IMPACTS OF FERC ORDER 881 ON UTILITIES

TACOMA POWER'S PATH ON AMBIENT ADJUSTED RATING & FERC ORDER 881 COMPLIANCE

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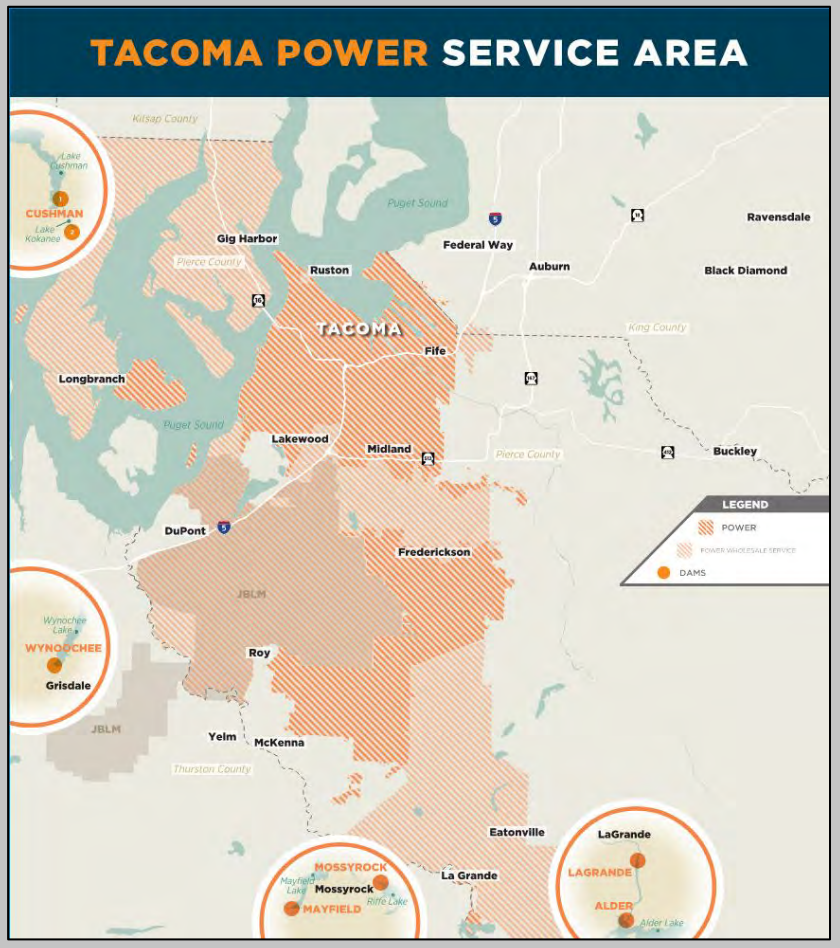
TACOMA POWER
TACOMA PUBLIC UTILITIES

ABOUT TACOMA POWER

- Tacoma Power is a publicly owned electrical utility serving the greater Tacoma area.
- Serve around 200,000 customers.
- Tacoma Power is a vertically integrated utility.
  - GO, GOP, TO, TOP, TP, DP, BA …
- Own and operate transmission system of 230kV and 115kV.
  - 308 miles of 115kV
  - 44 miles of 230kV



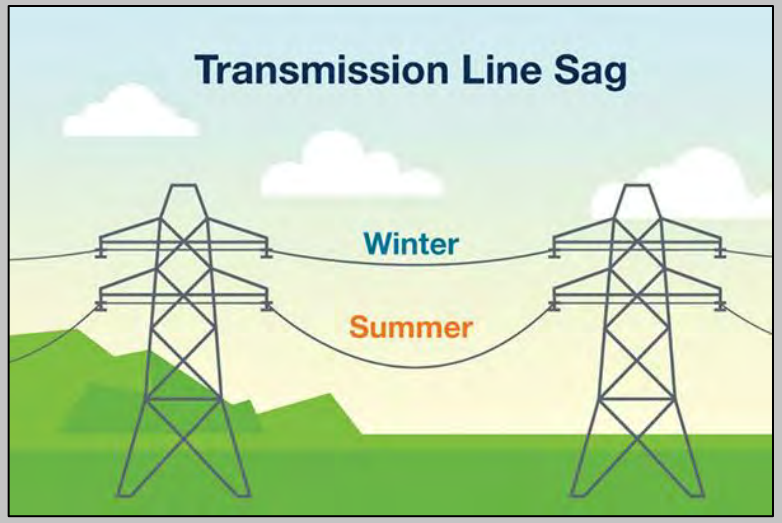
TRANSMISSION LINE RATINGS

What are they?

Transmission line ratings define the amount of electrical current a transmission line can safely carry under specific conditions without violating safety, reliability or equipment limits.

Why do we need them?

- **As conductor temperature increases, the conductor expands causing increased sag.**
- **If a conductor gets beyond a certain temperature, it could cause the conductor to sag beyond allowable clearances, ratings.**
- **There is a known temperature limit for the conductor.**
- **With some assumed external variables, the rating provides the amount of current that can flow before the allowable conductor temperature is exceeded.**



TRANSMISSION LINE RATINGS

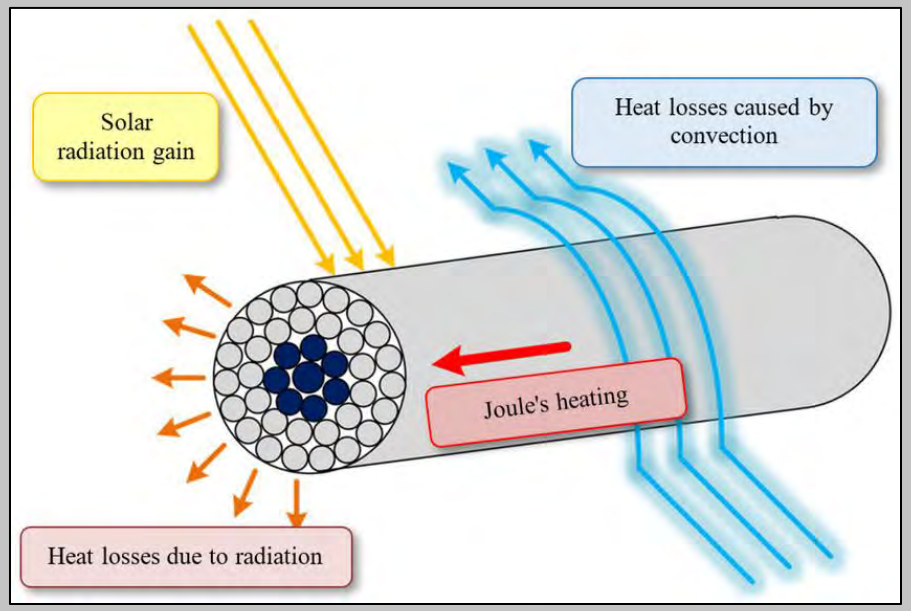
What factors play into a transmission line rating?

- Transmission line ratings are essentially a heat balance problem.
  - Heat in = Heat out, while at the maximum allowable conductor temperature.
- IEEE 738 – Calculating the Current-Temperature Relationship of Bare Overhead Conductors

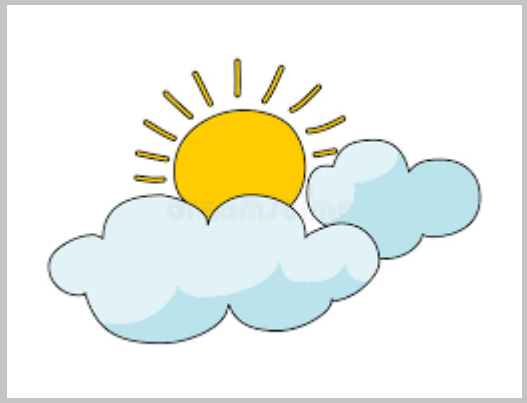
Components

- Solar Heat Gain (q_s)
- Convective Cooling (q_c)
- Radiative Cooling (q_r)
- Joule Heating (I^2R)

$$I = \sqrt{\frac{q_c + q_r - q_s}{R(T_{avg})}}$$



RATING PARAMETERS



Environmental Conditions

- Ambient Temperature
  - Higher Temperatures = Less Cooling
- Wind Speed & Direction
  - Higher wind speeds = More convective cooling
- Solar Radiation
  - Midday, Clear Sky = More Heating
    - Time of year, Time of day, Latitude, Elevation, Atmosphere Pollution

Conductor Properties

- Conductor Temperature
- Diameter
- Emissivity
  - How well it radiates heat.
- Absorptivity
  - How well it absorbs solar heat.
- Resistance
  - Heating is proportional to I^2R

All these parameters effect the ampacity calculation.

TYPES OF TRANSMISSION LINE RATINGS

Static

- Fixed rating used year-round.
- Often highly over conservative.
- Was the industry normal for most of history.

Seasonal

- Ratings change based on season.
- Different ambient temperature assumptions for each season.
- Had been widely used today by many utilities.

Ambient Adjusted Ratings (AAR)

- Ratings change in real-time based on measured ambient temperature.
- Ratings vary based on different ambient temperature windows.
- Adoption of AAR more becoming more prevalent. FERC 881 driven.

Dynamic Line Ratings (DLR)

- Ratings change in real-time based on measured ambient temperature and other components.
  - Wind Speed & Direction
  - Solar Radiation
- Still early in the industry but likely to become more prevalent.

HISTORY OF TACOMA POWER'S RATINGS

Static

- Used static facility ratings prior to 2007.

Seasonal

- Starting using seasonal ratings in 2007.
  - Different ambient temperature assumptions for Spring, Summer, Fall, Winter.
  - All other assumptions remained static.

Ambient Adjusted Ratings

- In 2017, Tacoma Power implemented a version of Ambient Adjusted Ratings.
- Tracking towards a full FERC 881 compliance in 2026.

Dynamic Line Ratings

- Tacoma Power is currently sponsoring a UW Seattle Capstone project to assess the feasibility of using DLR technologies.

TACOMA POWER AAR'S

Ambient Adjusted Ratings

- Tacoma Power uses seven different normal and emergency ratings based on ambient temperature.
- These ratings range from 0°C - 30°C (32°F - 86°F) in 5°C increments.
- All other variables are static.

Methodology

- Our line engineering department provides the allowable operating temperature for a line segment.
  - LiDAR data used to determine operating temp.
- The allowable ampacity for the given operating temperature is determined for a conductor at each ambient temperature window.
  - **Calculated per our Facility Rating Methodology.**

FACILITY RATING METHODOLOGY

Transmission conductor ratings are established based on IEEE 738 with the following assumptions.

Parameter	*Assumption*	
	Normal	*Emergency*
Duration	continuous	≤30 minutes
Conductor Surface Temperature	*	*
Ambient Temperature	**	**
Wind Speed	2 ft/sec	3 ft/sec
Wind Angle (90 degrees = perpendicular)	90 degrees	90 degrees
Emissivity of Conductor	0.5	0.5
Absorptivity of Conductor	0.5	0.5
Solar Heating (on or off)	On	On
AC Resistance@25˚C	***	***
AC Resistance@75˚C	***	***
Elevation	200 ft	200 ft
Time of Day	11:00 AM	11:00 AM
Solar Day	June 10	June 10
Latitude (Degrees - North positive)	47	47
Azimuth of Conductor (N-S=0, E-W=90 degrees)	90	90
Type of Atmosphere (clear or industrial)	Clear	Clear
Pre-loading condition (initial current, I_i)	N/A	60% normal rating

* Conductor Surface Temperature is specific to each individual line

** Ambient Temperature Assumptions are: 0˚C for Winter, 20˚C for Fall/Spring, and 30˚C for Summer. When needed, the actual ambient temperature can be considered to determine the conductor ratings.

*** Resistance is specific to each individual conductor

Takeaways

- Some assumptions considered conservative in nature.
- Lack of system constraints did not warrant additional review of assumptions.

AAR IMPLEMENTATION

How we calculate:

- Conductor type, operating temperature and rating assumptions are manually input into a program to determine the continuous and emergency ratings.
  - 14 conductor types, 3 operating temperatures and a handful of one-offs.
  - Roughly a 1000 manually calculated ratings… Do it once and done though! (Also done before my time)
- Ratings housed in an excel spreadsheet. This spreadsheet then determines the most limiting element for a defined Facility.
  - Transmission Line Section, Line Switch, Substation Bus, Substation Equipment.

How we use:

Real-time

- Temperature sensor at two of our substations.
  - Primary and Backup
- SCADA readings from sensor point back to a lookup table in EMS to determine which rating is in use.

Next Day Study

- Ratings based on forecasted ambient temperature used in next-day studies.

FERC ORDER 881

Managing Transmission Line Ratings

- Goal is to enhance the efficiency of transmission service and improve transparency of transmission line ratings.
- The order requires transmission providers to implement ambient adjusted ratings on the transmission lines which they provide transmission service.

Requirements of 881

- Transmission line ratings must reflect the actual ambient temperature.
- Ratings must be calculated for at least historical temperatures ranges with a +/- margin of 10°F.
- Ratings must be available for every 5°F change of temperature.
- Ratings account for daytime & nighttime solar heating changes.
- Entities provide forecasted ratings for every hour, extending 240 hours into the future.

IMPACTS OF FERC ORDER 881

How does this impact us?

Ratings must be available for every 5°F change of temperature ranging from historical high/lows with a +/- margin of 10°F.

- **All time high in Tacoma: 105°F in June 2021**
- **All time low in Tacoma: 5°F in November 1985**

- **Ratings must now extend from -5°F to 115°F.**
- **This would require 25 different continuous and emergency ratings compared to the 7 currently used.**
  - **How will the expanded range impact the ratings? And ultimately, system performance?**

Ratings account for day/night solar heating changes.

- **This would require an entire additional rating set, 50 total, with no solar heating assumptions.**
  - **How do we implement this in real-time operations?**

Forecast ratings for every hour extending 240 hours. Updated hourly.

- **No process currently in place.**

IDENTIFYING IMPACTS

Where do we go from here?

- Need to determine the impacts of the expanded temperature windows.
  - Start by building the new rating set with the existing methodology.
    - One with solar assumptions and one without.
  - With these new rating sets, perform power flow analysis using more extreme ambient temperature assumptions.

Step 1: Calculate New Ratings

- 60 different conductor type & operating temperature combinations.
- 25 different normal & emergency ratings for each conductor type/operating temp combo.
- Double that for night ratings with no solar component.

After adding all that up, we just need to manually calculate 6000 new ratings…

Sounds like a great project for the Summer Intern!

IDENTIFYING IMPACTS

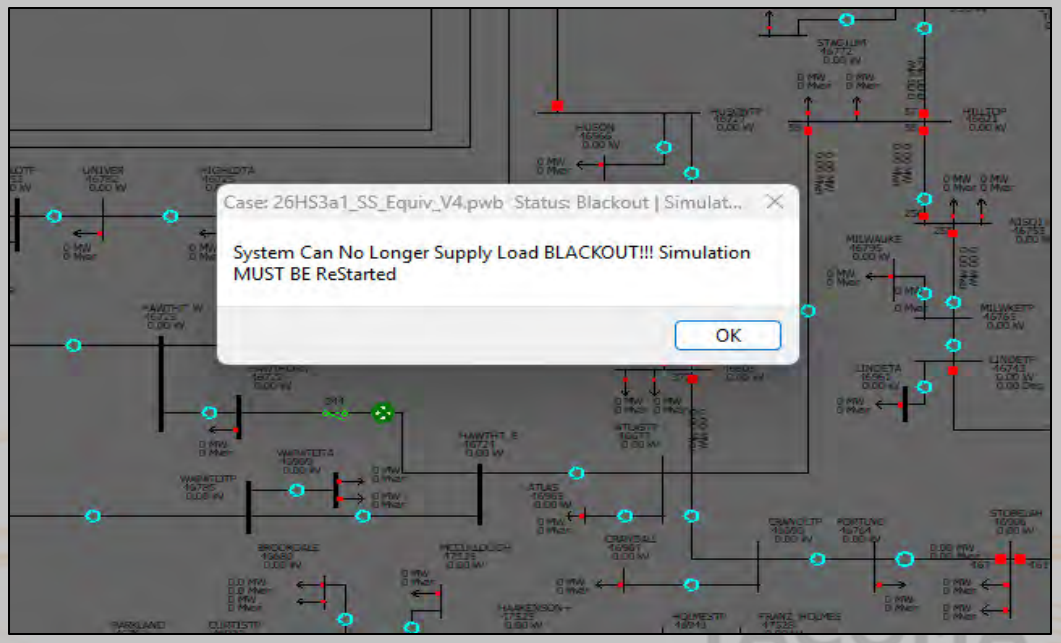
Fortunately, for us and the intern… We were able to get our hands on an excel based rating calculator that made things exponentially faster.

- **Shoutout to Ben Hutchins of WPP for providing this tool.**

Step 2: Analysis New Ratings

With the updated ratings, we could now perform some power flow analysis to see the true impact of higher ambient temperature windows.

The results:



INITIAL RESULTS

Initial results indicated that at high ambient temperatures, system performance requirements could not be met.

- More than 10 line sections exceeded continuous rating under N-0 conditions at 105°F.
  - Major lines at 400 and 500% of rating.
- N-1 scenarios intensify exceedances on previously limited sections.
  - Lines could exceed 600% of rating.

Overview

- Ratings at higher ambient temperatures were significantly reduced.
- System had many lines with operating temperature of 49°C. These lines had ratings pushed to near zero when ambient temps reach above 100°F.

INITIAL RESULTS

Example

- Ambient Temp: 104°F
- Loading: Peak Summer Day

Line Name	Existing 30°C Rating (Amps)	Existing Methodology Rating (Amps)	Percent Reduction (%)
115kV Line A	271 (54MW)	123 (24.MW)	54.6
115kV Line B	236 (47MW)	117 (23.3MW)	50.4
230kV Line A	1198	182	84.8
230kV Line B	1198	182	84.8

- Hourly average flows during peak Summer hours:
  - **230kV Line A: 326A**
  - **230kV Line B: 401A**

POTENTIAL MEDIATIONS

It was obvious from the results that action needed to be taken.

- Identified some potential ways to mediate.

LiDAR Assessment

- Another LiDAR study had just been performed on our transmission lines.
  - Performed in 2022. Analysis was on-going at this time.
- Hope was that the results would increase the operating temperature on many lines.
  - If not, provide most up-to-date limitations.

Revised Methodology

- Assumptions in our ratings calculation could be adjusted to help improve ratings.
  - Wind Speed Assumptions
  - Solar Day
  - Time of Day

LIDAR STUDY

Previous LiDAR Data Process

- LIDAR data was being provided to us by 3rd party. Results were provided at random.
- Line Engineering would then periodically process the results, and report any updates as needed.
    - No insight into reasoning for given operating temperature.
    - Higher allowable operating temps may have not been provided if previously adequate.

Revamped Process

- Streamlined Results
    - Discussed the importance of review.
    - Prioritized review of 49°C lines.
- More insight
    - Got access to information pertaining to results and operating temperature limitations.
    - Every degree for every line section.
- Call to action
    - Immediate Work Orders for small fixes such as pole tops, comms, etc.
    - Identified lines that necessitated larger fixes. Work Orders created.

UPRATE IN ACTION

A backbone 230kV line had an operating temperature of 49°C. Per our analysis, It was imperative that an uprate occurred.

The culprit for the limited operating temperature….

Some additional tensioning of the line increased the operating temp to 67°C.

UPRATE RESULTS

Results

- Initially, 80-line sections with an operating temperature of 49°C.
- All have been increased to at least 57°C.
    - 60 of these lines have been increased to 100°C.
- Almost 200 out of 328 had an increase in operating temperature.
    - Average increase of 31°C.
    - Roughly 80% of increases due to updated LiDAR results and full scope of data.
- Roughly 40 Work Orders Completed.
    - $500,000 in costs.

Quick Compare

Rated Ampacity of 1272AAC at 35°C ambient temperature:

Operating Temperature of 49°C : 429A

Operating Temperature of 100°C : 1344A

WIND SPEED ASSUMPTIONS

One way to increase a conductor rating is to increase the assumed wind speed.

- Wind Speed is one of the most impactful inputs for a line rating.

Quick Compare:

Rated Ampacity of 1272AAC at 25°C ambient temperature and 100°C operating temperature:

Wind Speed of 2ft/s : 1450A

Wind Speed of 4ft/s : 1707A

To justify any change to the existing methodology, we need to have data to back it up.

- In 2022, intern performed an historical analysis of instantaneous wind speed versus ambient temperature.
    - **Probabilistic Wind speed at temperature windows was analyzed using data back to 1950 from three local weather stations.**

WIND SPEED ASSUMPTIONS

*Table 3b. **0.05 quantile** wind speeds (ft/s). (Normal Rating)*

	72-77°F	77-82°F	82-87°F	87-92°F	92-97°F	97-102°F
Combined stations	2.92	3.57	3.92	4.34	4.28	4.58
Combined stations w/ noise	3.20	3.79	4.08	4.41	4.25	4.31

*Table 4b. **0.1 quantile** wind speeds (ft/s). (Emergency Rating)*

	72-77°F	77-82°F	82-87°F	87-92°F	92-97°F	97-102°F
Combined stations	4.15	4.89	5.28	5.76	5.70	6.04
Combined stations w/ noise	4.47	5.13	5.47	5.91	5.77	6.71

Table 5b. Number of samples used for wind speed quantiles.

	72-77°F	77-82°F	82-87°F	87-92°F	92-97°F	97-102°F
Combined stations	67836	28127	11358	3246	1049	145

ASSUMED WIND SPEED

Ambient Air Temp (F)	Wind Speed Assumptions	
	Normal (ft/sec)	Emergency (ft/sec)
<=70°	2	3
70°< and <=75°	2.18	3.28
75°< and <=80°	2.92	4.15
80°< and <=85°	3.57	4.89
85°< and <=90°	3.92	5.28
90°< and <=95°	4.28	5.70
95°< and <=100°	4.28	5.70
100°< and <=105°	4.58	6.04
105°< and <=110°	4.58	6.04
110°<	4.58	6.04

DAY & TIME ASSUMPTIONS

Solar Day

- Existing methodology assumes June 10th for all ratings. This is the most limiting day of year.
- Additional capacity can arise from using less conservative day.
    - Using actual day of each year would require a completely new rating set for each day.
    - For a seasonal use, the most limiting day for the season would need to be used.
    - Overall, the theoretical gain is small. Not worth the effort.

Time of Day

- Existing methodology assumes 11:00am for all ratings.
- Additional capacity can arise from using less conservative time of day.
    - Again, using actual time would require different data sets.
    - The theoretical gain is small.
- System is most constrained during peak hours. Analysis is done assuming peak scenarios.
    - Our ratings should reflect the time of day the system is most constrained.
    - This was justification to adjust the time of day to 8:00am/4:00pm.

UPDATED RATING RESULTS

To summarize mitigation efforts…

- Work with Line Engineering to prioritize review of LiDAR data and uprate of limited lines.
- Revised Facility Rating Methodology assumptions backed by engineering judgement and historical evidence.
  - Higher wind speed assumptions at high ambient temperatures.
  - Time of Day changed to capture peak load hours.

Now, the moment of truth…

Would these changes be enough to meet our system performance requirements at higher ambient temperatures?

UPDATED RATING RESULTS

Finished with no violations, custom monitor violations, unsolveable or aborted contingencies. Initial state restored.

No SOL violations at N-0 or N-1 scenarios! System Performance requirements were met.

- Even at assumed ambient temperatures of 115°F.
- 268/328-line sections saw an increased ampacity at 115°F compared to the previous 86°F ratings.

Not quite finished…

- Satisfied with the outcome of the new rating set, Facility Rating Methodology.
- However, still some remaining challenges.

IMPACTS TO EMS

New EMS Requirements

Due to these updates, EMS system required:

- Look up table with 25 different continuous and emergency ratings.
- Additional look up table for night ratings.
- New process to determine when Day/Night rating were in effect.

Outcome

- Started with collaboration between EMS group.
- Modified existing setup to accommodate additional ratings.
- Created an additional parameter to select day or night ratings.
  - Lookup table of sunset and sunrise times for each day.

ADDITIONAL FERC 881 IMPACTS

FERC Order No. 881 requires ISO's/RTO's to utilize AAR ratings in their:

- Real time congestion management process.
- Real time and look ahead market commitment process and look ahead reliability studies.
- Evaluation and curtailment of near term (10 days or less) transmission service.

RCWEST/CAISO

- To receive real time ambient adjusted ratings from TO's for use in their real time reliability monitoring process.
  - Went live in July 2025. RCWEST receives are real-time AAR's via ICCP.
- To receive forecasted ratings extending 240 hours for every hour to be used in market applications and look ahead reliability applications.
  - Still in development. Targeted functionality by Q3 2026. Required to begin submission before October, 2027.

240-HOUR LOOK AHEAD RATINGS

CAISO is using a OATI tool called WebLineR to collect and implement the forecasted facility ratings.

- WEIM Entities are required to submit their forecasted AAR's to this tool.
- Ratings must be submitted every hour extending 240 hours.

Tacoma Power has consulted with PCI to use their Line Rating Management System (LRMS) Software.

- Tacoma Power provides the facilities and ratings tables.
- The LRMS uses forecasted weather data to determine the assumed rating for each facility for every hour, extending 240 hours.
- The LRMS uses API to submit the ratings to the WebLineR every hour.
- LRMS will also update the TTC on OASIS for the next 240 hours.

CURRENT STANDING & NEXT STEPS

Current Standing

- Updated Facility Rating Methodology and Ratings.
- Completed development & testing of new EMS functionality.

Next Steps

- Get leadership approval on changes to methodology and implementation of new ambient adjusted ratings.
- Complete all development, review & testing of new ratings and impacted workflows.
- Develop a cutover procedure/timeline in coordination Operations.
- Integrate the PCI tool in Q4 of 2026 (No later than October 15, 2027).

Questions and Feedback?

Sources

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