EVALUATION OF THE IMPACT OF INTRA-DAY AND EXTENDED PV AND WIND GENERATION FORECASTS ON DECISION-MAKING IN THE PLANNING AND OPERATIONS OF THE JAMAICA PUBLIC SERVICE GRID SYSTEM

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OUTLINE

1. Objective and Approach
    - Key Issue: forecast value is NOT equivalent to forecast accuracy
2. Background on the Target System - Jamaica Public Service (JPS)
3. Conceptual Forecast Evaluation Approach and Metrics
4. Overview of 4 Key Types of Operational Decisions
    - Decision factors and implications
    - Relevant forecast attributes
5. Summary and Next Steps

OBJECTIVE AND APPROACH

- **Objective**: Maximize the value of wind and solar generation forecast information for operational decision-making
- Why is this an issue?
  - Most users employ forecasts that are not optimized for their applications
  - Forecast performance is typically measured with generic metrics (e.g. MAE, RMSE) that are often not strongly related to the way in which the user's applications are sensitive to forecast error
  - Most users have not determined which attributes of forecast performance are most important for their applications
- **Result:** A considerable amount of forecast value is not realized (or from another perspective: "is thrown in the trash")

- 4-part project to maximize forecast value for JPS has been initiated

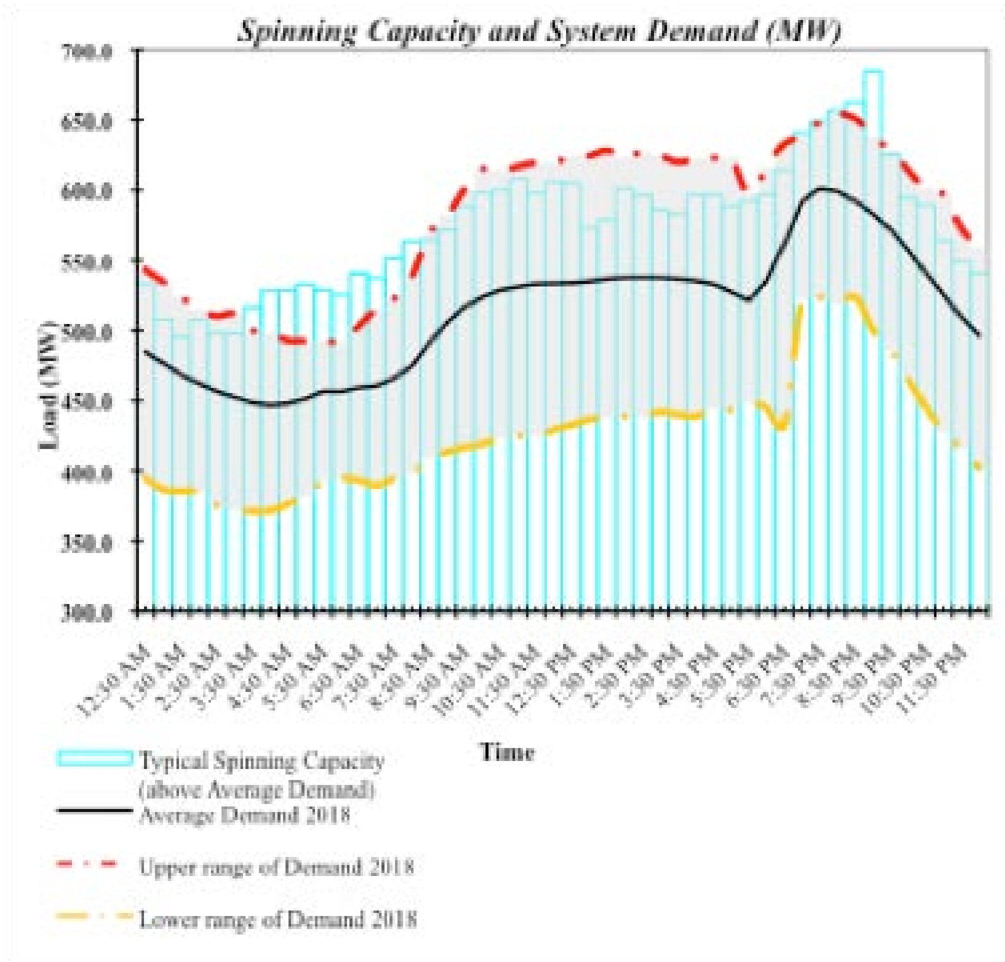
1. **Define** key decision-making time frames and issues (scenarios)
2. **Formulate** parameters that quantify the key forecast issues in each scenario
3. **Evaluate** forecasts of these parameters with application-customized metrics
4. **Optimize** forecasts to optimize performance on application-customized metrics

Focus of this presentation

BACKGROUND INFORMATION

- JPS Load Profiles
- JPS Generation Resources
- JPS Forecast System Specifications

JPS: 2018 NET DEMAND PROFILES



- Average daily peak demand: ~600 MW
  - Typically occurs between 5 PM and 9 PM LT
  - Absolute peak for 2018: 655 MW
- Average daily minimum: ~450 MW
  - Typically occurs between 2 AM and 4 AM LT
  - Absolute min for 2018: 372 MW
- Average mid-day demand is slightly above 500 MW
  - No evidence of a mid-day minimum
  - BTM solar gen is still within the noise range of the demand

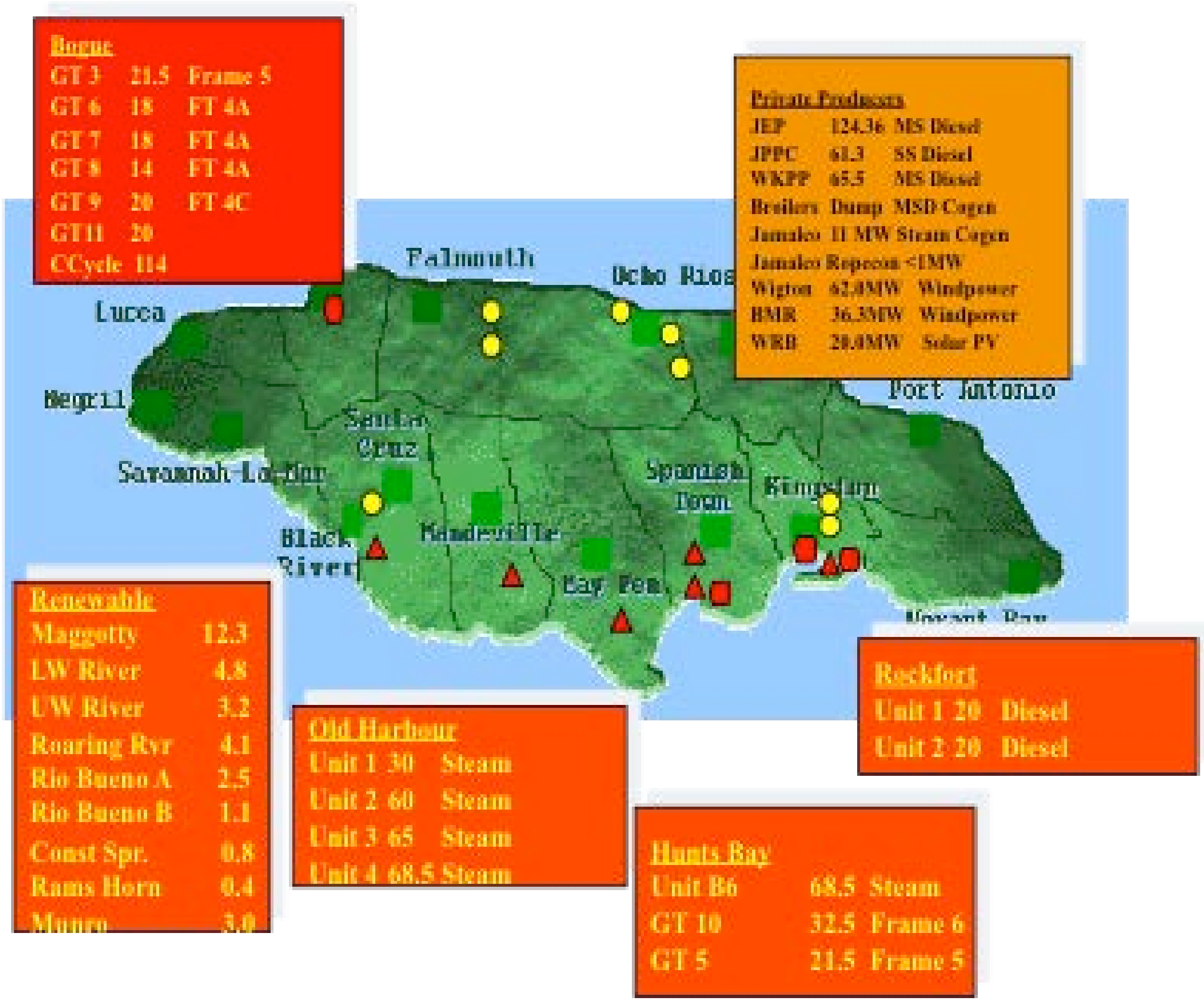
JPS: GENERATION RESOURCE PROFILE - 2018

Firm Generation Capacity

Station	Steam	Diesel	GT	Hydro	CC	Cogen	Total	MW
Bogue			6		1		7	225.5
Old Harbour	4	11					15	347.9
Hunts Bay	1	6	2				9	188.0
Rockfort		4					4	101.3
Other				10		1	11	40.1
Total	5	21	8	10	1	1	46	902.8

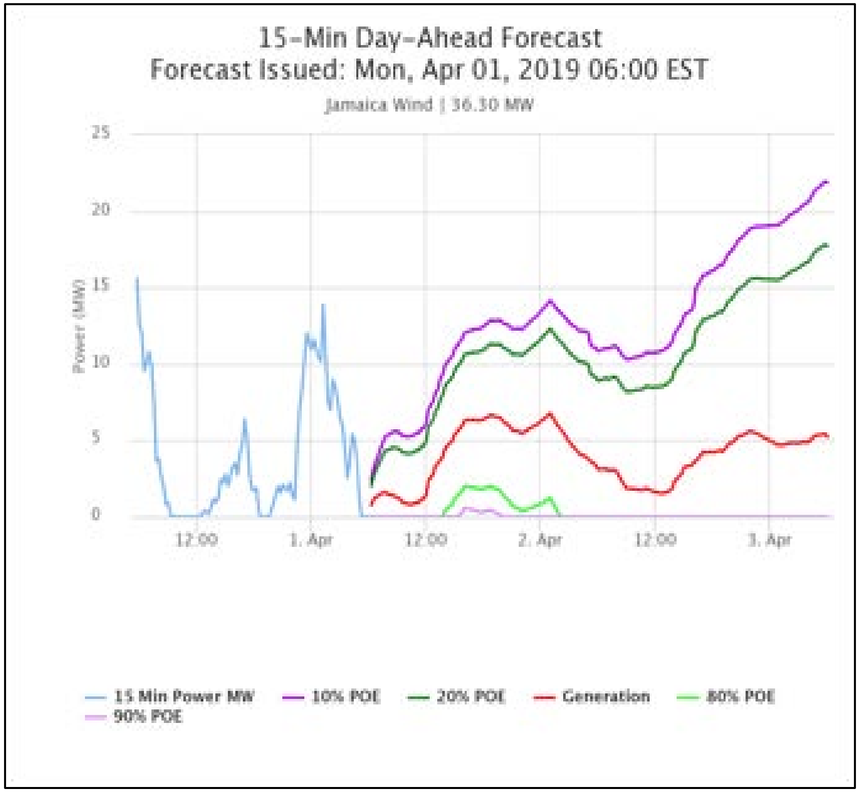
Facility	Type	Capacity (MW)
Wigton I	Wind	20
Wigton II	Wind	18
Wigton III	Wind	24
JPS Munro	Wind	3
BMR	Wind	36.3
Total Wind		**101.3**
Content Solar	Solar	20
Total Solar		**20**

JPS: GEOGRAPHICAL DISTRIBUTION OF GENERATION RESOURCES - 2018



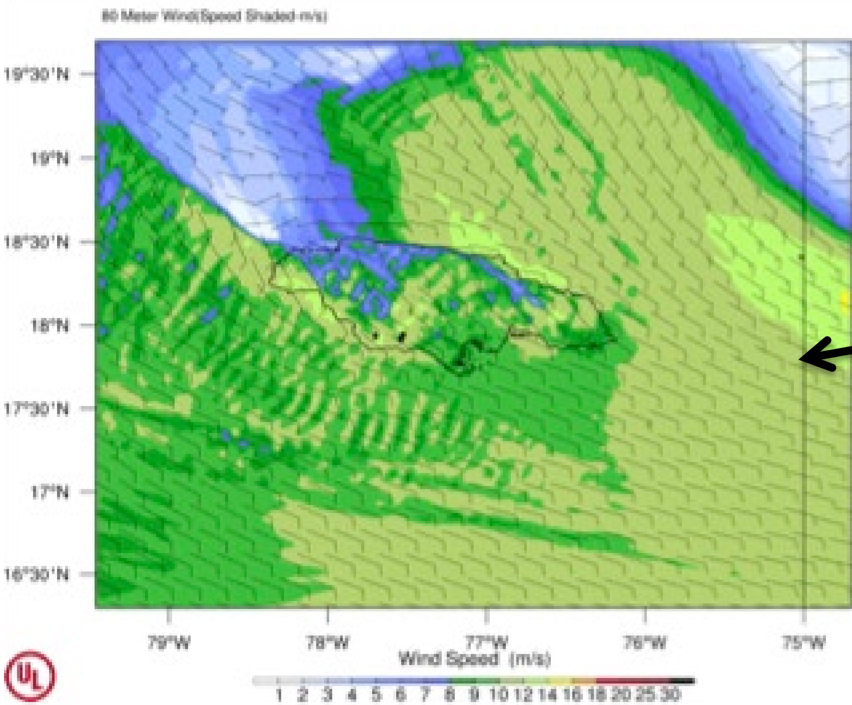
UL WIND AND SOLAR FORECAST SYSTEM: JPS

Example of a Wind Forecast Display

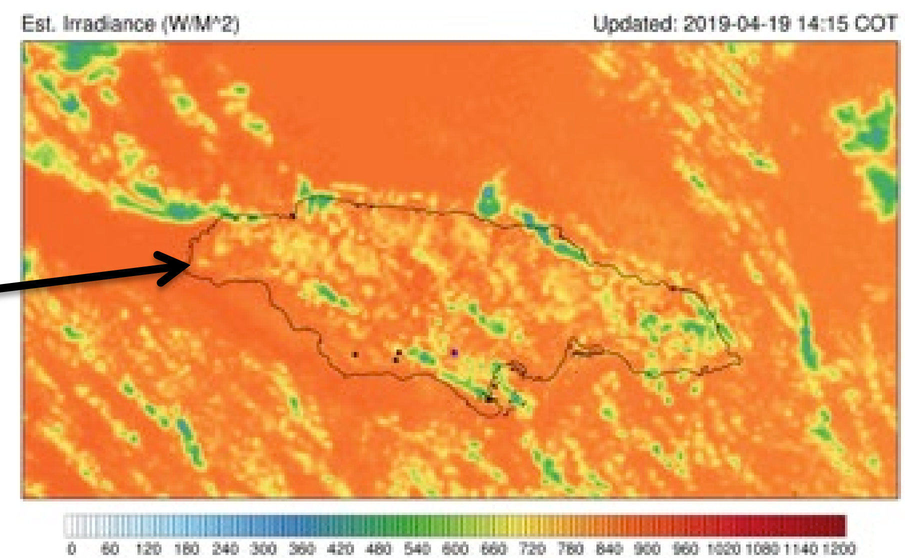


- JPS began receiving wind and solar forecasts from 2 providers in 2018
- One of the providers is AWS Truepower, a UL Company (AWST)
- AWST forecasts are produced from an ensemble of prediction-methods (physical and statistical)
- Three forecast (look-ahead) time horizons
  - Intra-day: 0-6 hrs ahead
    - ✓ 5-min updates & 5-min time steps
  - Next day: 0-midnight of next day
    - ✓ 6-hr updates & 15-min time steps
  - Long range: 0 - 14 days
    - ✓ Once per day (0600) update & 1-hr time steps
- Forecast format
  - 4 Probability of Exceedance (POE) values
  - Deterministic values (min squared error)

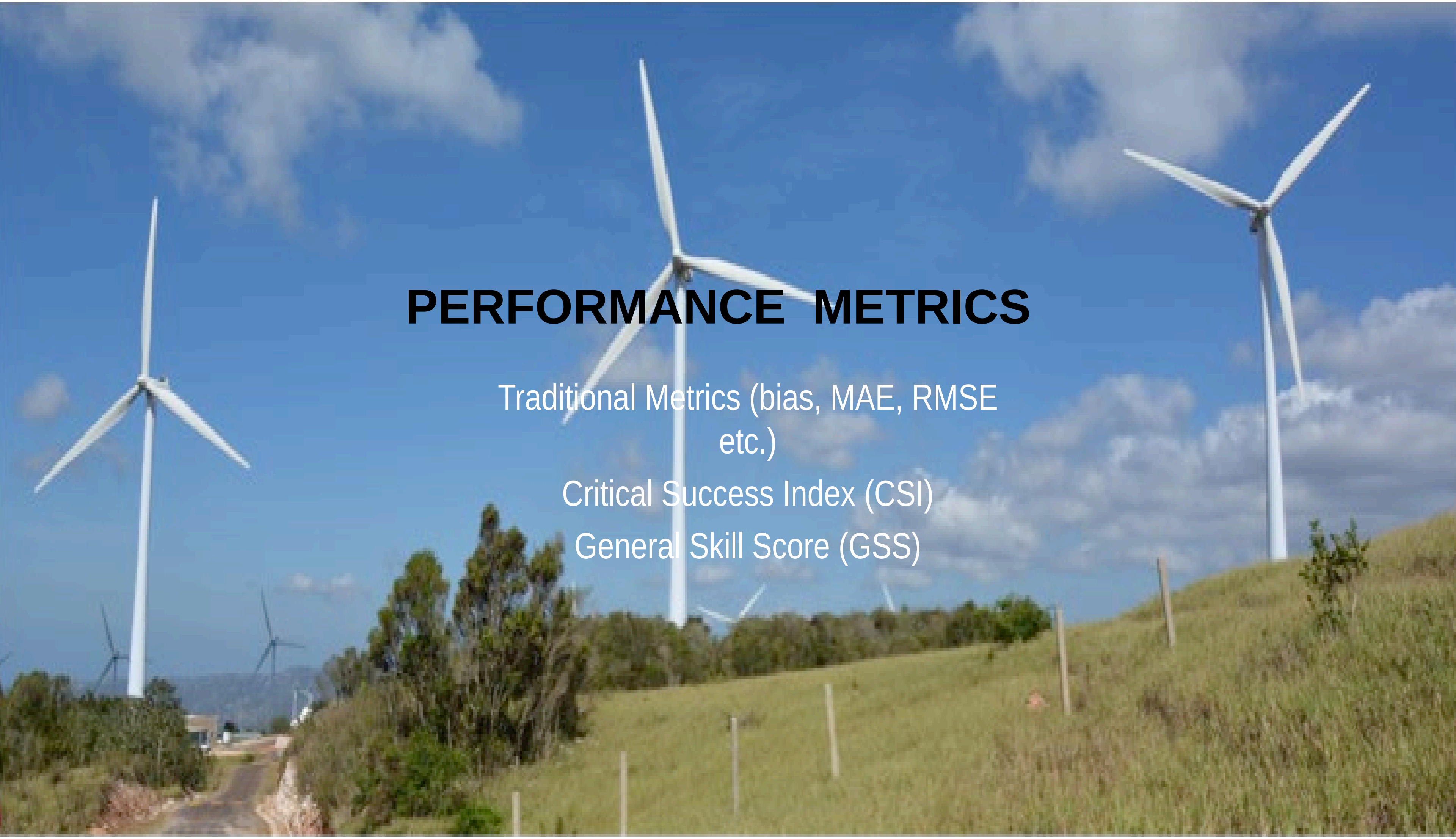
SITUATIONAL AWARENESS: TOOLS TO MONITOR OF CURRENT WIND AND SOLAR CONDITIONS



Estimated 80-m Wind Patterns – very short-term NWP forecasts blended with available wind sensor data



Estimated Global Horizontal (Solar) Irradiance (GHI) – from visible satellite imagery calibrated with ground-based sensor data



PERFORMANCE METRICS

Traditional Metrics (bias, MAE, RMSE etc.)

Critical Success Index (CSI)

General Skill Score (GSS)

TRADITIONAL FORECAST PERFORMANCE METRICS

- Mean Error (bias)
  - Average of the errors over all forecast intervals in a sample
  - Provides an indication of the systematic error (e.g. too low or too high)
- Mean Absolute Error (MAE)
  - Average of the absolute value of the errors over all forecast intervals in a sample
  - Provides an indication of the typical magnitude of the error
- Root Mean Square Error (RMSE)
  - Square root of the average of the squared errors
  - Provide an indication of typical error magnitude but heavier weighting of larger errors

- Issues
  - Heavily weighted towards performance under typical conditions
  - Not sensitive to performance under atypical (often the most critical) conditions
  - Often not focused on events that are most important to decision-making

CONCEPTUAL APPROACH

- HYPOTHESIS: A customized event-oriented category-based evaluation scheme would provide a more application-relevant assessment of forecast performance than a traditional forecast evaluation approach
  - Events defined by critical operational decision-making scenarios
  - Categories defined by operationally significant thresholds associated with the events
  - Events, categories and time frames customized for each decision-making scenario
  - Category-based performance metrics used to assess forecast performance

CATEGORY-BASED EVALUATION: CSI

Category #	Forecasted			
Observed	Category	Below	Typical	Above
	Below	1	2	3
	Typical	4	5	6
	Above	7	8	9

- Ratios of Correct and Incorrect Outcomes
  - Hits (H) = Cat #1 + Cat #9
  - Misses (M) = Cat #2 + Cat #3 + Cat #7 + Cat #8
  - False Alarms (FA) = Cat #4 + Cat #7 + Cat #3 + Cat #6
  - Critical Success Index (CSI) = H / (H + M + FA)
- Issues
  - Does not account for multiple category errors
  - Does not consider relative frequency of outcomes: could provide hedging incentive
  - Does not weight relative cost of errors
    - Does a miss of a “below” event cost the same as a miss of an “above” event?
    - Is the cost of a “miss” the same as a “false alarm”?

CATEGORY-BASED EVALUATION: GSS

- General Skill Score (GSS)
  - Measures skill relative to a random forecast of categories considering the relative frequencies of outcomes (0= same as a random forecast, 1= perfect)
  - Can be formulated to have relative weighting for errors
  - All of this accomplished through a scoring matrix: s_{ij}

$$GS = \frac{1}{N} \sum_{i=1}^{K} \sum_{j=1}^{K} n(F_i, O_j) s_{ij}$$

N = Total # of fcst-outcome pairs
n(F,O) = # of pairs in each fcst-outcome bin
S = Scoring matrix (score for each bin)
K = # of forecast categories

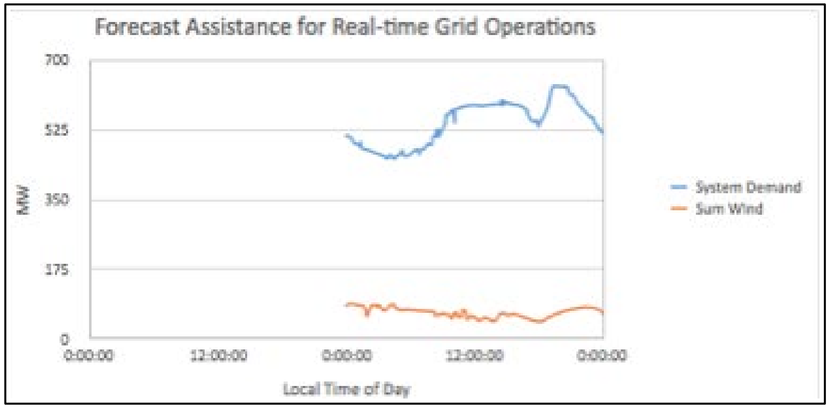
- Example of a Scoring Matrix (s_{ij})
  - Based on a 10%, 80%, 10% (below, typical, above) frequency of outcomes
  - 2-category errors are penalized twice as much as a 1-category errors
  - All other errors have the same weighting (misses, false alarms etc.)

SCORING		Forecasted		
	Category	Below	Typical	Above
Onserved	Below	1	-4	-1
	Typical	0	1	0
	Above	-1	-4	1

KEY DECISION MAKING TIMES AND ISSUES

SCENARIO #1: SHORT-TERM UNIT COMMITMENT FOR PEAK DEMAND PERIOD (5-9 PM LT)

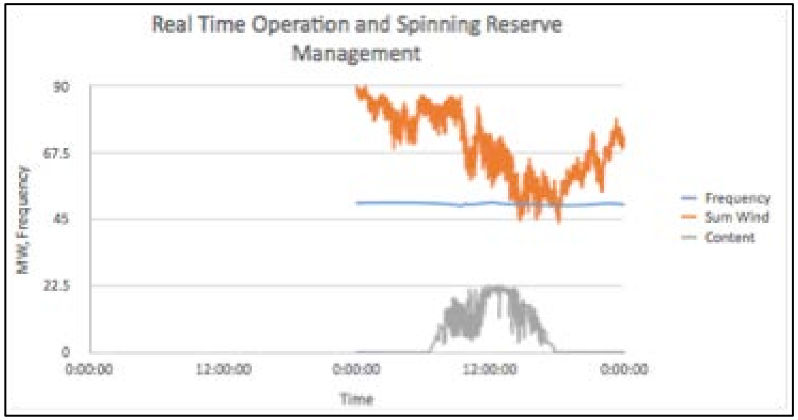
- Issue: What is the minimum wind generation that will be available?
- Example: June 11, 2018 (forecast products not yet available)
  - o Total actual wind generation: 40-90 MW
  - o 14 MW gas turbine was committed for evening demand peak period
  - o Spinning reserve was 39.6-89.8 MW
  - o If reliable wind forecast available:
    - ✓ 14 MW GT would not have been committed (savings)
    - ✓ Spinning reserve would have been: 25.6-75.8



Key forecast attribute: minimum wind generation during evening peak demand period forecasted at 1 PM each day

SCENARIO #2: MID-DAY SPINNING RESERVE MANAGEMENT

- Issue: What is the amplitude of wind and solar variability in the mid-day period?
- Example: April 15, 2018 (forecast products not yet available)
  - o Highly variable mid-day wind and solar generation
  - o A major responsive unit offline; 3 units operational- droop control disabled on one
  - o Frequent operation of Under Frequency Load Shed (UFLS) scheme
  - o If reliable forecast of the mid-day variability available:
    - ✓ Ensure that droop control was enabled for responsive units
    - ✓ Bring online the most efficient gas turbine with droop control

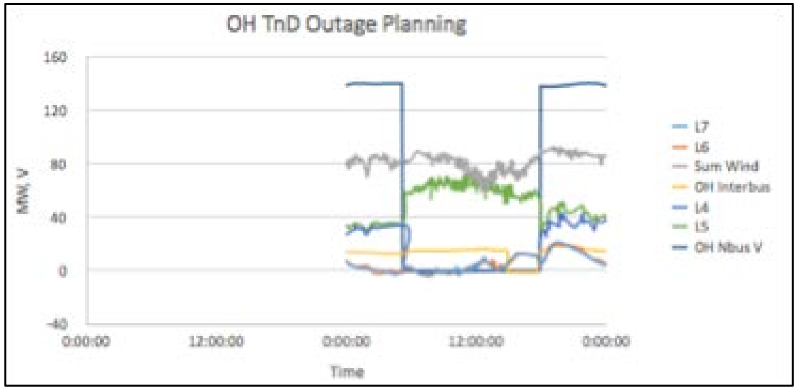


Key forecast attribute: hourly max & min of wind & solar generation during mid-day period: (1) next day outlook at 1 PM and (2) intra-day updates at hourly intervals from sunrise to mid-day

SCENARIO #3: DAY-AHEAD UNIT COMMITMENT AND T&D OUTAGE PLANNING

- Issue: What is wind and solar generation profile for the next day?
- Example: March 11, 2018 (forecast products not yet available)
  - o Substation with 2 transmission lines to major load center / 100 MW wind gen capacity
  - o Transmission outage scheduled and executed on one line for 5 AM – 5 PM
  - o Forced transmission through remaining line; wind curtailed at 10 AM
  - o If reliable wind and solar forecast during transmission planning:
    - ✓ further curtail inefficient thermal units that have long required uptime that are connected to the substation.
    - ✓ allow the acceptance of maximum output from the wind plants and any generation deficit made up by a more efficient unit at the same substation

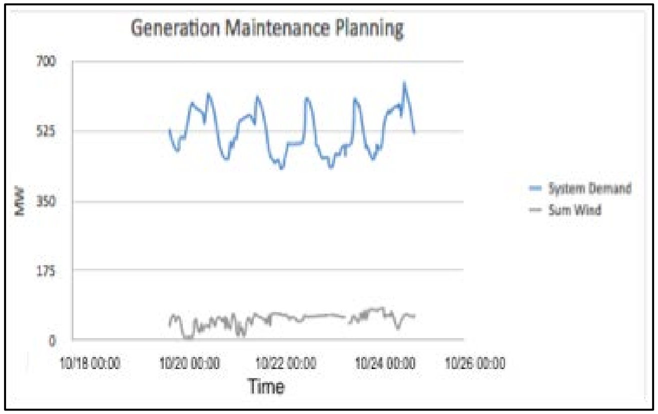
Key forecast attribute: minimum wind or solar generation for locations and periods of planned transmission lines outages provided at 1 PM of preceding day



SCENARIO #4: PLANNING FOR GENERATION MAINTENANCE

- **Issue:** will there be a sufficient contingency reserve during the peak demand period (i.e. the evening peak) to accommodate the planned outage ?
- Example: October 19-23, 2017 (forecast products not yet available)
  - o Generation outage of 30 MW (non-renewable) unit proposed
  - o 80 MW contingency reserve needed; renewable gen currently not considered
  - o Reserve considerations:
    - ✓Forecasted peak load: 625 MW
    - ✓Capacity without proposed outage: 714 MW
    - ✓Outage (-30 MW) results in reserve shortfall of 20 MW (outage declined)
    - ✓HOWEVER: minimum wind gen during evening peak was 19.9 MW – consideration of wind with a reliable forecast could have resulted in granting of the outage

Key forecast attribute: (1) min wind gen during the evening demand peak and (2) min wind and solar gen for mid-day for maintenance outage period provided 7-14 days in advance



SUMMARY AND NEXT STEPS

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- First phase of a 4-part project is underway to optimize the value of wind and solar forecasts in electric system operations of the Jamaica Public Service
    1. Identify key decision-making scenarios and critical forecast attributes
        - 4 have been identified thus far
    2. Define operationally-relevant forecast variables and performance metrics
        - Event-oriented and category-based approach will be used (not RMSE!)
    3. Evaluate (non-customized) existing forecasts with customized metrics
    4. Customize forecasts to obtain optimal performance for the key metrics

- Next Steps:
    - Compile application-relevant performance statistics for EXISTING (not-application-optimized) forecasts
    - Customize forecasts to achieve optimal performance for application-relevant metrics
    - Calculate the application-relevant performance statistics for CUSTOMIZED forecasts