WECC

Western Assessment of Resource Adequacy Modeling Approach

January 24, 2025

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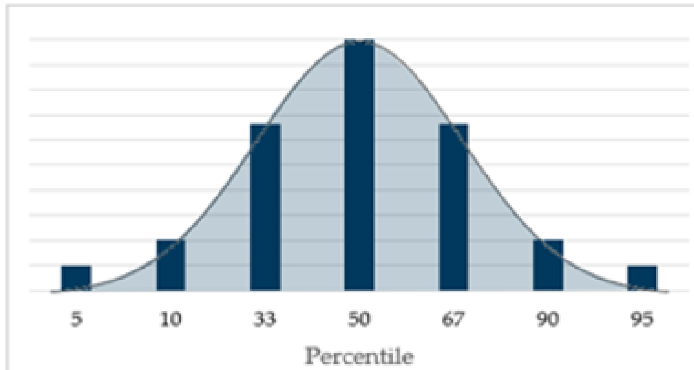
Modeling Methodology

To determine the demand at risk hours (DARH) in the Western Assessment of Resource Adequacy (Western Assessment), WECC uses the Multiple Area Variable Resource Integration Convolution model (MAVRIC). MAVRIC is WECC's internally developed modeling tool that performs energy-based probabilistic assessments by applying the convolution method. In addition to applying the convolution method, a subset of assumptions within the model are also derived via a Monte-Carlo Markov-Chain method (see Appendix B). For a primer on Monte Carlo simulations and convolution methods, please see NERC's Probabilistic Adequacy and Measures Report.

MAVRIC examines the probability that demand and resource availability will intersect at expected energy values given their probability distribution curves. Figure 1 is an example of a probability curve. The curve shows the probability of potential outcomes based on an expected value. For example, if an expected value falls at the 50th percentile, this value has a 1-in-2 chance of occurring. MAVRIC evaluates the probability curves of demand and resource availability together (Figure 2). The overlapping area of the demand and resource availability curves represent the potential for unserved load, or DARHs. The more the two curves overlap, the greater the potential for demand at risk. The goal is to keep the two curves far enough apart that overlap is kept below a certain threshold. For the Western Assessment, WECC has set this threshold to the one-day-in-ten-year (ODITY) level, meaning 99.98% of the demand for each hour is covered by available resources. Put another way, the area of overlap for the availability and demand curves is equal to no more than 0.02% for any given hour.



Probability	Percentile	Likelihood of Occurrence
1-in-20	5th	5%
1-in-10	10th	10%
1-in-3	33rd	33%
1-in-2	50th	50% (expected)
1-in-3	67th	33%
1-in-10	90th	10%
1-in-20	95th	5%

Figure 2: A conceptual normal probability curve with percentiles and likelihood of occurrence

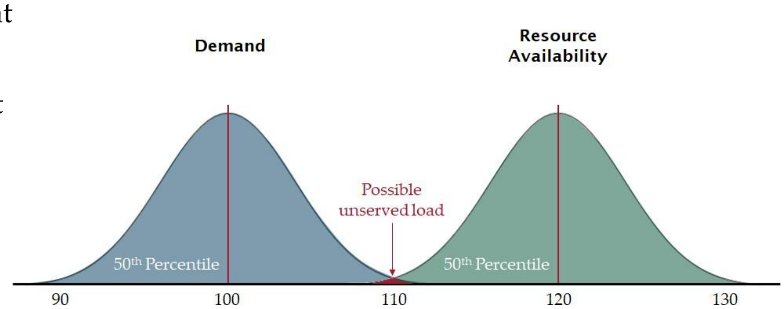


Figure 1: Evaluation of the supply side and demand probability curves for overlap which represents demand at risk

The potential for DARHs can increase or decrease when the demand or availability curves shift, expand, or contract. A shift in the position of a demand curve closer to the availability curve happens when demand uniformly increases without a corresponding increase in resource availability. When rare events occur more frequently, the demand probability curve changes shape and expands. When one or both curves change shape in this way, the overlap can increase, making it more likely that demand will exceed resource availability, as shown in Figure 3. For example, heat waves like those that occurred in the West in 2020 and 2021 were once rare events. The August 2020 Heat Wave was a 1-in-30 event. But, when evaluated considering climate change, it becomes a 1-in-20 event, widening the demand curve.

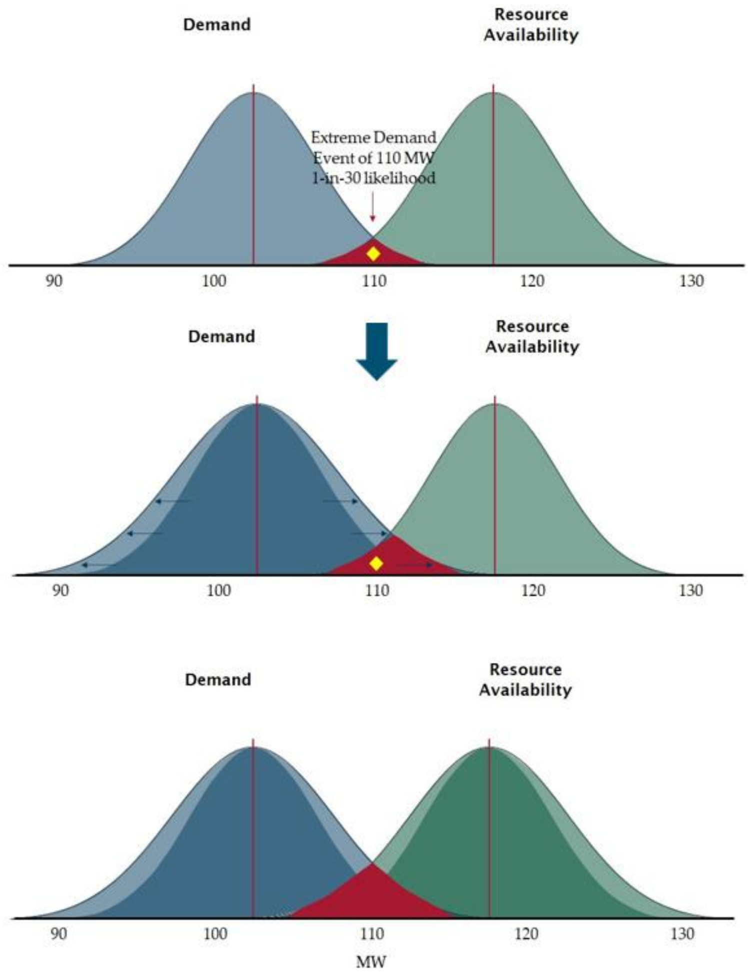


Figure 3: Demand and resource availability curves with increasing overlap due to increased frequency of extreme weather events

As additional variable energy resources (VER) are added to a portfolio, the resource availability curve expands like the demand curve expands when extreme events become more frequent. The variability in output of wind, solar, and hydro resources widens the potential range of expected values. Conversely, a decrease in unplanned outage frequency, or mean time to return from outages, would move the tails of the resource availability curve away from the demand curve. If resource availability decreases, the resource availability curve will shift closer to the demand curve, increasing overlap.

Calculating the Planning Reserve Margin

Assessing DARHs allows for the creation of planning reserve margins (PRM). Figure 4 shows a system with a 1-in-2 chance that demand is 100 MW and resource availability is 120 MW. A 20-MW—or 20%—PRM is needed to maintain 99.98% resource adequacy. This is based on the shapes of the demand and resource availability curves. If the availability curve shifts to the left, and only 115 MW of resources are available, the reserve margin has decreased to 15 MW. This amount of reserve margin will no longer maintain the ODITY threshold. Figure 5 shows the increased DARHs if the PRM does not increase to accommodate the change in distribution shape. To accommodate the change in distribution shape and maintain 99.98% resource adequacy, the PRM must increase. If the PRM is increased to 22 MW, the system returns to being 99.98% resource adequate, maintaining the ODITY threshold (Figure 6). Actual distributions for each subregion are in Appendix D.

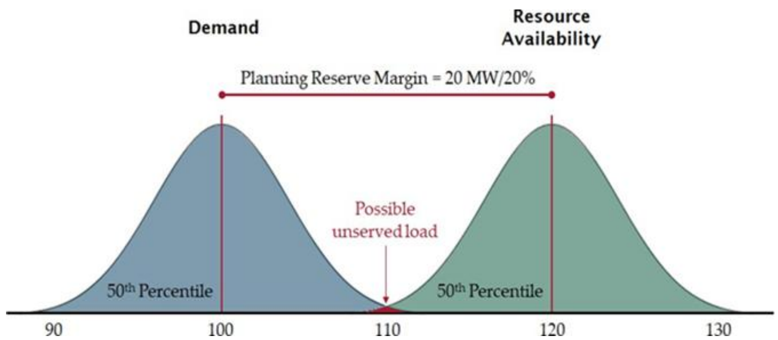


Figure 4: Conceptual system with 99.98% resource adequacy at a PRM of 20 MW

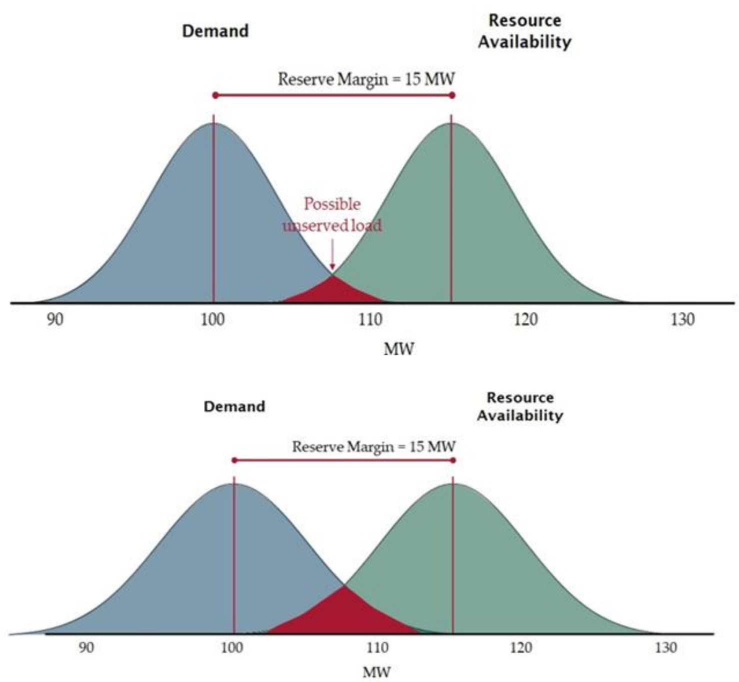


Figure 5: Demonstrates the increased demand at risk if the distributions expand or shift

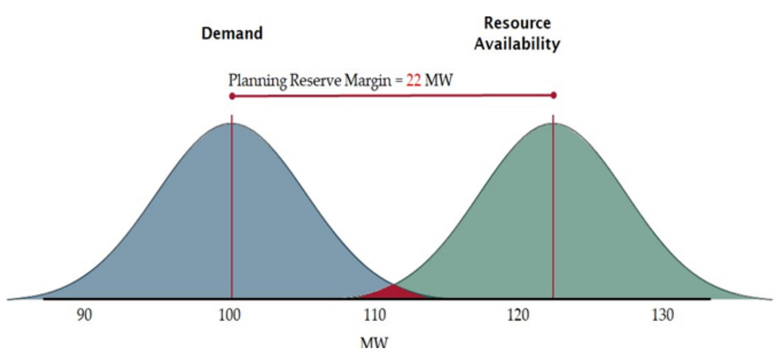


Figure 6: Shows the increased PRM required to maintain 99.98% resource adequacy with the wider distributions

Appendix B: MAVRIC Inputs, Assumptions, & Processes

The Western Interconnection has many transmission connections between demand and supply points, with energy transfers playing a significant role in reliable operations. On top of this, the Western Interconnection is geographically large and contains both winter-peaking and summer-peaking areas. To add to the complexity, there is a large amount of hydro capacity that experiences seasonal variability, and rapid adoption of solar and wind resources, which can vary hourly in output. WECC developed MAVRIC to handle these intricacies. MAVRIC can study all hours of the year, it can factor in dynamic imports from neighboring areas, and account for varying generation patterns dependent on geographical location and resource type. MAVRIC calculates resource adequacy through loss-of-load probabilities (LOLP). It calculates LOLPs on each of the stand-alone Balancing Authorities (BA) without transfers, then balances the system cohesively with transfers to a probabilistic LOLP (see Appendix A). This section will discuss the inputs, assumptions, and processes within MAVRIC required to perform this LOLP calculation. Figure 7 provides an overview of the MAVRIC process.

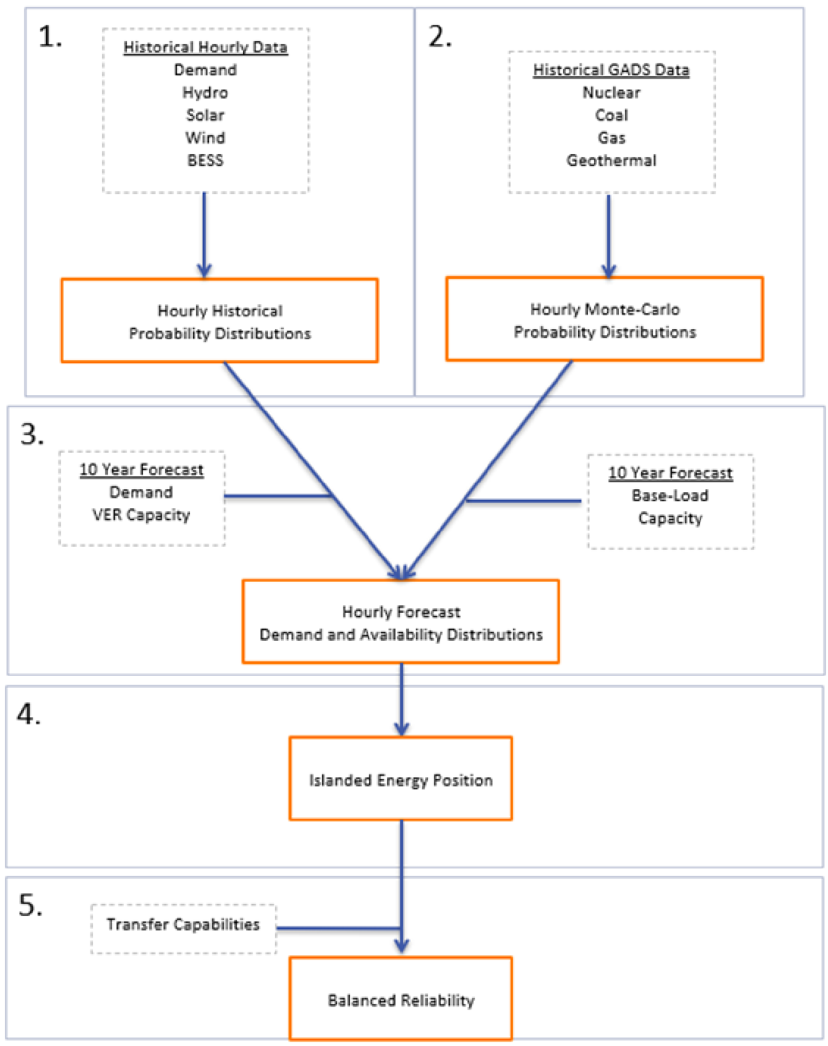


Figure 7: MAVRIC inputs and processes

In step one of Figure 7, hourly historical data for demand and energy output from hydro, solar, wind, and battery energy storage system (BESS) resources are collected in WECC's annual Loads and Resources (L&R) Data Request. To develop hourly probability distributions for demand, hourly demand from previous years must be aligned. The first Sundays of each historical year are aligned so that weekends and weekdays are consistent. Each hour is then compared against a rolling seven-week average for the same hour of the same weekday. This establishes the difference between the historical hour and the average. MAVRIC uses each of these percentages to calculate a percentile probability for a given hour based on the variability of three weeks before and three weeks after the given hour for each historical year. The output of this step is a series of hourly percentile profiles with different probabilities of occurring. Figure 8 represents a demand probability distribution for a single hour. The peak is the expected deterministic forecast and is set at 100%. The profiles to the right of the peak are greater than 100% and those to the left are lower than 100%.

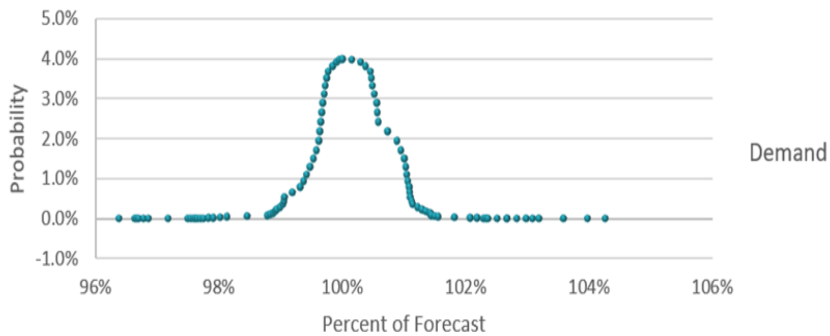


Figure 8: Example of a single hour's demand profile

The availability probability distributions for the VERs, which includes hydro, wind, and solar resources, is derived in a similar manner to that of the demand calculations but with two notable differences. The primary difference is the period used in calculating the VER availability distributions. For VERs, the day of the week does not influence variability, as weather is always variable. Therefore, the need to use data from the same day of the week is not necessary. This allows the VER distributions to be condensed to a rolling seven-day window using the same hour for each of the seven days. The second difference is that the historical generation data is compared against the nameplate capacity to determine the historical capacity factor for that hour, which is then used in the percentile probability calculation. Using nameplate in the denominator allows for the incorporation of unit outages due to non-fuel-related issues. The output of this process is a series of hourly percentile profiles with different probabilities of occurring. A random hour profile for each of the VER types is shown in Figure 9. Wind and hydro run-of-river units are positively skewed, whereas solar and hydro storage units are negatively skewed, meaning their distributions "lean" to the left and right, respectively. The highest point of the distribution indicates the most frequently anticipated capacity factor from the resource for a given hour. For instance, the hour represented in Figure 9 for wind tends to perform at the lower end of the capacity factor spectrum, whereas solar frequently performs at capacity factors above 90%. Hybrid resources such as solar with BESS or wind with BESS, are treated as VERs. MAVRIC does not account for the BESS properties of these resources.

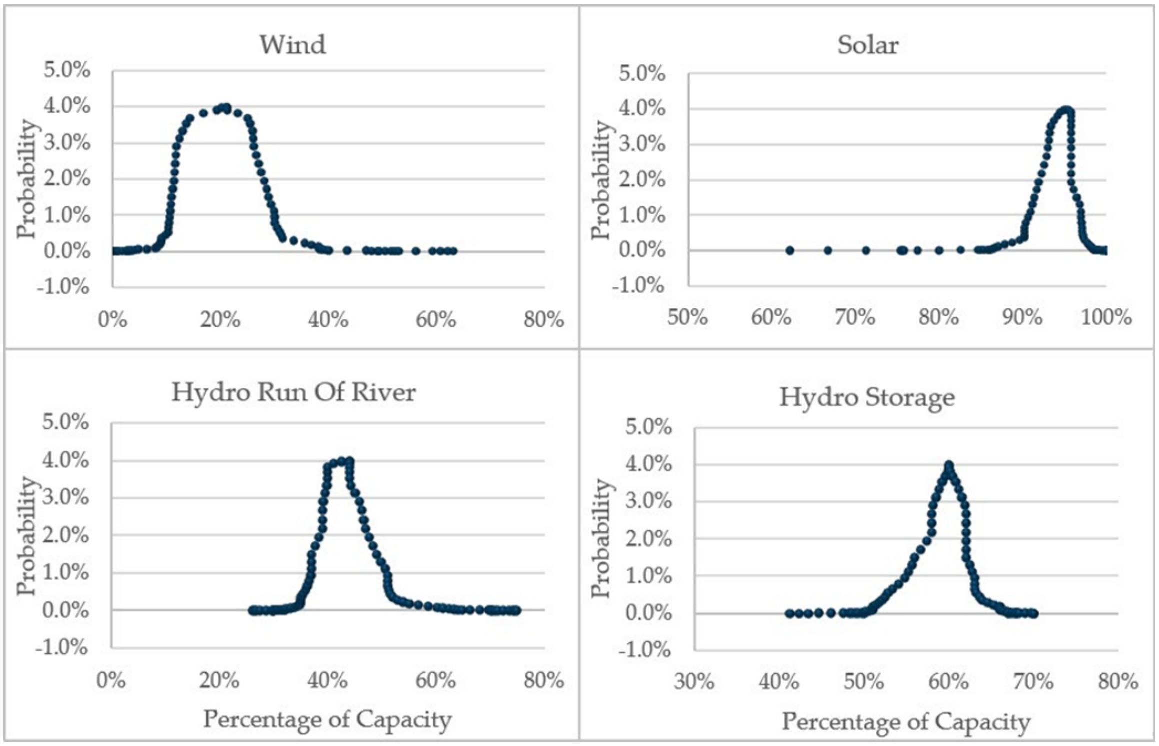


Figure 9: Examples of hourly profiles for each of the VER resource types

Hydro facilities with storage capability are highly correlated with demand. The ability to store the fuel leads to different operating characteristics between weekdays and weekends. Therefore, the availability distributions for hydro facilities with storage are calculated in the same manner as the demand distribution.

For the purposes of baseload resources, MAVRIC uses a Monte-Carlo Markov-Chain method (Step 2 in Figure 7). The distributions of nuclear, coal-fired, gas-fired, biofuel and geothermal resources, are determined by using the historical rate of unexpected failure and the time to return to service from NERC's Generation Availability Data System (GADS). The annual frequency of unexpected outages and recovery time from these outages is used to calculate the availability probability distributions for baseload resources. Based on this data, a random value is calculated for the first hour of the year for each of the units within a BA. If that random value falls below the frequency calculation to be available, the model will force the unit offline. Conversely, if the random value does not fall below the availability frequency calculation, the unit is deemed as available. Available resources are capable for their maximum winter or summer capacity rating, depending on the season. Once the status of each resource is determined, the next hour is then processed. If the resource was determined unavailable in the previous hour, the model will keep the resource unavailable until the average duration of the historical unplanned outages is reached. If the unit was determined as available the previous hour, the random variable for the next hour is checked against the forced outage frequency calculation and the process repeats. Through this random sampling method, MAVRIC performs 1,000 iterations for each resource for each hour. After 1,000 iterations, the data points of availability for each hour are used to generate availability probability distributions. Figure 10 demonstrates a baseload availability distribution. It is consistent with the VER distributions, in that a series of expected values for capacity factors are produced for each hour. BESS resources are treated in the same manner as baseload generators. Their full capacity is available to be discharged when the resource is not in outage. MAVRIC does not account for the charging behavior of batteries.

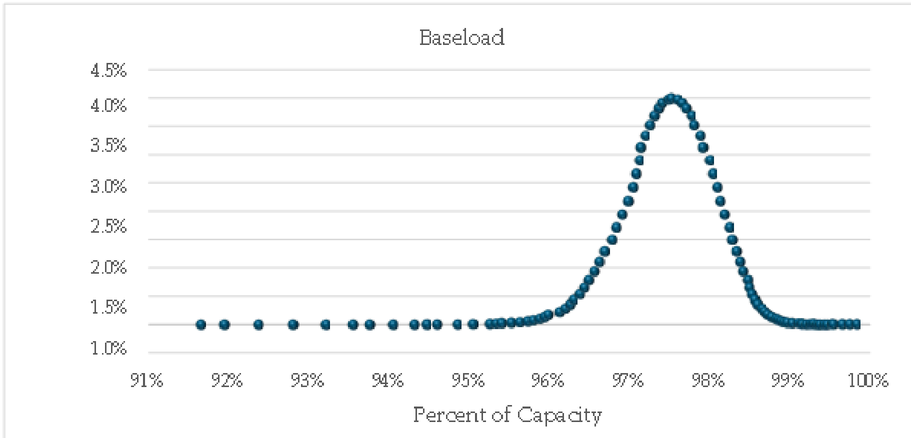


Figure 10: Example hourly probability distribution for thermal resources

In Step 3 of Figure 7, MAVRIC combines the 10-year demand forecast and resource availability to represent the hourly forecast demand and availability distributions. The 50th percentile of the demand distributions is set equal to 100% (as displayed in Figure 8), with the low and high side variability represented by the percentiles to the left and right, respectively. The hourly demand forecast in megawatts is multiplied by each of the percentiles of the probability distribution, creating a distribution of hourly megawatt forecasts. For availability, each of the probability distributions represent capacity factors. Therefore, by taking an expected capacity of each of the different types of resources and multiplying it by each of the hourly profiles, a distribution of hourly megawatt forecasts is derived.

Step 4 represents the comparison of the hourly demand distributions with the hourly availability distributions. For each hour, the distributions are compared to one another to determine the amount of overlap in the upper tail of the demand distribution with the lower tail of the availability distribution. The amount of overlap represents the LOLP. If the probability for a given hour is greater than a selected threshold (such as the ODITY threshold discussed in Appendix A), then that hour is a DARH.

If DARHs are identified in in Step 4, MAVRIC analyzes potential transfers to mitigate them. This is Step 5 in Figure 7. MAVRIC undergoes a step-by-step balancing logic in which excess energy, which is energy above an area's PRM, can be used to satisfy another area's resource adequacy shortfall. This depends on neighboring areas having excess energy and available transfer capability to allow the excess energy to flow. MAVRIC only allows for first and second order transfers to occur. Transfer capabilities are a deterministic input into MAVRIC, and they vary based on the direction of flow (see Appendix C). MAVRIC considers first-order transfers (external assistance from an immediate neighbor) and second-order transfers (external assistance from a neighboring entity's immediate neighbors). After balancing all areas in the system for a given hour, MAVRIC then moves to the next hour and balances the system as needed. The result is an analysis of the Western Interconnection that reflects the ability of all defined areas or subregions to maintain a PRM equal to, or less than, the ODITY threshold.

Appendix C: MAVRIC Topology

Transfer capabilities are a deterministic input into MAVRIC, and they vary based on the direction of flow and season. MAVRIC topology uses a zonal approach, considering the transfer capability between regions but not accounting for nodal congestion. The transfer capabilities within MAVRIC are provided by BAs and Transmission Operators (TO) and resemble expectations during system peaking conditions. The transmission topology in MAVRIC is shown in Figures 11 and 12 for the summer and winter seasons, respectively.

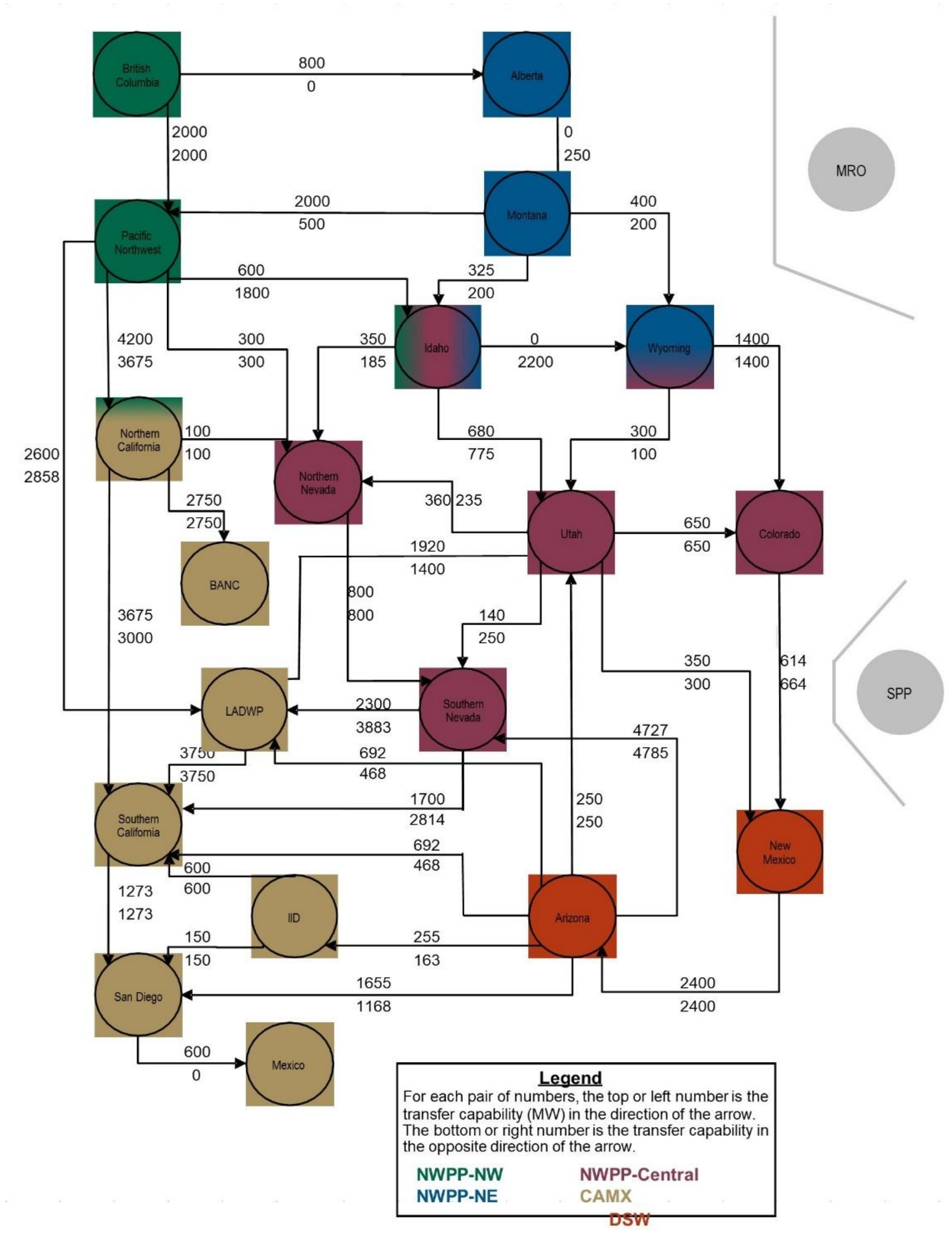


Figure 11: Summer topology in MAVRIC

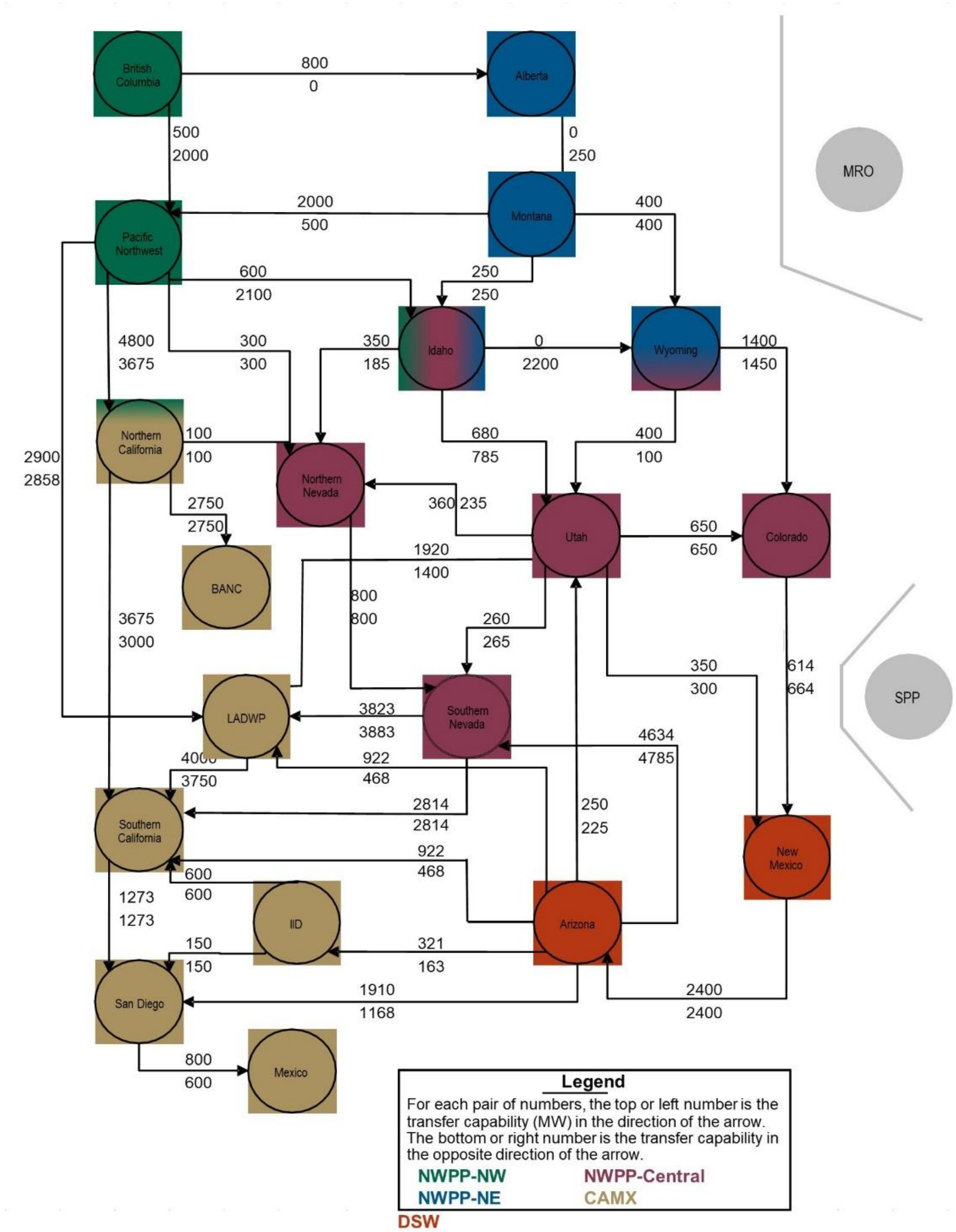


Figure 12: Winter topology in MAVRIC