Modeling Multiple Load Shapes in Resource Adequacy Studies

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I. Objective

The objective of this report is to document the results of our efforts in utilizing a new feature in MARs that allows the use of multiple load shapes. Part of this effort was to establish criteria for choosing the appropriate load shape to include in each of the seven Load Forecast Uncertainty (LFU) bins.

Then, after choosing the appropriate load shapes, efforts were needed to incorporate the historic demand response into the external control area load shapes and to align them to the NYISO top three peak days

II. Background

In IRM studies to date, hourly load modeling was restricted to a shape based on a single year. NYSIO attempted to use a year based on the hourly averages of several years, but this was ultimately rejected. Average load shapes did not capture the impact of heat waves on the system[1]. If the average load shape had five days within 90% of the peak, what would happen in a year where there were considerably more days near the peak? For example, the year 2002 had 13 days where the daily peak load was within 90% of the system peak. Using the five day case would result in an under built system and an artificially low IRM, unable to withstand a 2002 type year. To avoid this, average load shapes were no longer considered, and the analysis turned to using a single historic load shape year.

The single load shape year however raised concerns that it might be too conservative. The LFU modeling accounts for weather conditions above and below the expected or design weather conditions by increasing the peak load forecast based on multipliers which are derived from how the power system responds to varying temperature and humidity conditions. Each of the LFU bins has a probability assigned to it such that the weighted average of each of the bin peak loads summed to the expected or design peak load forecast. These probabilities are actually applied to the LOLE calculated for each LFU bin to calculate an overall LOLE. For the upper LFU bin or extreme weather conditions, the much higher peak load in conjunction with a load shape which had an above average number of days near the peak would compound the load forecast uncertainty and result in

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[1] The reference to heat waves is indirectly related to the number of days where the system peak is within 90% of its actual peak.

what was thought to be by some an overly conservative model. The new modeling feature offers the ability to select appropriate load shapes for each LFU bin. This functionality allows for the selection of load shape year for each LFU bin which more closely aligns with what might be expected. In this way, the concern of the compounding of uncertainty can be mitigated and a model that appears to be overly conservative avoided.

III. Assigning Load Shapes to LFU Bins

The MARS model for calculating LOLE has the capability to probabilistically evaluate the impact of loads that exceed forecast or are less than forecast based on a load forecast uncertainty (LFU) distribution. The probability distribution presented in Table 1 is divided into seven uncertainty bins as a percent of the forecast with the following probabilities:

Table 1

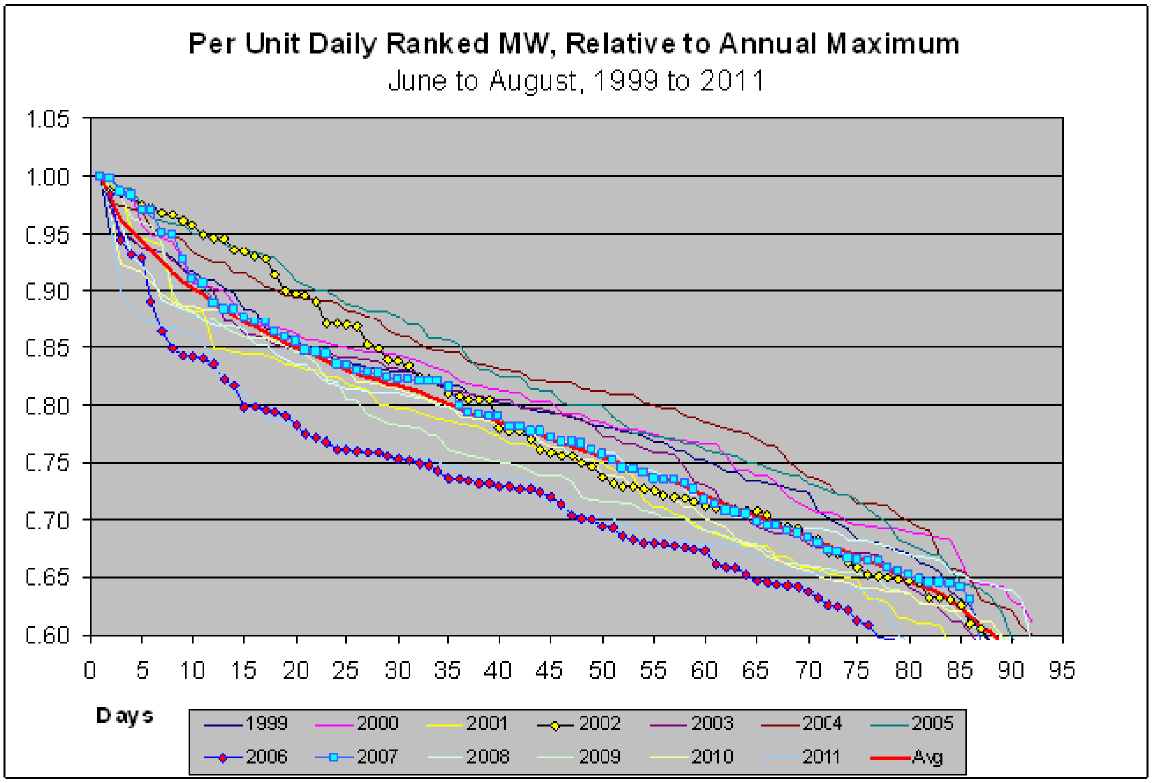
LFU Probability Distribution

Bin	Prob.	Cum Prob.	Bin Mid Point	Peak as % of the Design Day
1	0.0062	0.0062	0.0031	85.2%
2	0.0606	0.0668	0.0365	90.0%
3	0.2417	0.3085	0.1877	95.0%
4	0.3830	0.6915	0.5000	100.00%
5	0.2417	0.9332	0.8124	104.7%
6	0.0606	0.9938	0.9635	109.0%
7	0.0062	1.0000	0.9969	112. 5%
sum	1.0000			

Another key aspect of the impact of loads on reliability is the overall load shape. It is known that a flatter load shape will require a higher installed reserve margin than a more peaked load shape. For the flatter shape you have more hours or daily peaks occurring at higher load levels than for the more peaked shape. The result is more hours with higher potential for a loss-of-load (LOL) event in the flatter shape versus the more peaked shape. The relative shape of the load profile as a per unit of the peak is an important risk factor that needs to be considered in establishing an installed reserve margin.

Figure I presents a daily peak load duration curve as a per unit of the daily annual maximum peak load for the top 95 days of the year or less for the years 1999 to 2011. The curves with the higher per unit values would be considered a flatter load shape curve. The ones with lower per unit values would be considered a more peaked load shape curve from an LOLE perspective. However, it should be noted that these per unit values are based on the annual peak which could have been experienced at weather conditions that were considerably above or below the design conditions.

Figure 1
Multi-Year Load Duration Curve



Prior to the release of MARS version 3.15, the model only had the capability to input one load shape. As a result, historical data was analyzed and load shape which was flatter than the average shape was used to capture the impact of the risk exposure for the years that would have a higher number or duration of peak days closer to the peak than a year that was average. This turned out to be the year 2002. However, this engendered significant discussion as to whether the year chosen was too conservative or should an average year be used. As discussed earlier, there is a risk if the load shape that is included in the base case does not have enough hours at higher loads. An average load shape could not capture this risk. The new MARS version release 3.16 introduced the capability to utilize different load shapes in the LFU bins, potentially solving this problem.

In order to use this capability a process will need to be developed to identify and assign load shapes to the LFU bins. The process must rank historical load shapes by their relation to the design conditions and then further classify them by the number of times the shape stresses the system. A metric was developed that took annual peak and divided it by the weather adjusted peak for the year. In addition to the data for the years 1999 to 2011, data for 2012 is now available to analyze. This metric indicates whether an experienced peak was close to design, above design or below design conditions. This metric can be rank ordered and provides an indication of which LFU bin a particular year could be assigned to. Table 2 presents the results of that process which rank ordered from the lowest to highest per unit value.

Table 2

Rank Order of the Annual Peak as a Per Unit (PU) of the Design Peak

Lowest to Highest

Rank or Bin	Year	Annual Peak As a Per Unit of Design
1	2004	0.91
2	2009	0.94
3	2000	0.95
4	2007	0.97
5	2008	0.98
6	2003	0.99
7	2005	1.00
8	2012	1.00
9	1999	1.03
10	2002	1.03
11	2001	1.05
12	2010	1.06
13	2006	1.08
14	2011	1.08

The annual peaks as a per unit (PU) of the weather normalized peak or design peak range between 90% and 108% of the expected peak load. The observed data covers the range from LFU bin 2 to approximately LFU bin 6.

The next step was to develop a metric that relates to the number of times the system is stressed, or the relative "peakedness" of the load shapes that were observed in each of the bins. The SCR study indicated that from an LOLE perspective it was the top thirty peak days where the greatest potential for loss-of-load events existed. To measure the relative peakedness of the different years of load shapes a metric which measures the magnitude of daily peaks relative to the annual peak was developed. This metric divides the annual peak into the daily peak for the top thirty days to create a per unit (PU) measure of the daily peak relative to the annual peak. Creating a metric that is a PU of the annual peak is consistent with how the shapes are input into MARS. The thirty days of PU values are then averaged together. A higher thirty day average implies that a particular year had relatively more load days that were closer to the peak than a year with a lower average. This measure, however, does not recognize whether the year had weather conditions that exceeded or were below design conditions. Therefore, the thirty day averages were mapped into the rank or bins that were defined by taking the weather normalized peaks and dividing it into the annual peak for a given year. Table 3 presents the mapping of the thirty day PU average with the PU of the annual peak divided by the normalized peak for that year.

Table 3

PU Annual Peak Ranking and Associated Load Shape PU

Rank or Bin	Year	Annual Peak As a Per Unit of Design	Avg. of the Thirty Top Peak Days as PU of the Annual Peak	Cumulative Probability
1	2004	0.91	0.92	0.071
2	2009	0.94	0.87	0.143
3	2000	0.94	0.90	0.214
4	2007	0.97	0.89	0.286
5	2008	0.98	0.87	0.357
6	2003	0.99	0.88	0.429
7	2005	1.00	0.93	0.500
8	2012	1.00	0.90	0.571
9	1999	1.03	0.88	0.643
10	2002	1.03	0.92	0.714
11	2001	1.05	0.87	0.786
12	2010	1.06	0.87	0.857
13	2006	1.08	0.87	0.929
14	2011	1.08	0.83	1.000
Average		1.00	0.89	

The average for the annual peaks as a PU of the normalized peaks is 1.0 which is what would be expected. The average of thirty day PU is 0.89 which aligns with year 2007. However, year 2007 was 3% below design conditions. If we define those PU that are above the average of 0.89 as flatter load shapes and those that were below 0.89 as more peaked, we see that, out of 14 observations, 5 were above the average or could be characterized as flatter shapes while 8 were below the average or relatively more peaked shape. It appears the highest bins tend to be more peaked while the middle set of bins tend vary above and just below the average with the higher PU average occurring close to design or above. Below design conditions you have a mix of the flatter and more peaked shapes. The end result is, that as defined by the thirty highest PU average days, the flatter shapes and the more peaked shapes are distributed at, above and below design conditions except the more peaked shapes tend to dominate at the upper extremes but are also observed at below design conditions. The conclusion is that there is no straight forward or clear cut way to statistically assign shapes to the LFU bins. Overall, the correlation of the relative flatness of a curve year and its exposure to above or below design conditions is not clear except at the extremes. This makes it difficult to accurately assess the year shapes between the middle and the extreme bin. Over time and given the accumulation of more data, a statistical based method for assigning load year shape years to LFU bins could emerge.

Ideally, if there were sufficient observations and MARS was configured appropriately, the best approach would to calculate the probability of the occurrence of load shapes by LFU bins and weight the LOLE results for each shape within an LFU bin and then weight the LOLE results across the LFU bins. Unfortunately, there aren't sufficient observations to do this and MARS would need to be restructured accordingly. Therefore, the NYISO is proposing to use a combination of 2007 which was tested as a sensitivity in the 2013 IRM study to represent the average or typical shape, the 2002 to capture risk associated with a flatter load shape and the shape that has been used in IRM studies for the last several years and the 2006 shape to represent a more peaked or have a PU shape less than the average shape associated with extreme conditions. In addition, this keeps the number year shapes that have to be processed to a more manageable level.

IV. Results of Using Multiple Load Shapes

Table 4 presents the combination of load shapes that the NYISO is testing by LFU bin. These shapes are selected such that they capture the impact of the typical year shape, the risk of year shape were the occurrence of the number of peak load days as a per unit of the annual peak load is higher than the expected shape and a year shape were the occurrences of the number of peak load days as a per unit of the annual peak is less than the expected year. Year 2007 as the typical or base shape is being assigned to LFU bins 1 through 4. Year 2002 is assigned to bins 5 and 6 which gives it weight of approximate 30%. Load shape year 2006 was assigned to LFU bin 7 in order to account for the load shape at extreme conditions which would most likely be more peaked and below average based on the PU ranking.

Table 4
Load Shape Year by LFU Bin and Associated Probability

Bin	Prob.	Cum Prob.	Peak as % of the Design Day	Proposed Load Shape By LFU Bin
1	0.0062	0.0062	85.2%	2007
2	0.0606	0.0668	90.0%	2007
3	0.2417	0.3085	95.0%	2007
4	0.3830	0.6915	100.0%	2007
5	0.2417	0.9332	104.7%	2002
6	0.0606	0.9938	109.0%	2002
7	0.0062	1.0000	112. 5%	2006
sum	1.0000			

Because the load shapes of 2007 and 2006 when combined with 2002 in the aggregate represent a less conservative shape than 2002 by itself, it was observed that the LOLE's of the external areas as well NYCA had dropped below 0.100 days/year. Policy 5-7 specifies that external control areas whose LOLEs are below the 0.100 days/year criteria need to be adjusted back to at least 0.100. Table 5 below shows the LOLE results for the IRM base case, the initial multi-load shape case, and the final adjusted multi-load shape case. It should be noted such an adjustment for the external areas was not made for the sensitivity contained in the 2013 IRM study.

Table 5
Multiple Load Shape LOLE Results

Control Area	IRM base case	Initial MLS* case	Final MLS* case
New York	0.100	0.065	0.100
PJM	0.424	0.291	0.306
New England	0.104	0.044	0.100
Ontario	0.104	0.033	0.100
Quebec	0.100	0.061	0.103

*Multiple Load Shape

Table 6 presents the LOLE results for the 2013 IRM study base case VS the final Multiple-Load Shape (MLS) case by load level or LFU bin with NYCA at 0.100 days/year LOLE.

Table 6
Load Level Risk for NYCA

LFU (Bin)	Base Case LOLE	MLS LOLE
1	0.0010	0.0000
2	0.0010	0.0010
3	0.0020	0.0010
4	0.0130	0.0010
5	0.0130	0.0120
6	0.6780	1.2520
7	5.6710	3.3410

Finally, the effect on the IRM can be estimated using the “sensitivity” method utilized by the ICS. Once the external control areas are at or above the 0.100 LOLE criteria, capacity can be removed from all zones within NYCA, until the NYCA LOLE returns to the 0.100 days/year criterion. Table 7 shows these margin results indicating that the IRM would drop on the order of 0.6 percentage points due to the use of the Multiple Load Shape modeling on the IRM base case.

Table 7
Multiple Load Shape Margin Results

Area	Base Case Margin	MLS Margin
NYCA	**17.1%**	**16.5%**
NYC	**83.7%**	**83.3%**
LI	**102.0%**	**101.5%**

V. Conclusion

The multiple load shape functionality contained in the MARS model has been found to be functioning properly and as designed. Although there was not a direct way to map load shapes into LFU bins on a statistical or probabilistic basis, the NYISO concluded that a good approach would be to use a combination of load shape years 2007, 2002 and 2006. Load shape year 2007 which had been tested as a sensitivity last year is selected to represent the average or typical load shape. Load shape year 2002, which has been the study load shape for the last several years, is selected to represent a flatter shape or a shape with a higher number of days of risk exposure than the typical. Load shape year 2006 to capture a more peaked shape which would most likely be experienced at the extremes. The combination of these load shapes on a weighted basis represent a less conservative load shape than using 2002 by itself. In addition, the use of just three load shape years to adequately model the LOLE risk resulting from varying load shapes will be much easier to maintain and update because the number of different load shape years is kept to reasonable number.

The use of the multiple load shape approach resulted in a reduction in the IRM as discussed above by 0.6% when compared to the 2013 IRM base case. Also, the analysis shows that the majority of the risk resides in the LFU bins at the higher load levels. This isn’t surprising given that loss-of-load events are rare (extreme events) and this analysis is about adequately modeling the risk associated with those extreme events. These LOLE events are most likely to be observed when the system is most stressed which includes the higher loads or LFU bins. At an LOLE of 0.1 which was derived from a 1,000 years of simulations or 36,500 daily peaks one would expect only about 100 loss-of-load events on average.

VI. Recommendation

The NYISO is recommending that multiple load shape modeling be used for the upcoming IRM study using load shape years 2002, 2006 and 2007.