APPLICATIONS AND ISSUES OF UNCERTAINTY FORECASTS TO NET LOAD PREDICTION AT HECO

John W Zack, Ph.D.
Vice President – Grid Solutions
jzack@awstruepower.com

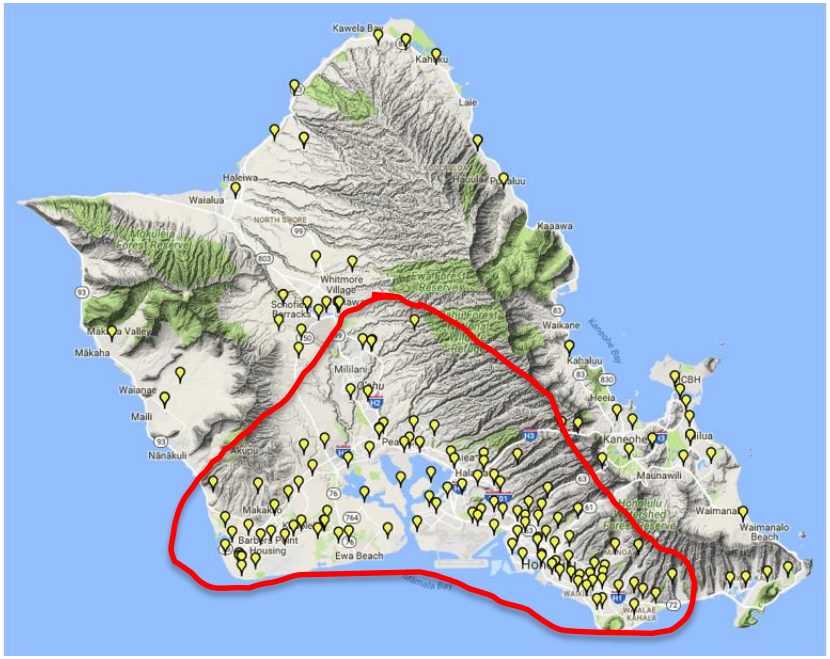
AWS TRUEPOWER

OVERVIEW

- Background:
  - Hawaiian Electric's operating environment
  - Hawaiian Electric's forecast system (SWIFT)
- Key attributes of uncertainty estimation (probabilistic forecasts)
- Two examples of system-impact solar ramp events on island of Oahu
- Implications for focus of efforts to increase forecast value

BACKGROUND:
HAWAIIAN ELECTRIC OPERATING ENVIRONMENT

- Business
  - Vertically integrated utility: no market
  - Most gen mix decisions: 0-4 hr ahead
  - RPS: 2020: 30%; 2040: 70%; 2045: 100%
- **Oahu** Grid System
  - Gross load range: 700 MW to 1200 MW
  - High level of renewable penetration
    - ✓ ~ 400 MW Solar (mostly BTM)
    - ✓ ~ 100 MW Wind
  - Island system: no interconnections
- Meteorology
  - Dominated by small scale weather features driven by interaction of island terrain and large scale flow
  - Islands in the middle of Pacific (data sparse in all directions)

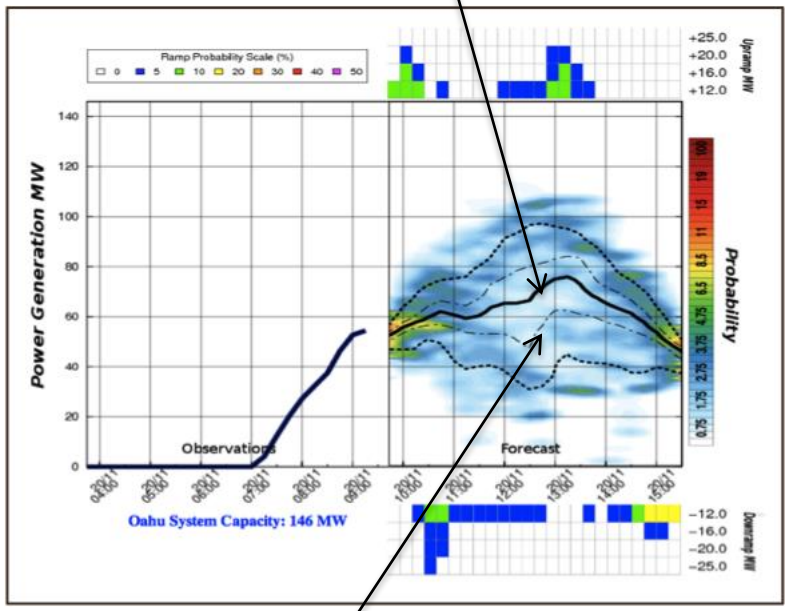


Oahu: locations of “virtual generators” for the forecasting of aggregated BTM solar-based generation

BACKGROUND:
HAWAIIAN ELECTRIC'S FORECAST SYSTEM

- Solar and Wind Integrated Forecast Tool (SWIFT)
- Products
  - 0-6 hr forecasts
    - ✓15-min updates
    - ✓ Probabilistic 15-min avg gen
    - ✓ Probabilistic: 30-min ramp rate
  - 0-168 hr forecasts
    - ✓ 1-hr updates
    - ✓ Probabilistic 1-hr avg gen
- Forecast System Components
  - Large scale (global) NWP
  - Hi-res regional NWP
  - Rapid update NWP (HRRR & in-house)
  - Satellite-based cloud feature advection
  - Time series models

Lines: Probability of Exceedance (POE)

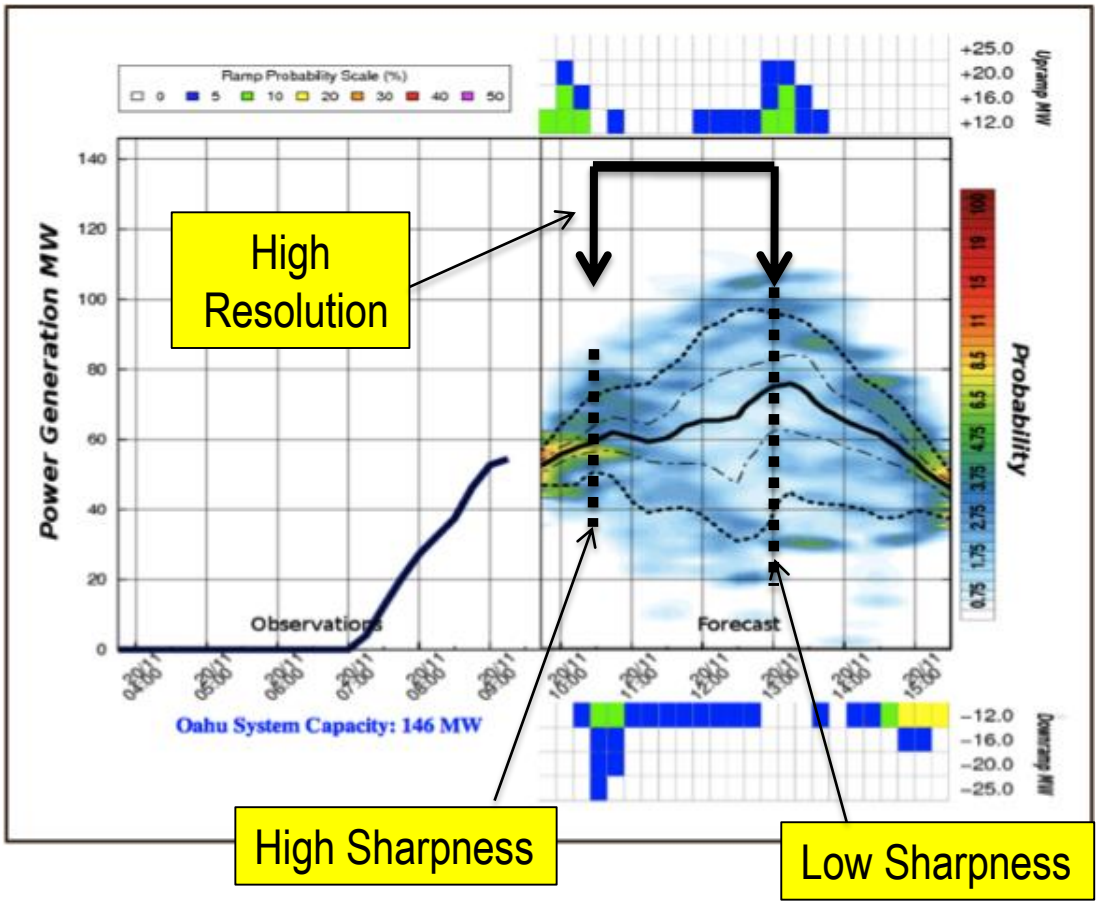


Color shading: probability density

AWS TRUEPOWER

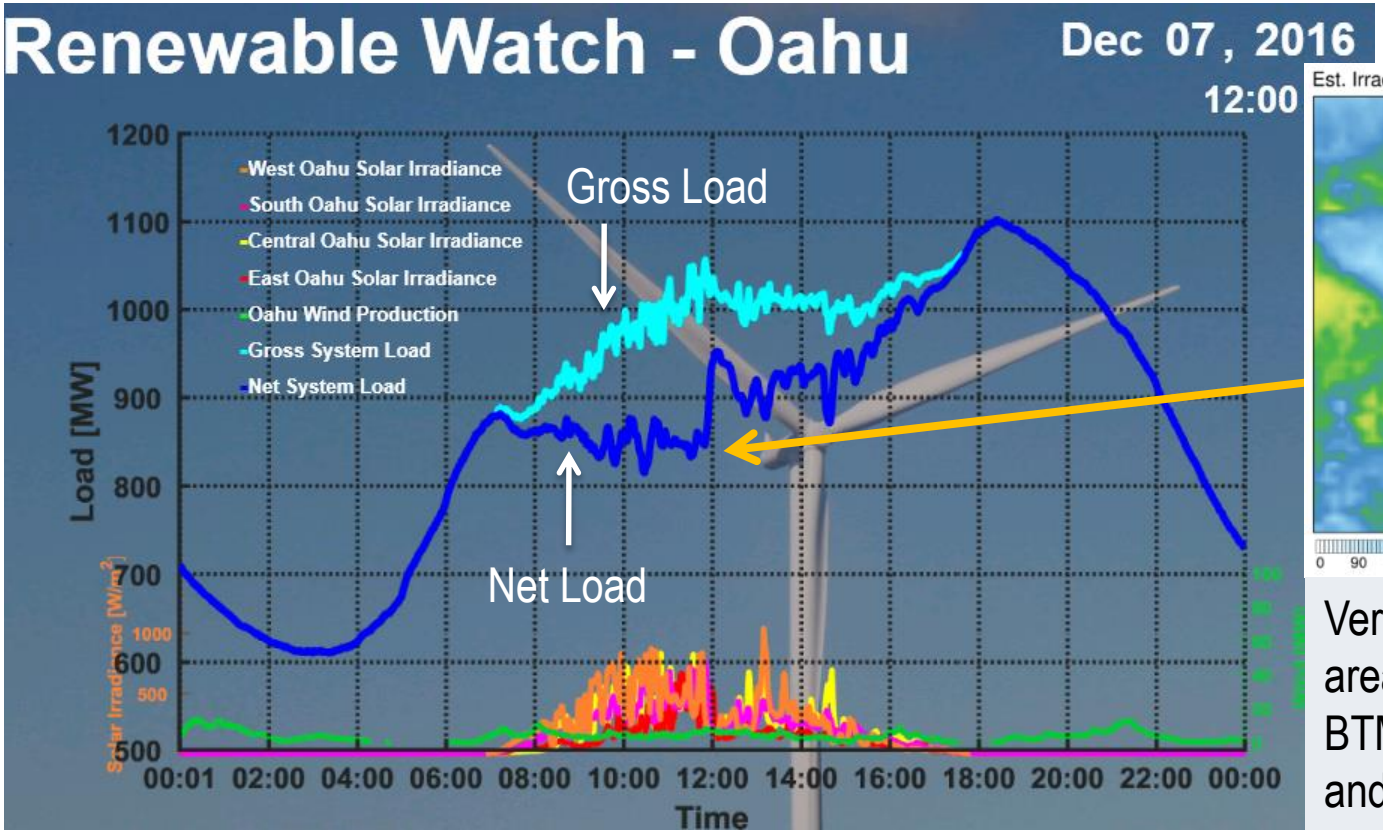
KEY ATTRIBUTES OF PROBABILISTIC FORECASTS

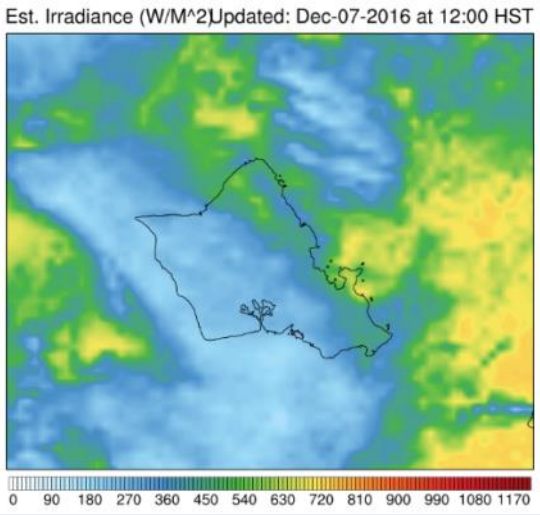
- **Reliability:** agreement between forecasted probability and frequency of observed outcomes
- **Sharpness:** the amount of dispersion (spread) in a forecasted probability distribution
- **Resolution:** ability to reliably differentiate differences in probability distributions among prediction scenarios (e.g. forecast look-ahead times, forecast cycles etc.)



CASE #1: NET LOAD UP RAMP – DEC 7, 2016

- Morning had been mostly sunny over PV generating areas with high frequency variability
- System experienced sharp increase in net load in about 15 minutes around noon
- Cause was a -100 MW/15 min ramp rate in BTM solar generation
- Resulted in a need to quickly ramp-up non-renewable generation to “chase net load”



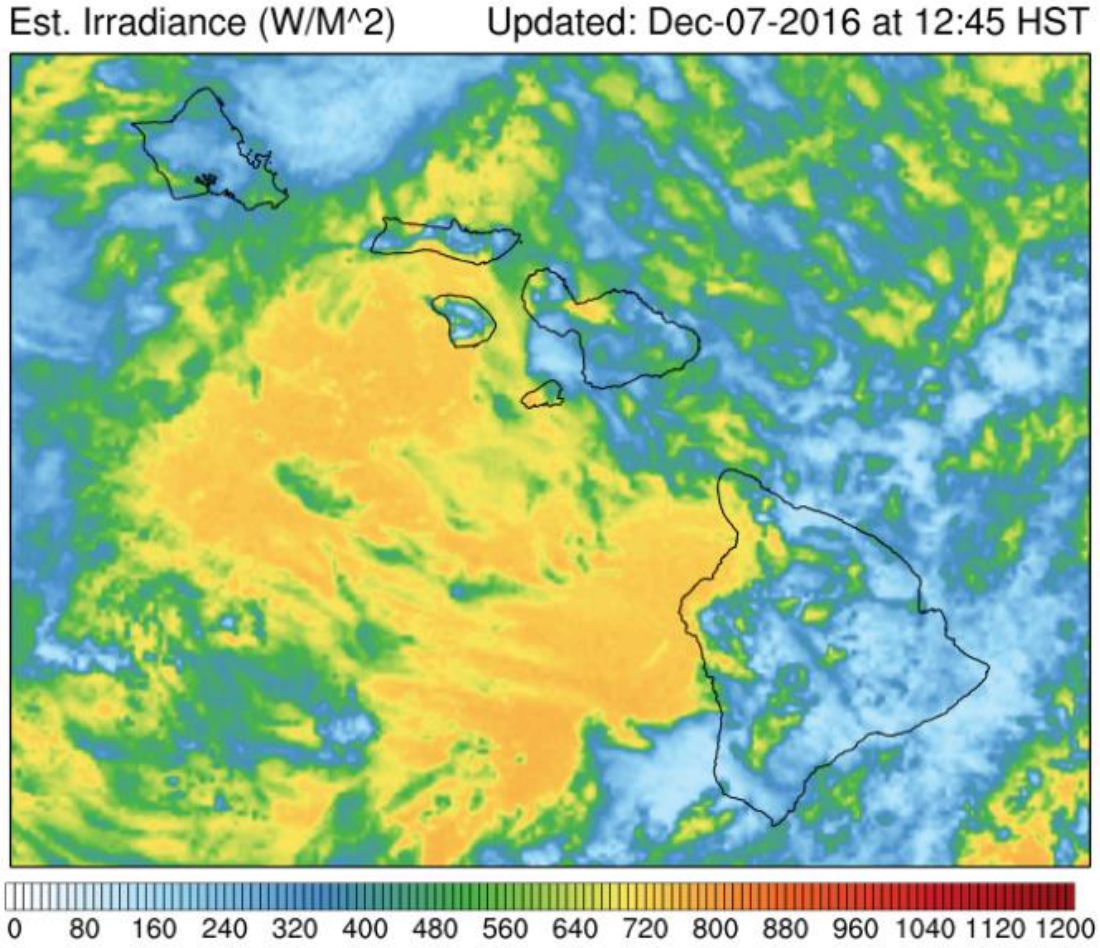


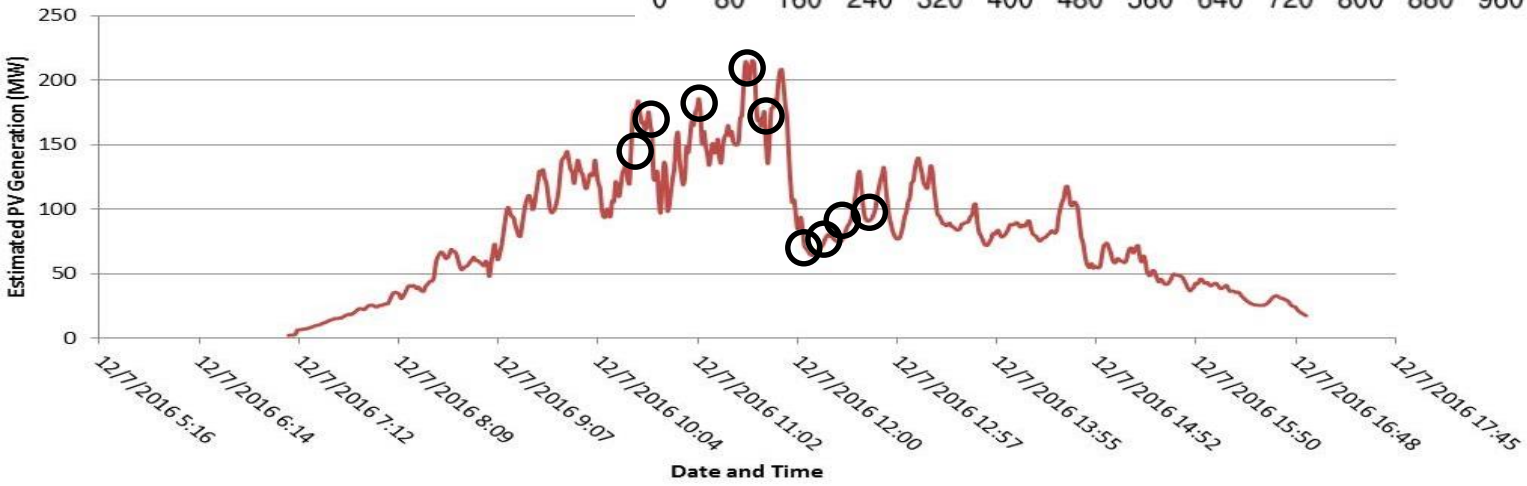
Very low Irradiance over areas with a high density of BTM PV systems in South and Central Oahu

CASE #1:

EVOLUTION OF THE CLOUD FEATURE

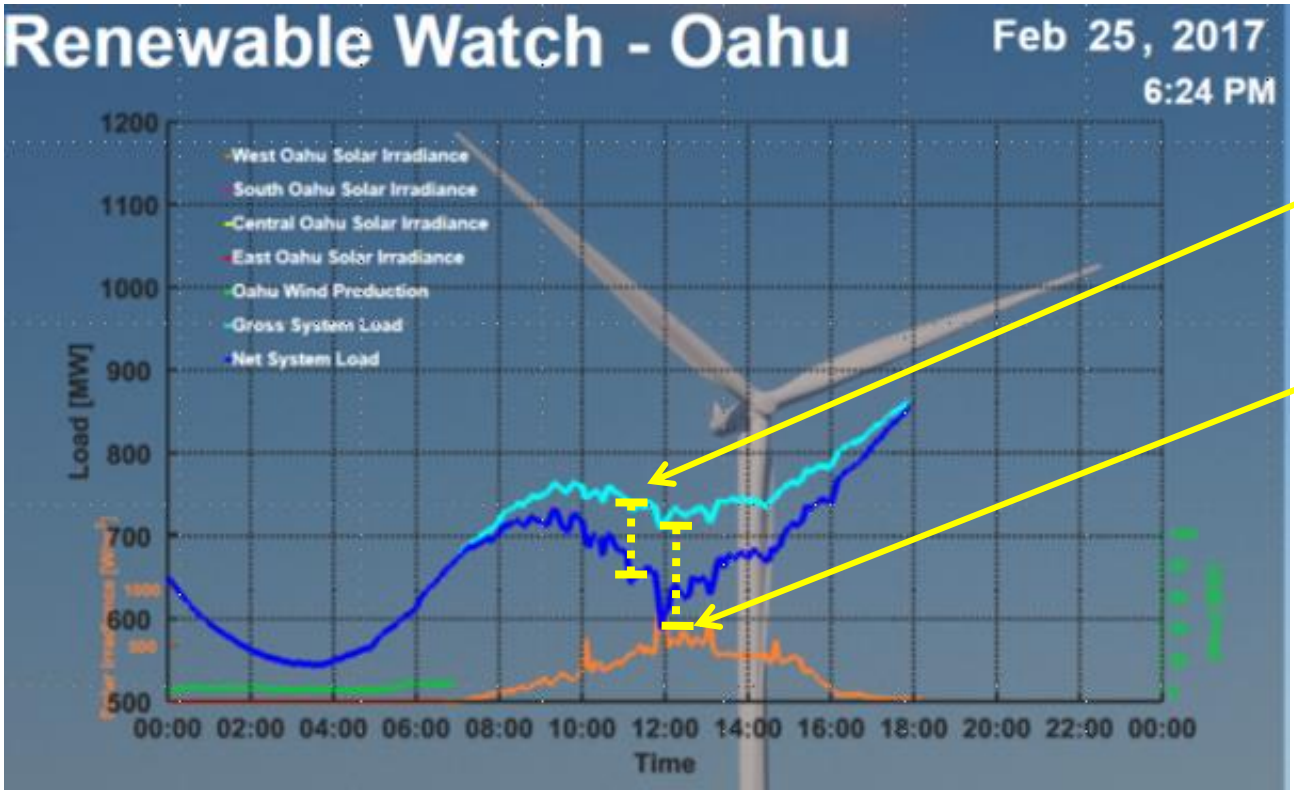
- Visual tracking of cloud evolution suggests 30-min warning could have been available
- Impact is very sensitive to cloud track and evolution
- Not captured by rapid update NWP systems





CASE #2: FEB 25, 2017 – "OVER FREQUENCY EVENT"

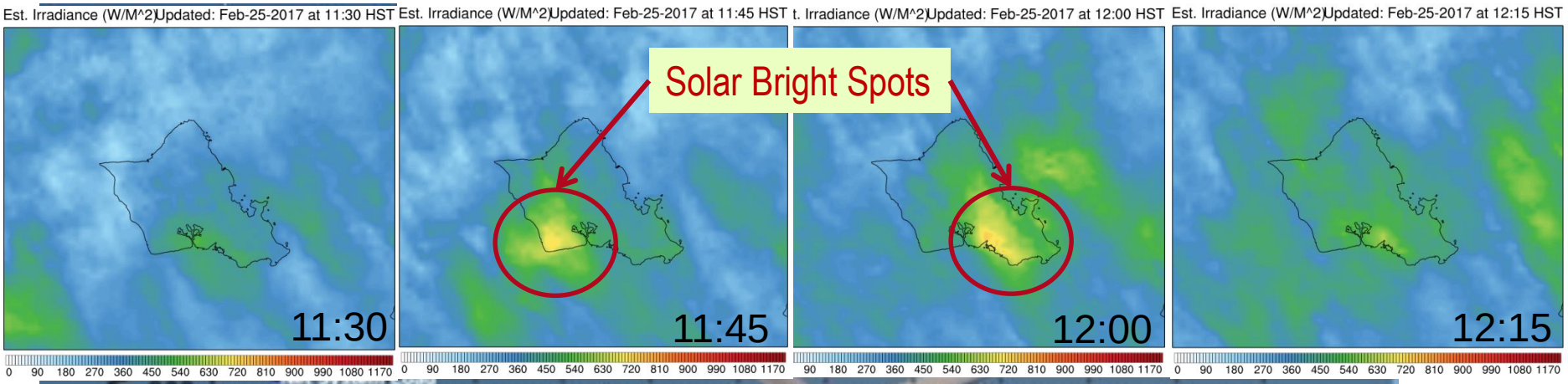
- System experienced an "over frequency" event
- Morning forecast: low to moderate PV generation due to extensive middle & high clouds
- Saturday in the cool season: low gross loads
- Due to expected low PV, system was positioned with additional non-renewable generation, which had to be "backed down" to minimum generation

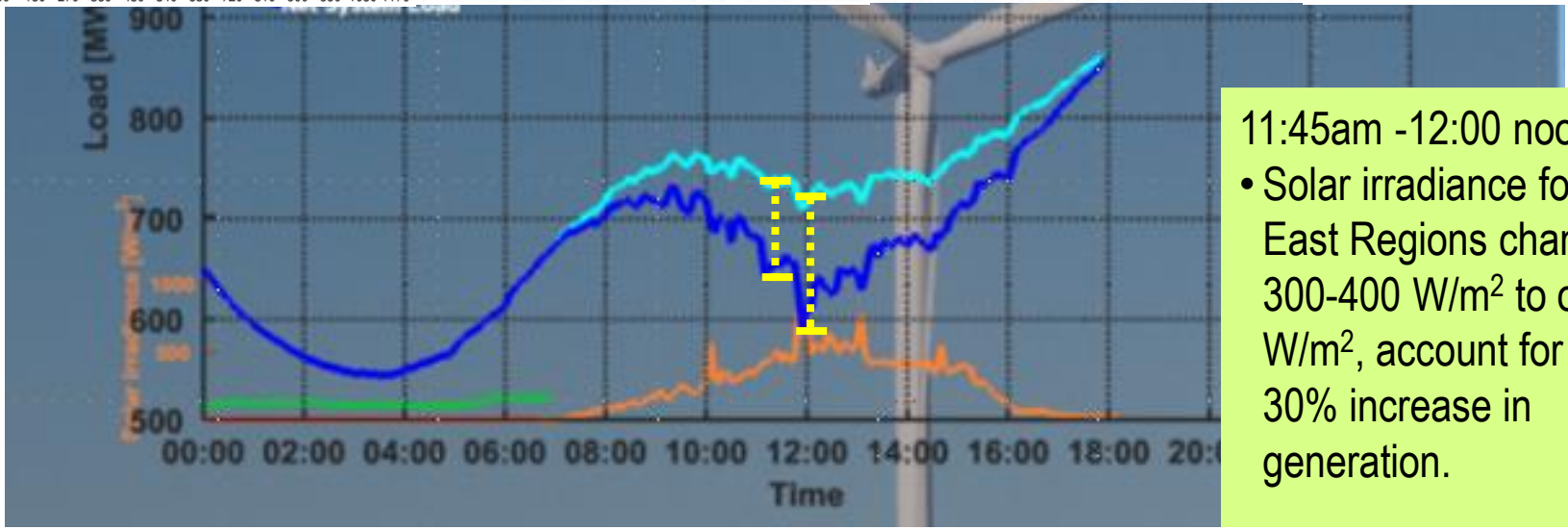


11:40-11:50am,
- Behind the meter PV generation contributing to grid estimated at 120 MW

12noon
- Behind the meter PV generation contributing to grid jumps to 200 MW
- +80 MW / 15 min ramp rate
- Drops system daytime min-load below 600 MW

CASE #2: EVOLUTION OF THE EVENT





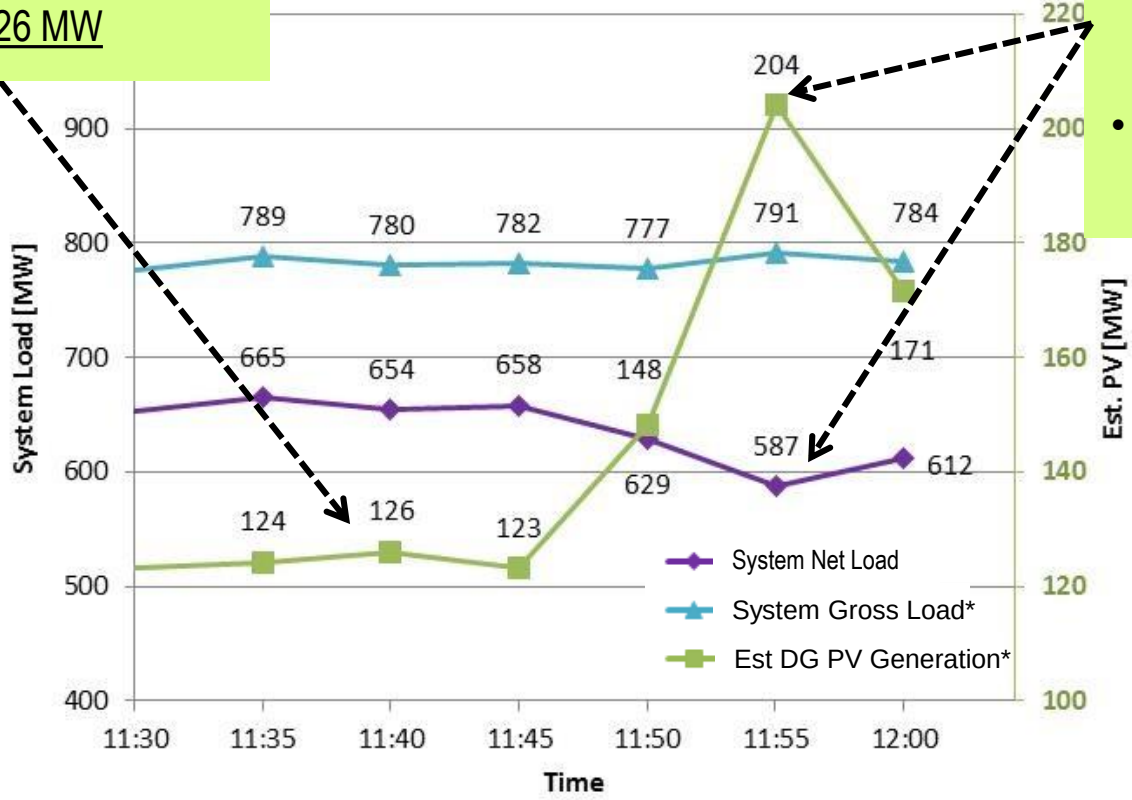
11:45am -12:00 noon

- Solar irradiance for South & East Regions changed from 300-400 W/m^2 to over 750 W/m^2, account for nearly 30% increase in generation.

CASE #2: DETAILED VIEW OF EVENT PERIOD

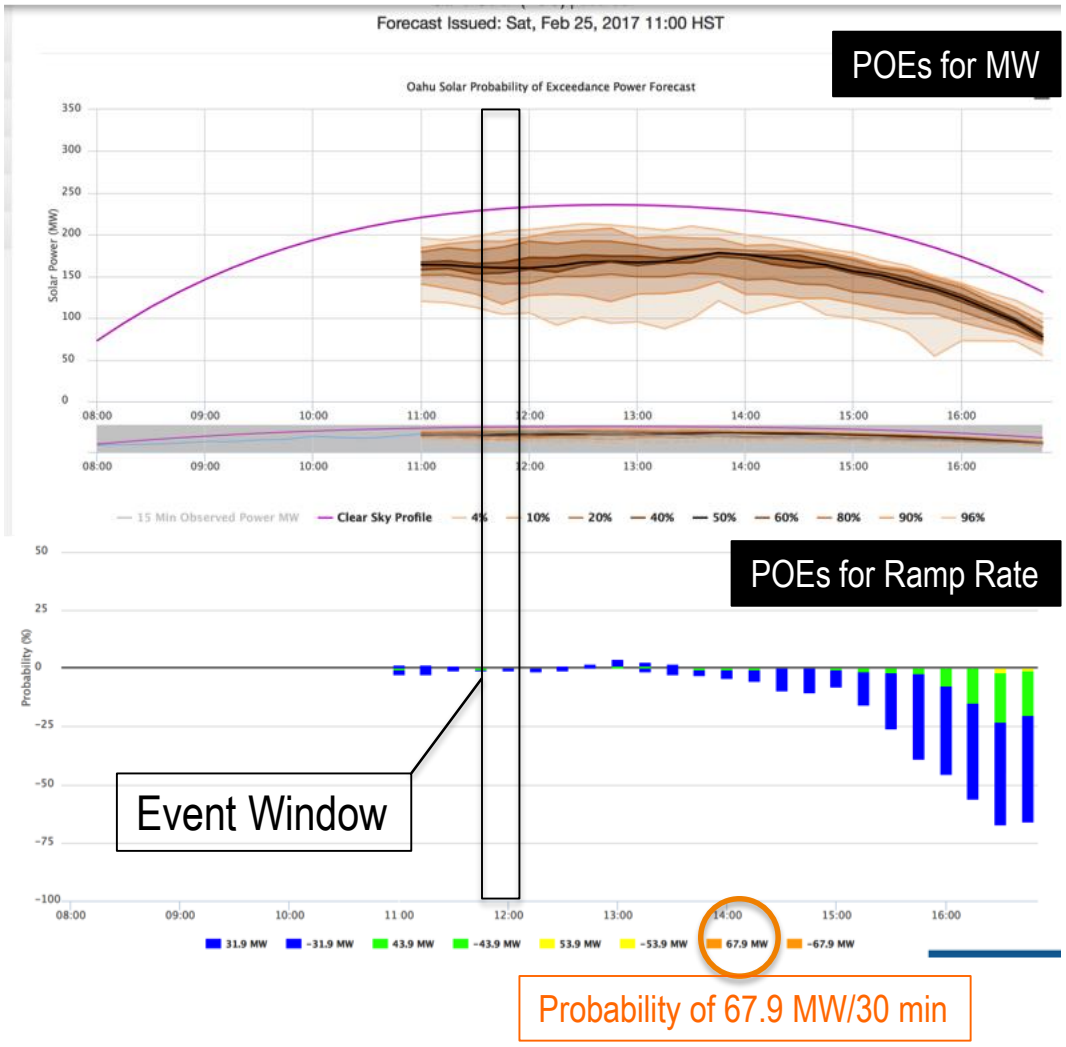
11:40-11:50am,
- Behind the meter PV generation contributing to grid estimated at 126 MW

11:55 - 12noon Period
- Behind the meter PV generation contributing to grid estimated at 204 MW (approx. 80 MW jump) and
- Daytime system minimum load drops below 600 MW



* Gross load & Solar Production are calculated values

CASE #2: 1100 HST SWIFT SOLAR GEN FORECAST



- SWIFT 1100 HST Oahu solar gen forecast: 1-hr before the event
- SWIFT predicted generally cloudy conditions for remainder of the day
- Relatively high uncertainty (i.e. wider than typical spread of POE bands) for the midday period
- No temporal resolution in probability distributions to indicate greater uncertainty near event time
- Ramp rate threshold probabilities did not indicate elevated probability of significant up ramp

FORECAST ISSUES

- **These type of events are very difficult to deterministically forecast even 0-4 hrs ahead**
  - Short-lived features on small spatial scales
  - Rapid update NWP had very little signal of the events (probably inadequate initialization)
  - Satellite-based cloud advection failed since feature structure evolved rapidly
  - Time series models (even advanced ML) don't have sufficient predictive information (data) or enough of a training sample (of these events) to identify a signal
- **More realistic goal: probabilistic forecasts to identify periods with elevated probability**
  - Need a forecast system with probabilistic forecasts with "high resolution"
  - How do you get that? Accurately model all of the key sources/scales of uncertainty
    - ✓ Identify key sources/scales of uncertainty in all prediction methods
    - ✓ Need more than NWP ensembles: blend uncertainty info from multiple predictive methods (NWP, satellite advection, time series etc.)