Planning for High Levels of Renewable Penetration

Key Challenges and Approaches for Caribbean Island Systems

CARILEC Renewable Energy Forum

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Overview

High penetrations of renewables, in excess of 30% of the annual electricity demand, have the potential to lower and stabilize generation costs in Caribbean island systems. While attaining such levels has been shown to be feasible, successful implementation requires careful planning, adaptation of operating practices and inclusion of new technologies to better handle the increased variability and uncertainty associated with wind and solar. This presentation will describe best practices and lessons learned from past studies of the efficient and reliable integration of renewables, and will discuss key challenges and approaches to effective planning in systems with high renewables penetrations.

Cost of Generation

Primary fuel for islands are typically petroleum based

- Fuel Oil #2 (FO2) and Fuel Oil #6 (FO6)
  - FO2 is cleaner but twice as expensive as FO6
  - FO6 has lower cost but fuel characteristics (e.g., higher viscosity) leads to less operational flexibility
  - Both are used commonly for reciprocating engines, and in some islands for steam turbines and gas turbines
- Ease of transportation via ship, barges and trucks
- Impact of oil price fluctuations is much larger for island systems
  - Oil price impacts transportation cost of fuel
  - In some islands, the rule of thumb is:

    Price for a barrel of FO6 = Price for a barrel of crude oil at WTI
- Results in high marginal cost of generation
  - At WTI crude oil price of $100/barrel
  - FO2 based about $400/MWh
  - FO6 based about $200/MWh

High Resource Potential in the Caribbean

Ample renewable resources

- Many islands have good wind resources
  - High pressure system that circulates counter-clock-wise through the Caribbean
  - Temperature difference of land and sea creates wind
  - Wind profiles of islands tend to better correspond to load profiles
- High solar irradiance year-round
- Biomass, hydro, geothermal
  - Island-specific resources with good potential
- Opportunities to develop solar/wind resources
  - Short-run marginal cost is close to zero
  - Installation costs are low enough to make renewables competitive
  - Reduces reliance on fuel oil (fuel diversification)
  - No carbon dioxide emissions
- Political agenda/goals
  - Aruba and Saint Lucia: Become 100% renewable by 2020
  - U.S. Virgin Islands: Reduce fossil energy consumption by 60% by 2025
  - Hawaiian Clean Energy Initiative: 40% of energy from renewables by 2030

Challenges of Variable Resource Integration

Island Load Characteristics

- Small load in limited geographic region
  - Dominant industry is often tourism: hotel A/C loads can be 60-70% of total load
  - Relatively smooth and predictable load profile with little growth
  - Limited diversity of load

Existing Generation Characteristics

- Designed to serve historical island load
  - Limited ramping capability (smooth load did not require ramping capability)
  - Limited ancillary service capability (some generators provide no regulation)
  - Smaller generators with lower inertia

Renewable Resources

- Requires ancillary services for successful integration
  - Limited geographical diversity
  - Difficulty of optimizing capacity
    - A single plant may become a huge portion of the capacity mix
    - Smaller size leads to higher capital costs

Long Term – Security of Supply

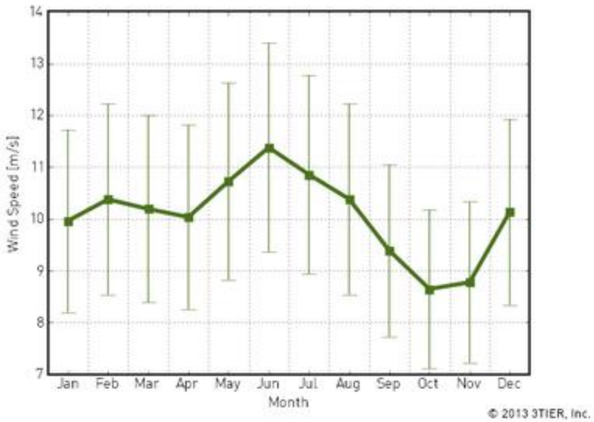
Developing generation capacity is like buying insurance

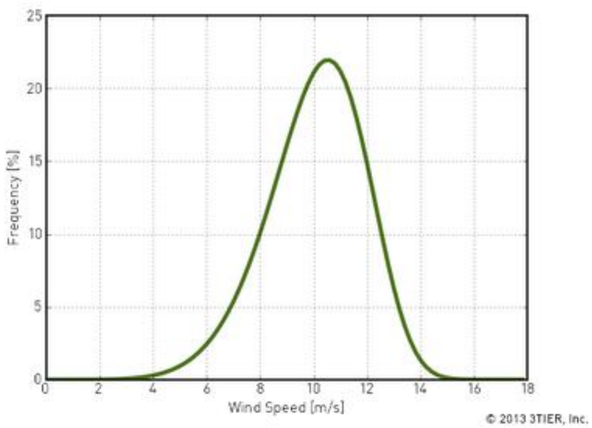
Utilities need physical insurance

- Renewables do not offer physical insurance in the islands
- Traditional thermal generation needs to be maintained as physical insurance
- Alternatively, storage may also provide physical insurance

High and volatile fuel costs require "financial insurance" (hedging)

- Renewables do provide fuel diversity and financial hedging
- Annual renewable "yield" varies
  - The difference between a good and a bad year for wind can be over 50%!
- To ensure enough yield ("insurance coverage"), plan for a bad renewable year…





Impacts on Operation

Wind and solar are variable resources

- Minute by minute variation of the renewable resource generation can be much larger than load variations

<table>
<tr><th>Challenge</th><th>Timeframe</th><th colspan="2">Description</th></tr>
<tr><td>1. Stability/ Inertia</td><td>milliseconds – seconds</td><td colspan="2">Small system inertia, load shed during unit outages, wind units usually provide no inertia response</td></tr>
<tr><td>2. Regulation</td><td>seconds – minutes</td><td>Large net load fluctuations</td><td rowspan="3">Low diversity in demand, wind and solar resource</td></tr>
<tr><td>3. Ramps/ Load Following</td><td>minutes – hours</td><td>Large ramps</td></tr>
<tr><td>4. Demand Cycles</td><td>hours – months</td><td>High peaks and low valleys</td></tr>
<tr><td>5. Voltage Regulation</td><td>seconds – hours</td><td colspan="2">Newer wind and solar units can provide voltage control</td></tr>
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Impacts on Operation

Operating flexibility is a key need

Required ancillary services

- Fast response to address regulation needs (especially for solar)
- Increase operating range to accommodate sustained ramps (up and down)
- Responses to address contingencies and maintain reliable service (unit trips etc.)
- Batteries or flywheels are usually needed to attain high renewable penetrations in small island systems

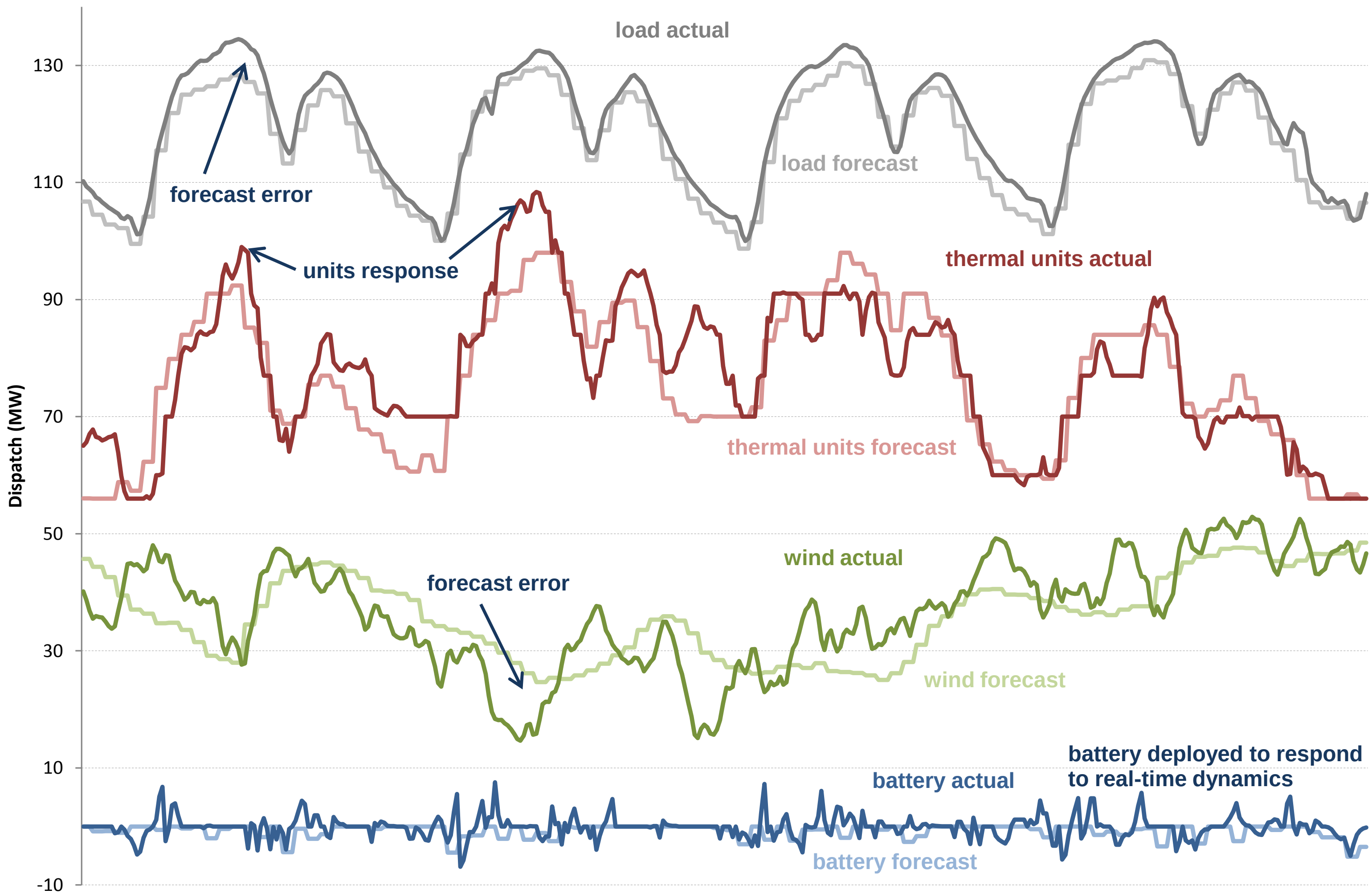
Minimum generation constraints of thermal units

- Low net load situations tend to drive curtailments in some systems
- Effective minimum generation is higher than technical minimum when thermal units provide down reserve
- Reduce minimum generation when possible…

Renewable generation (and storage) control is critical

- Systems with high renewables and distributed "net metering" developments can be very challenging to operate
- Not all storages are equal
- Utilities must be able to curtail renewables

Impacts on Operation – Simulation



4-day summary of a PSO operations simulation for an island system

Skilled Manual System Operation

Recommendations

Full system automation is required

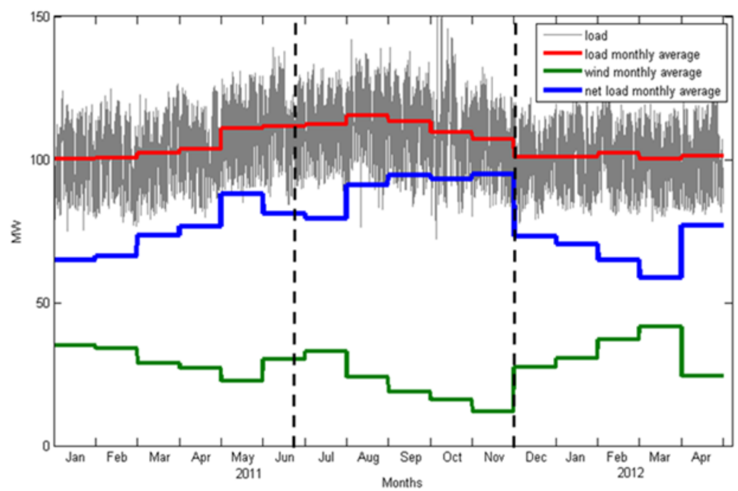
- Wind and solar fluctuate continuously
- Automation is needed for decision making (e.g., when to start a unit) and for their implementation (e.g., start the unit)
- Dispatch/load sharing/following/regulation
- Start up/shut down

Operational forecasts

- Required for automation
- Load forecasts
  - Very specific for each utility
- Wind and solar forecasts
  - Joint procurement of forecasts
  - Meteorological data sharing

Sensing, metering and recording

- Start measuring and recording now…
  - Operations data
  - Renewable potential



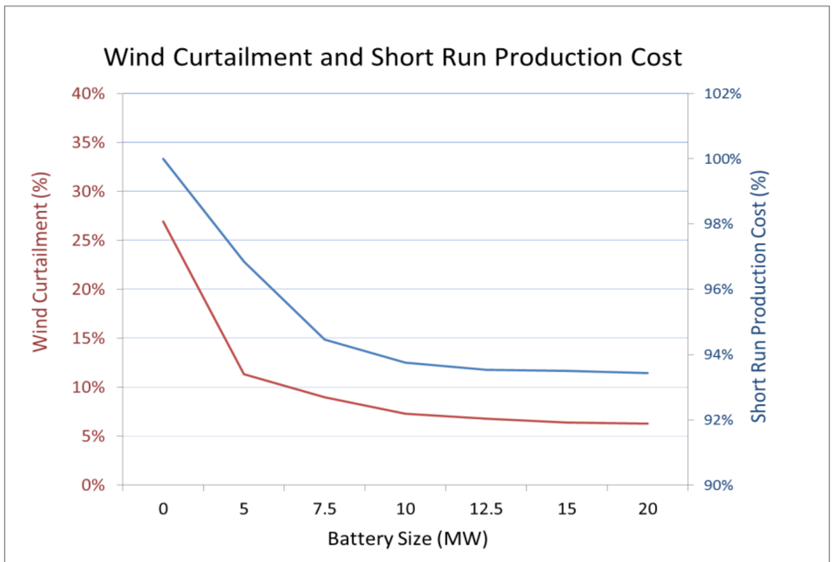
Period \ MW	Average Load	Wind Generation	Net Load
Dotted Period	110.4	41.4	69.0
Other Periods	103.1	58.6	44.5
Entire Period	106.2	51.4	54.8

Successful Integration

Successful integration: Utilizing renewable potential with minimum curtailment to replace fossil fuel generation reliably and cost-effectively.

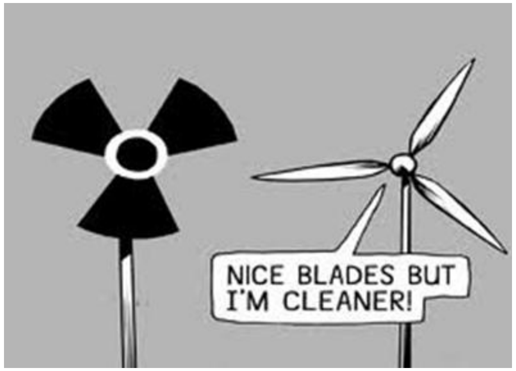
60MW of wind + 10MW of solar in an island with an average load of 100MW

- Peak load: 135MW
- Min load: 75MW



- Automation implemented
  - Payback period of 1-2 years
- Battery/flywheel system
  - Largest benefit (and cost)
  - Mostly for reserves
- Wind providing reserves
  - Modest benefits (less than 1% in SRPC, 2 – 3% reduction in wind curtailment)
  - Additional payment method for curtailing wind
  - No reason not to implement
- Demand response (peak shift)
  - Sizable benefits (2 - 4% in SRPC, about 8% reduction in wind curtailment)
  - Most savings remain in the utility and customers
- In all options, number of starts, especially for quick-start units, were reduced significantly.

Contacts



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