Comparison Study of the Four-Bubble and Five-Bubble PJM Models

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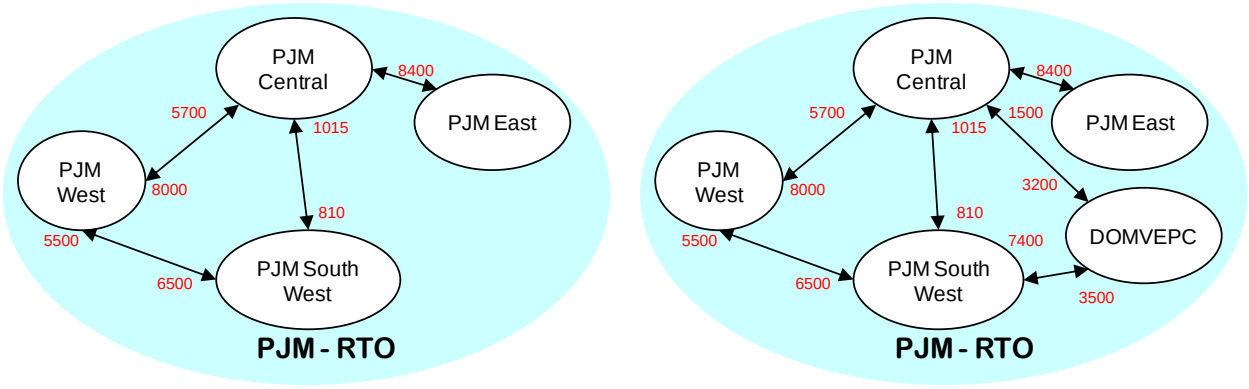
1. Introduction

In the annual New York State Reliability Council (NYSRC) Installed Reserve Margin (IRM) Study, the PJM Regional Transmission Operator (RTO) system interconnected to the New York Control Area (NYCA) has been traditionally represented by a four-bubble model in the GE-MARS program, as depicted in Figure 1a. In 2015, PJM revised its system model by splitting the PJM Southwest bubble into two bubbles, resulting in a new DOMVEPC bubble and an updated PJM Southwest bubble, as depicted in the five-bubble representation in Figure 1b.



(a) PJM four-bubble model in 2016 IRM Study (b) PJM revised five-bubble model

Fig. 1 – PJM four-bubble vs. five-bubble MARS models

In 2015, the NYSRC Executive Committee, upon the recommendation of the Installed Capacity Subcommittee, began considering whether a transition in the modeling of the PJM RTO system to a five-bubble model would be appropriate in the IRM Study.

Interested parties raised concerns over the revised PJM RTO system representation because this model change could potentially impact the IRM Study results associated with changed emergency assistance from PJM in two respects: (1) an additional interface was added to the PJM Central bubble, which effectively added an additional 1,500 MW of transfer capability from the southern regions of PJM to the northern PJM areas; and (2) a new separate load shape would be used for the new DOMVEPC bubble with the PJM Southwest load shape also being updated due to the separation of the new DOMVEPC bubble.

The NYSRC therefore requested the New York Independent System Operator, Inc. (NYISO) to evaluate the impact of the revised PJM RTO system model from a four-

bubble to a five-bubble representation. The NYISO's analysis was based upon the 2016 IRM Study final base case assumptions, which included a 2,000 MW limit on the transfer capability between PJM and Southeastern New York. From this review, ICS would then recommend whether a five-bubble model should replace the current four-bubble model in GE-MARS for the IRM Study.

2. Impact Assessment of the Additional 1,500 MW Transfer Capability within PJM Five-Bubble Model

When the NYISO was asked to evaluate the impact of the PJM five-bubble model on the 2016 IRM Study final base case in late 2015, a separate load shape for the new DOMVEPC bubble and an updated load shape for the PJM Southwest bubble were unavailable. As a result, the NYISO initially focused its evaluation on the impact assessment of the additional 1,500 MW transfer capability within the PJM model.

The assessment started using the 2016 IRM Study final base case with NYCA loss of load expectation (LOLE) of 0.1 days/year and the PJM LOLE at the designated level of 0.14 days/year. Then, a new DOMVEPC bubble was created using the interfaces and transfer limits of the topology as shown in Fig. 1(b). The generation resources in the original PJM Southwest bubble that belong to the DOMVEPC area were also separated out and modeled in the new DOMVEPC bubble. The combined generation capacity of the new DOMVEPC bubble and the updated PJM Southwest bubble equaled the total generation capacity of the original PJM Southwest bubble.

Due to the lack of separate load shapes for the new DOMVEPC bubble and the updated PJM Southwest bubble, the load shape of the original PJM Southwest bubble was used for both the aforementioned bubbles. In addition, the hourly loads of the original PJM Southwest bubble were broken into two loads based on the ratio of the PJM zonal peak load forecast for the new DOMVEPC bubble and the updated PJM Southwest bubble. Hence, any possible LOLE and IRM changes in this test case would be caused solely by the topology change of the PJM five-bubble interfaces and transfer limits.

Under the above assumptions, it was observed that the test case with the five-bubble topology showed no appreciable effect on the LOLE for NYCA. In other words, the NYCA LOLE remained at 0.1 days/year despite this topology change. Since the test case was studied for the Tan 45 point on the IRM-LCR curve, an unchanged LOLE

indicates that the original Tan 45 point would also not change. Therefore, for the model as studied, the additional 1,500 MW transfer capability within PJM five-bubble model had no impact on the 2016 IRM Study final base case results.

3. Impact Assessment of the New Separate Load Shapes for the PJM Five-bubble Model

Load shapes are critical to the Monte Carlo simulation used in the GE-MARS program to assess the probability of loss of load for the reliability studies. In 2016, PJM staff provided the NYISO with the hourly load data for the new DOMVEPC bubble and the updated PJM Southwest bubble. After aligning the top three days with the NYCA load forecast, the new PJM load shapes were tested to evaluate their possible impact on the 2016 IRM Study final base case. The test consisted of applying the new PJM load shapes to both the PJM four-bubble and five-bubble model.

3.1 Test on the PJM four-bubble model

In order to know if the two PJM hourly load shapes for the new DOMVEPC and updated PJM Southwest bubbles, when combined together, would have the same behavior as the original PJM Southwest load shape used in the four-bubble model (see Fig. 1a) of the 2016 IRM Study final base case, the first step was to test the PJM four-bubble model using the new load shapes.

The hourly data of the new separate load shapes for the DOMVEPC bubble and the updated PJM Southwest bubble were added to form a merged load shape. This merged load shape was then used to replace the original PJM Southwest bubble load shape of the 2016 IRM Study final base case. Next, the 2016 IRM Study final base case was rerun with this merged load shape under the same PJM LOLE level of 0.14 days/year. Had NYCA LOLE changes been observed, a sensitivity case would have been run to return NYCA LOLE to the criterion of 0.1 days/year so as to evaluate the impact on the 2016 IRM Study final base case result.

The test results, contained in Table 1, show that the merged load shape functions slightly different from the original PJM Southwest bubble load shape. If used in the 2016 IRM Study final base case, the merged load shape would cause NYCA LOLE to decrease by 0.002 days/year. Corresponding to this small change in the NYCA LOLE,

the IRM value would be slightly reduced from 17.4% to 17.3%. The LCR values of Load Zones J and K would also be reduced by no more than 0.1%.

Table 1
Test results on the PJM four-bubble model

Simulation Case	IRM (%)	LCR_J (%)	LCR_K (%)
2016 IRM Study final base case	17.4	80.8	102.4
PJM four-bubble model with new load shapes	17.3	80.7	102.3

3.2 Test on the PJM five-bubble model

In order to understand whether the PJM five-bubble model could impact the IRM Study results, the two separate PJM load shapes were applied to the PJM RTO representation with the five-bubble topology.

The starting point of this test was still the 2016 IRM Study final base case with NYCA LOLE of 0.1 days/year and the PJM LOLE at 0.14 days/year. The PJM RTO topology was then changed from the present four-bubble model to the five-bubble representation as shown in Fig. 1. All the generation resources in the original PJM Southwest bubble were separated out and modeled in their corresponding bubbles of the PJM five-bubble topology. This was done in the exact manner as it was performed in 2015 for the IRM sensitivity case. Next, the new separate PJM load shapes were applied to the new DOMVEPC bubble and the updated PJM Southwest bubble, respectively. In addition, the peak loads of these two bubbles were scaled according to the ratio of their corresponding PJM zonal peak load forecast so as to keep the PJM LOLE at 0.14 days/year to maintain consistency with the 2016 IRM Study final base case.[1]

Because it was demonstrated that the additional 1,500 MW transfer capability within PJM five-bubble model had no impact on the 2016 IRM Study final base case results, the possible NYCA LOLE and IRM changes, if any, observed in this test case would be solely attributed to the use of the new separate PJM load shapes. Had NYCA LOLE changes been observed, a sensitivity case would have been run to return NYCA LOLE to the criterion of 0.1 days/year so as to evaluate the impact on the resulting IRM.

[1] The application of Policy 5-9 to these cases results in maintaining the PJM LOLE at 0.14 days/year.

The test results, as shown in Table 2, are identical to those in Table 1. This means that any potential change in the IRM from the 2016 IRM Study final base case results in adopting the new load shapes for the DOMVEPC bubble and the updated PJM Southwest bubble—regardless of whether the load shapes are separate for the five-bubble model or merged for the four-bubble model. It also confirms the NYISO's previous findings from the 2015 investigation that the topology change from four bubbles to five bubbles alone within the PJM RTO system had no appreciable impact on the 2016 IRM Study final base case results.

Table 2

Test results on the PJM five-bubble model

Simulation Case	IRM (%)	LCR_J (%)	LCR_K (%)
2016 IRM Study final base case	17.4	80.8	102.4
PJM five-bubble model with new load shapes	17.3	80.7	102.3

3.3 Comparison of emergency assistance between PJM and NYCA

To further evaluate the use of the PJM RTO system five-bubble model, the NYISO simulated results for emergency assistance between PJM and NYCA at critical hours of NYCA loss of load events using the new PJM load shapes. The results, contained in Table 3, show that the expected values of maximum emergency assistance from PJM to NYCA upstate zones (Zones A and C) and from PJM to NYCA Southeast New York zones (Zones G through K) in the four-bubble and five-bubble model tests both increased by a few MW from the 2016 IRM Study final base case. Notably, such increases are the same for both the four-bubble and five bubble models. In addition, the expected values of maximum emergency assistance from NYCA upstate zones (Zones A and C) to PJM are the same for all three cases.

The aforementioned observations indicate that the use of the new PJM load shapes may slightly increase the level of emergency assistance from PJM to NYCA zones. However, the increased emergency assistance is the same whether modeling PJM system as either a four-bubble one with the new PJM load shapes merged or a five-bubble system with the new PJM load shapes kept separate. This evidence actually explains why the two tests with the new PJM load shapes showed a small reduction of IRM and LCR values on the 2016 IRM Study final base case, while there was no appreciable impact when the PJM system representation was changed from four-bubble model to five-bubble model.

Table 3

Expected values of maximum emergency assistance between PJM and NYCA

Simulation Case	IRM (%)	PJM→A&C (MW)	A&C→PJM (MW)	PJM→SENY (MW)
2016 IRM Study final base case	17.4	368	851	1284
PJM four-bubble model with new load shapes	17.3	370	851	1292
PJM five-bubble model with new load shapes	17.3	370	851	1292

4. Conclusion and Recommendation

The NYSRC is considering the impact of transitioning the PJM RTO system from a four-bubble to a five-bubble representation for the IRM study. The NYISO tested this model change using the 2016 IRM Study final base case in order to evaluate the potential impacts. The NYISO found that (1) the additional 1,500 MW transfer capability within the PJM five-bubble model had no impact on the 2016 IRM Study final base case results, and (2) the new PJM load shapes for the PJM Southwest bubble and the DOMVEPC bubble had a minor impact on the 2016 IRM Study final base case results.

Based on the test results, it is concluded that employing a five-bubble model of the PJM RTO system, under the guidance of NYSRC Policy 5-9, has limited impact on the IRM study results for the 2016 IRM Study final base case when compared to the current four-bubble model. In addition, PJM has confirmed that the revised five-bubble model is more accurate representation of the PJM RTO system and that only this five-bubble model data will be provided to the Northeast Power Coordinating Council Inc. (NPCC) and NYISO for purposes of future data exchange. Given the NYISO's test results set forth above, as well as the NPCC's acceptance of the PJM model transition in 2015, the NYISO recommends acceptance of transitioning from the current four-bubble model to the revised five-bubble model for the PJM RTO system representation in the 2017 IRM Study.