reported by PJM in the reference case and sensitivities is the PJM region-wide REC price based on the regional demand for RECs and varying levels of alternative compliance penalties.

PJM is modeling the economic fundamentals of renewable energy credit trading markets, but similar to its representation of the capacity market, PJM is not attempting to represent the various strategies that participants within REC markets may adopt which can create volatility and even decouple the link between investment and price signals.

Summary of PJM Simulation Results

The quantitative reference model simulation results in the accompanying presentation reflect assumptions on fuel prices, federal and state policies and the limitations of modeling complicated market constructs. The modeling results do not represent a future forecast or future prediction of energy and capacity market outcomes.

Given the uncertainty about future market conditions, it is best to focus on the qualitative aspect of the modeling results, which show directionally, how the key factors impact the resource outcomes in the results.

A Summary of key observations

a. New investment is challenging for non-natural gas resources because of natural gas combined cycle resources' low capital costs and efficiency of operation, and the ability of natural gas combined cycle to significantly influence or set price in both capacity and energy markets.

b. Existing resources with the highest going forward costs, primarily coal and nuclear but other steam resources as well, face the greatest economic risks in the early years of the simulation, due to gas prices being at their lowest point.

c. In general, low energy market prices place greater dependence on revenues from the capacity market for resources to remain in commercial operation to maintain resource adequacy.

d. Existing resources with high going forward costs and new entrants with relatively high upfront costs must depend more on capacity market payments to be viable.

e. Retirements increase capacity prices, providing an opportunity for solar to enter the market even in the absence of RPS policies.

f. Coal resources have greater risk of exit than nuclear resources. This is due to reduced operating hours as a result of competing with natural gas combined cycle resources.

g. Entry of renewable technologies is supported by out-of-market incentives over the study horizon.

h. In the low gas price sensitivity, emission from Clean Power Plan affected resources are below the Clean Power Plan emissions targets through 2030.

Analysis Timeline Going Forward

Going forward, PJM will evaluate all the CPP compliance pathways for state and regional compliance. The analyses will include various sensitivity studies. PJM is in a unique position to be a resource to the states and other policymakers.