First Draft Methodology Highlights of PJM Effective Load Carrying Capability Model

July, 2020

ELCC Methodology Highlights

Dispatch - General Considerations

The dispatch of the limited resources in the ELCC model is largely based on the principle that the more available resources are dispatched before the less available resources. Exceptions to this principle are Demand Response (i.e., Load Management), which PJM will dispatch last, and intermittent resources, which cannot be dispatched (apart from curtailment). The reason for following the “more available first” principle is that it intuitively makes sense to first use resources that can run for more hours and then address any remaining potential unserved load with resources that can run for a more limited amount of hours.

The dispatch order resulting from following the above principle, taking into consideration the noted exceptions, is as follows:

1. Intermittent (Wind, Solar, Run-of-River Hydro without Storage, Intermittent Landfill Gas)
2. Thermals
3. Hybrids - Solar with 10-hour Energy Storage Resources (open-loop)
4. Hybrids - Solar with 10-hour Energy Storage Resources (closed-loop)
5. 10-hour Energy Storage Resources
6. 8-hour Energy Storage Resource (including existing pumped hydroelectric storage fleet)
7. Hydro with Water Storage
8. Solar with 6-hour Energy Storage Resources (open-loop)
9. Solar with 6-hour Energy Storage Resources (closed-loop)
10. 6-hour Energy Storage Resources
11. Demand Response

Dispatch - Specific Considerations

Thermal Resources

Thermal resources are dispatched as long as they are not on a forced or planned outage

Intermittent Resources

The development of the output profile for intermittent resources entails producing an Hourly Output Shape (HOS) based on the historical weather years used in the construction of the Hourly Load Shapes (HLS). The HOS for a class of intermittent resources (e.g., wind) comprises actual (and sometimes putative) output from existing members of the class and putative output from planned members of the class.

If there are N HLS based on N historical weather years, then there will be N HOS for each class of intermittent resources. The derivation of HOS for a historical weather year H is described as follows:

- Calculate hourly actual metered output in MW and hourly actual Maximum Facility Output (MFO) in MW from all units that were classified as existing in year H
- Calculate hourly total putative output in MW and hourly putative Maximum Facility Output (MFO) in MW from all units that were classified as planned in year H.
- Calculate the hourly total output in MW (by including actual and putative outputs) and hourly total MFO (by also including actual and putative outputs).
- For each hour, divide the hourly total output by the hourly total MFO. The result constitutes the Hourly Output Shape (HOS) for historical weather year H.

The hourly output of the renewable class during an ELCC target year T depends on the HOS based on each historical weather year and the forecasted penetration level of the class for year T, Pt.

If there are 7 historical weather years, then there are 7 HOS. The hourly dispatch for the renewable class for target year T based on each of the historical weather years is as follows:

Historical Weather Year 1 → Hourly Output Year 1 = HOS1 x Pt

Historical Weather Year 2 → Hourly Output Year 2 = HOS2 x Pt

…

Historical Weather Year 7 → Hourly Output Year 7 = HOS7 x Pt

The underlying assumption for determining the output of Intermittent Resources in this manner is that the output of renewables under future penetration levels and weather conditions will be similar to that identified in the “history” comprising the combination of actual output of existing units and the putative (i.e., backcasted) output of planned units.

10-Hour Energy Storage Resources, 8-Hour Energy Storage Resources, 6-Hour Energy Storage Resources
The dispatch of Energy Storage Resources (including Pumped Storage) follows the following **daily** two-step procedure.

Part 1

- Calculate the hourly margin between load and available capacity prior to the dispatch of the resource (for example, if the dispatch is being calculated for 10-hour Energy Storage Resources, the available capacity will be determined by the sum of thermal resources, intermittent resources and solar hybrids with 10-hour Energy Storage Resources). In the summer period, analyze the 24 hourly margins in one block; in other seasons, split the hourly margins in two blocks of 12 hours each.

- In each block, identify the hours in which the resources will be dispatched at their maximum hourly output (for example, if there are 10,000 MWh of 10-hour Energy Storage Resources, identify the hours that have a margin greater than or equal to 1,000 MW).
- Calculate the Adjustment Factor for each block as the number of hours in which the resources need to be dispatched at their maximum hourly output divided by number of hours that the resources can be at their maximum hourly output. If the result is less than 1, the Adjustment Factor is set to 1. For instance, in the case of 10-hour Energy Storage Resources, if the number of hours in which the resources need to be dispatched at the maximum output is 11, then the adjustment factor will be 11/10 = 1.1; on the other hand, if the number of hours in which the resources need to be dispatched at the maximum output is 9, then the adjustment factor is 1.0)
- Divide the maximum hourly output by the Adjustment Factor (for example, if there are 10,000 MWh of 10-hour Energy Storage Resources and the Adjustment Factor is 1.1 then the division is 1,000 MW / 1.1 = 909 MW). The result constitutes the Adjusted Maximum Hourly Output for each hour during a block.

The objective of the Adjusted Maximum Hourly Output is to capture the fact that the resources will attempt to output power during all the hours in a day that are likely to pose a reliability risk.

Part 2

Initialize the state of charge at 0. Then, for each hour of a day in a sequential (chronological) manner

- Determine the needed charge. If the hourly margin between load and available resource is positive (i.e. load is greater than available resources), charging cannot occur. If the hourly margin is negative, the hourly amount of charge is constrained by the hourly margin or the Maximum Hourly Charging Limit, whichever is lowest. After charging, update the state of charge.
- If the hourly margin between load and available resource is positive (i.e. load is greater than available resources), attempt to discharge. The amount of discharge is constrained by the hourly margin, the available MWh in the battery or the Adjusted Maximum Hourly Output, whichever is lowest. After discharging, update the state of charge.

The two-step procedure assumes imperfect foresight. On one hand, it assumes that resources can estimate the amount of hours in a day that they will have to run at maximum output. Such number of hours is then used to restrict (if needed) their hourly maximum output (via the Adjusted Maximum Hourly Output) so that they can potentially produce output during all the hours. On the other hand, the procedure does not assume which specific hours are the ones in which the resources will be needed to be producing at their maximum output.

Hybrids - Solar with 10-hour Energy Storage Resources (open-loop)

The dispatch for hybrids is a daily two-step procedure where the MFO Adjusted Maximum Hourly Output for the battery portion of the hybrid resource is calculated using a methodology similar to the one described in Part 1 of the procedure to dispatch Energy Storage Resources.

Part 1

- Calculate the Adjusted Maximum Hourly Output following the 4 steps in Part 1 of the procedure to dispatch Energy Storage Resources

- Determine the number of hours in which the Adjusted Maximum Hourly Output could not be fully delivered because of the MFO constraint as well as the total MWh that could not be delivered because of the MFO constraint
- Divide the total MWh from the previous step by the number of hours in which the resources need to be dispatched at their maximum hourly output minus the number of hours from the previous step.
- Add up the result from the previous step to the Adjusted Maximum Hourly Output. The result is the MFO Adjusted Maximum Hourly Output.

The objective of the MFO Adjusted Maximum Hourly Output is to capture the fact that the resources will attempt to output power during all the hours in a day that are likely to pose a reliability risk and that any power that cannot be delivered during those hours because of an MFO constraint will be output during similar high risk hours.

Part 2

Initialize the state of charge of the battery at 0. Then, for each hour of a day in a sequential (chronological) manner

- Determine the needed charge. If the hourly margin between load and available resource is positive (i.e. load is greater than available resources), charging cannot occur. If the hourly margin is negative, the hourly amount of charge is constrained by the hourly margin or the Maximum Hourly Charging Limit, whichever is lowest. After charging, update the state of charge. The output of the hybrid resource during a charging hour is the sum of the solar output and the amount of charge during the hour (additional load)
- If the hourly margin between load and available resource is positive (i.e. load is greater than available resources), attempt to discharge. The amount of discharge is constrained by the hourly margin, the available MWh in the battery, the Adjusted Maximum Hourly Output or the difference between the Maximum Output Facility of the Hybrid and the amount output by the solar portion, whichever is lowest. After discharging, update the state of charge. The output of the hybrid resource during a discharging hour is the sum of the solar output and the amount of battery discharged during the hour.
- If the hour is neither a discharging nor a charging hour, the output of the hybrid resource is equal to the output of the solar portion.

Hybrids - Solar with 10-hour Energy Storage Resources (closed-loop)

The dispatch for hybrid resources is a daily two-step procedure where the MFO Adjusted Maximum Hourly Output for the battery portion of the hybrid resource is calculated as described in Part 1 of the procedure to dispatch Hybrids - Solar with 10-hour Energy Storage Resources (open-loop).

Part 1

(see Part 1 of the procedure to dispatch Hybrids - Solar with 10-hour Energy Storage Resources (open-loop))

Part 2

Initialize the state of charge of the battery at 0. Then, for each hour of a day in a sequential (chronological) manner

- Determine the needed charge. If the hourly margin between load and available resource is positive (i.e. load is greater than available resources), charging cannot occur. If the hourly margin is negative, the hourly amount of charge is constrained by the solar output in the resource or the Maximum Hourly Charging Limit, whichever is lowest. After charging, update the state of charge. The output of the hybrid resource during a charging hour is the solar output that was not used for charging purposes.
- If the hourly margin between load and available resource is positive (i.e. load is greater than available resources), attempt to discharge. The amount of discharge is constrained by the hourly margin, the available MWh in the battery, the Adjusted Maximum Hourly Output or the difference between the Maximum Output Facility of the Hybrid and the amount output by the solar portion, whichever is lowest. After discharging, update the state of charge. The output of the hybrid resource during a discharging hour is the sum of the solar output and the amount of battery discharged during the hour.
- If the hour is neither a discharging nor a charging hour, the output of the hybrid resource is equal to the output of the solar portion.

Hydro with Water Storage (i.e. Pondage or Reservoir Storage)

Final dispatch methodology to be determined.

Demand Resources (i.e., Load Management)

It is assumed that all the Demand Resources are Firm Service Level (FSL) emergency resources. The forecasted deployment levels (Nominated MW) are as per the most recent PJM Load Forecast.

The procedure to dispatch DR is as follows:

For each hour of a day, in a sequential (chronological) manner,

- Determine the margin between load and available capacity prior to the dispatch of DR.
- If the margin is positive (i.e. load is greater than available resources) and the hour is within the DR availability window, dispatch DR. The amount of available DR is calculated as the Nominated MW value times a Load Adjustment Factor. The Load Adjustment Factor is calculated as the Hourly Simulated Load divided by the 50/50 Simulated Load. The Load Adjustment Factor is used in the estimation of available DR resources to capture the FSL nature of the performance of such resources. For instance, if the simulated load in a given hour is 6% above the 50/50 simulated load (e.g. 90/10 conditions) then the Load Adjustment Factor will be 1.06 and the amount of available DR in that hour will be the Nominated MW value times 1.06.