# How much renewable energy can the Caribbean grid take- The Jamaican Experience

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## How much renewable energy can the Caribbean grid take

- Portugal kept its light on for 4 days straight on renewables only in May
- Germany in the same month on one day announced that clean energy produced more that 90% of its energy needs one day in the same month
- Hawaii clean energy initiatives target is 100% by 2045

## Overview of presentation

- A brief look at Integrating Variable Renewable Resources (VRR)
- The main challenges posed by VRR integration
- The Jamaican Experience
- Short term responses/longer term solutions-spinning reserves, storage, smart grid
- Looking Forward

## Global Context

- Globally, significant investments are being done in renewable energy technologies
- Increased focus of decarbonisation and protecting the environment
- Cost for Renewables are reducing at a significant rate
- Technology advancements-Smart Grid /Storage-improved, lower cost

# Regional Context

- Energy vital to growth and socio-economic development
- Most Caribbean countries import fossil fuels to satisfy more than 90% of its energy needs
- Caribbean markets highly susceptible to world energy price volatility

The Caribbean Community (CARICOM) has launched the latest renewable energy roadmap targeting 48 percent renewable energy generation by 2027


# Regional Context

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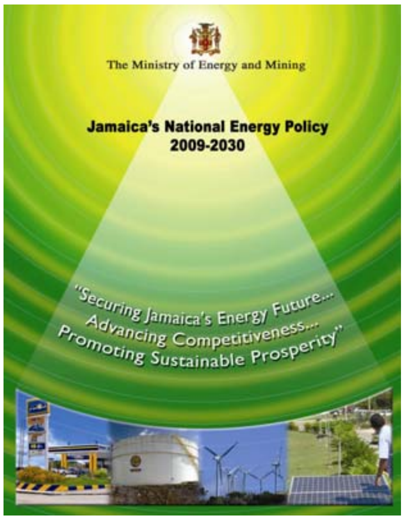
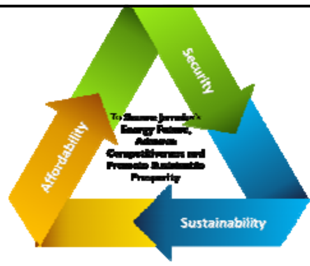
## Jamaican Context – Energy Policy 2009-2030

- Reduce the over-dependence on imported oil for electricity production
- Requires a diversified energy base with focus on “green” and “clean” technologies
- Requires reduction of our carbon footprint and protection of the environment
- Promotion of energy efficiency and energy conservation and grid modernization to accommodate these goals
- Requires that by 2030, renewables (solar, hydro, wind, biofuel) will be 20% of the energy mix.




## About JPS

- Est. 1923
- Ownership: EWP (Korea) 40% Marubeni (Japan) 40%, GOJ ~ 20%
- Vertically Integrated Utility - Sole Transmission and Distribution, Liberalized Generation (incl. IPPs)
- Installed Capacity: ~ 1,024 MW (JPS + IPP), Fossil, Hydro, Wind, Solar
- Peak Demand: ~ 655 MW, May 16, 2016
- Approximately 16,000 km of T&D, 138kV and 69kV, 55 Substations, 28 Generating Plants
- Customer base: ~ 606,650
- Staff: ~ 1700




## Two major Categories of Challenges

- **Technical Challenges**: Ensuring power system reliability and stability as uncertainty and variability increase.

- **Economic, Policy, and Regulatory Challenges:** Effectively managing the cost of RE integration and designing policies to harness maximum value from RE (true cost on integrating renewables, IRPs)

## Technical Challenges

- The uncertainty and variability of wind and solar generation can pose challenges for grid operators. Variability becomes increasingly difficult to manage as penetration levels increase.

  - Electric power system operators must consider the **frequency response** and system balancing ( load/generation)

  - Historically, this led grid managers to monitor load and direct generators to ramp up or down in response to load variation. **As wind and solar penetration has risen, grid managers now also need to take into account sudden increases or decreases in power output from these weather-dependent generators**

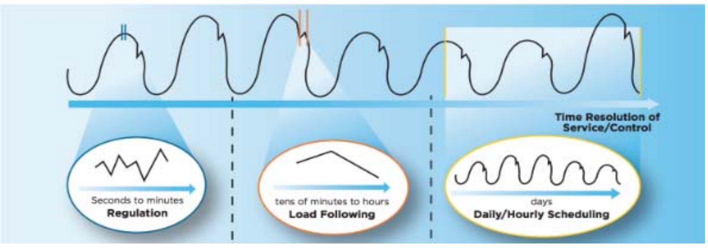
## Primary concern for Grid Stability is System Balancing

- Generation (supply) and system load (demand) must be balanced at all times
- **This balance is measured by system frequency (nominal frequency = 50 Hz)**
- If generation is higher than load, frequency rises above 50 Hz; if generation is lower than load, frequency declines below 50 Hz.

## What is the impact of VRR on grid stability

- If generation suddenly reduces-wind stop blowing or turbine trips off lines, or there is a sudden cloud covering-frequency will suddenly decrease resulting in instability.
- Large sudden frequency reduction can lead to under-frequency load shedding and cascading grid instability
- As Island Grid systems, we cannot rely on neighboring interconnected utilities for contingency support.

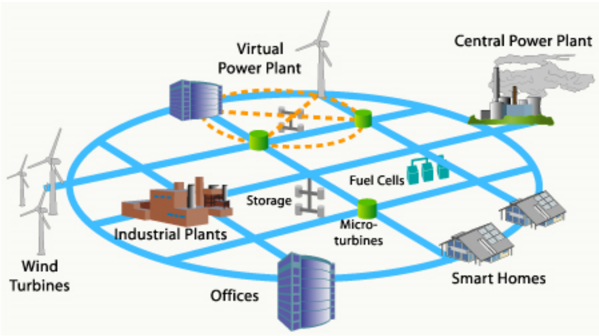
## Effects of VRR on the Power Grid-The Jamaican Experience




- Intermittent renewables are challenging the traditional methods for planning the daily operation of the electric grid.
- VRR is now forcing the grid operator to adjust its day-ahead, hour-ahead planning to **real-time operating** procedures.

## Installed Renewables-Oct 2016

- **80 MW Intermittent Power addition in 2016**
  - 24 MW Wind Power in May 2016
  - 36 MW Wind Power in June 2016
  - 20 MW Solar Power in May 2016



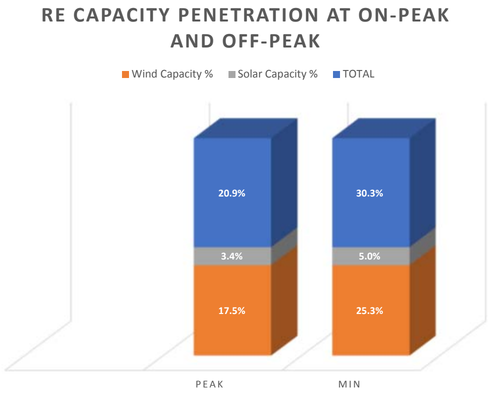

**Total**

- Installed Hydro Capacity - 29.12 MW
- Installed Wind Capacity - 101.3 MW
- Installed Solar Capacity - 20 MW
- Roof Top Solar - 4MW

## The Jamaican Context – Renewable Energy Capacity Penetration

- Total Capacity = 1,024 MW
- Existing RE capacity =150MW or 14.6%
  - VRR (Wind + Solar) = 120MW or 11.8%
- Projected RE Capacity = 17.7%
  - VRR (Wind + Solar ) = 14.5%

| | Day Peak | Min |
|---|---|---|
| **Demand (MW)** | **580.0** | **400.0** |
| Wind Capacity % | 17..5% | 25.3% |
| Solar Capacity % | 3.4% | 5.0% |
| **TOTAL** | **20.9%** | **30.3%** |

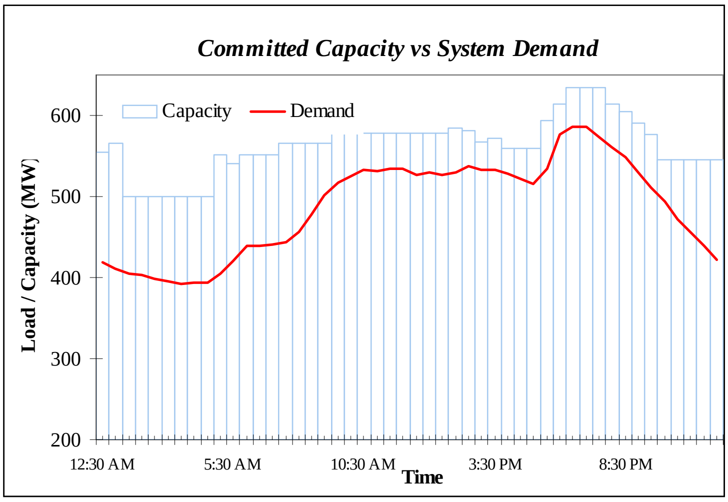


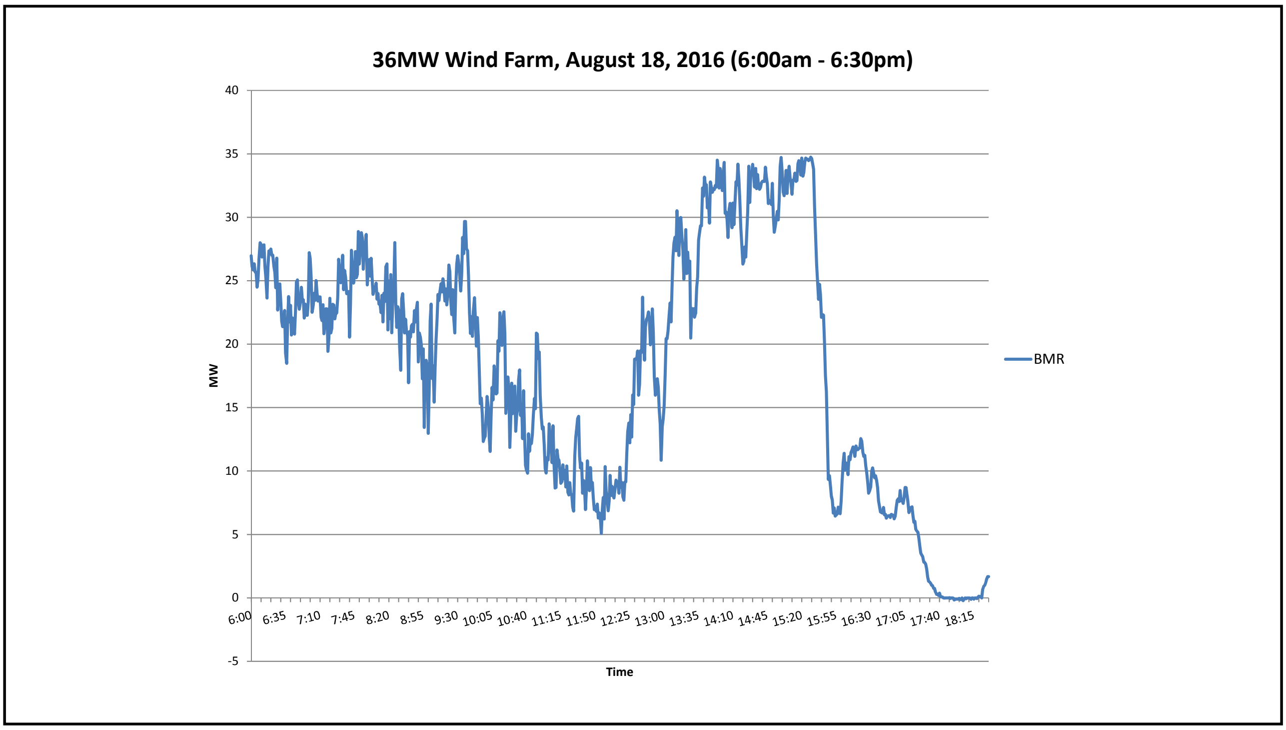

Research indicates that in most large scale grid systems, VRR < 10% of peak capacity has little impact on system operation. Larger Shares will present challenges for System Operators.

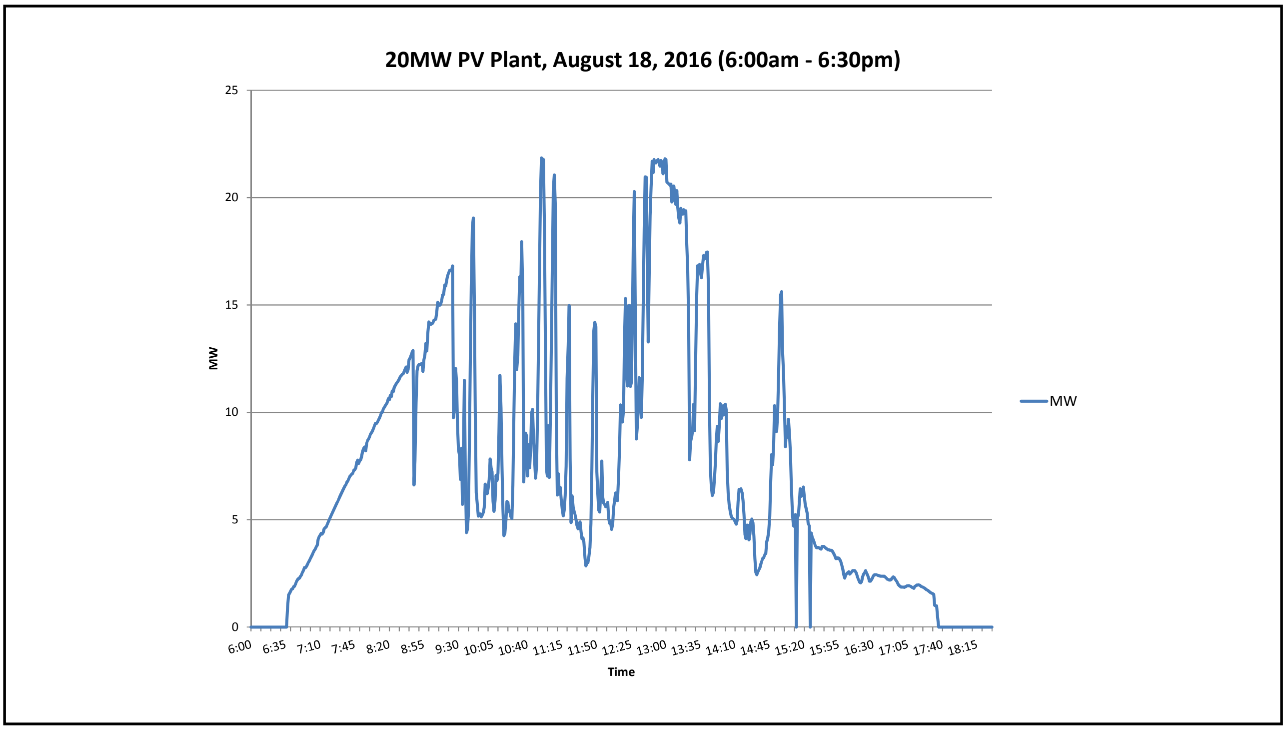
*Wind Energy and Power Systems Operations: A review of Wind Integration Studies to Date" The Electricity Journal, Vol 22, Issue 10, 34-43.*

## Jamaica Load Profile and Capacity

- Evening Peak - Highest energy demand
- Demand met by load-following dispatchable base-load plant
- Quick-Start GT's brought online for short term capacity shortfall or peaking
- Current demand intermittency is absorbed by spinning reserves – 29 MW




36MW Wind Farm, August 18, 2016 (6:00am - 6:30pm)
MW
40
35
30
25
20
15
10
5
0
-5
6:00
6:35
7:10
7:45
8:20
8:55
9:30
10:05
10:40
11:15
11:50
12:25
13:00
13:35
14:10
14:45
15:20
15:55
16:30
17:05
17:40
18:15
Time
BMR


20MW PV Plant, August 18, 2016 (6:00am - 6:30pm)
MW
25
20
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8:55
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17:05
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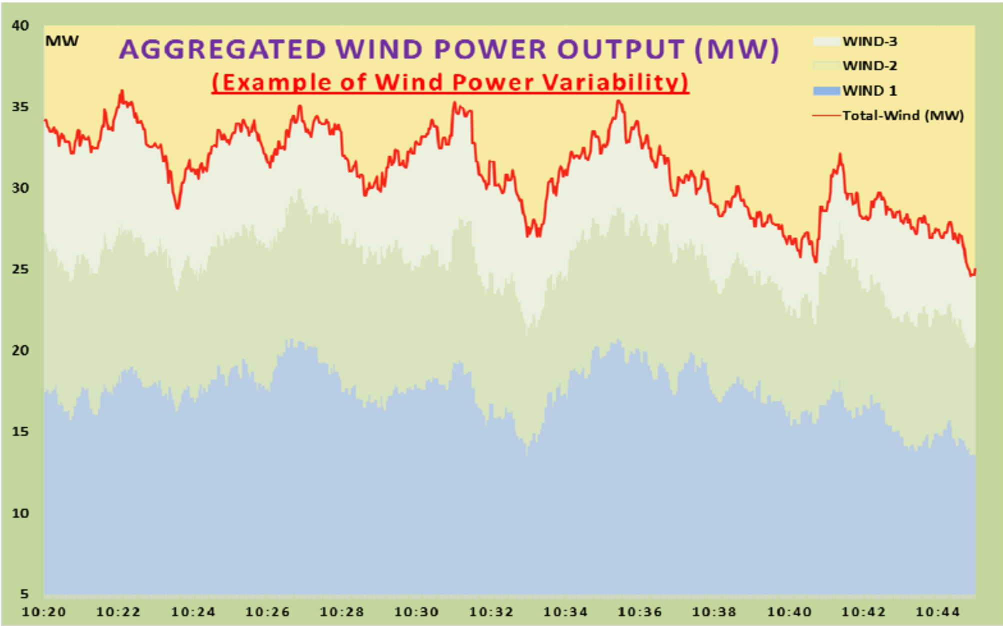
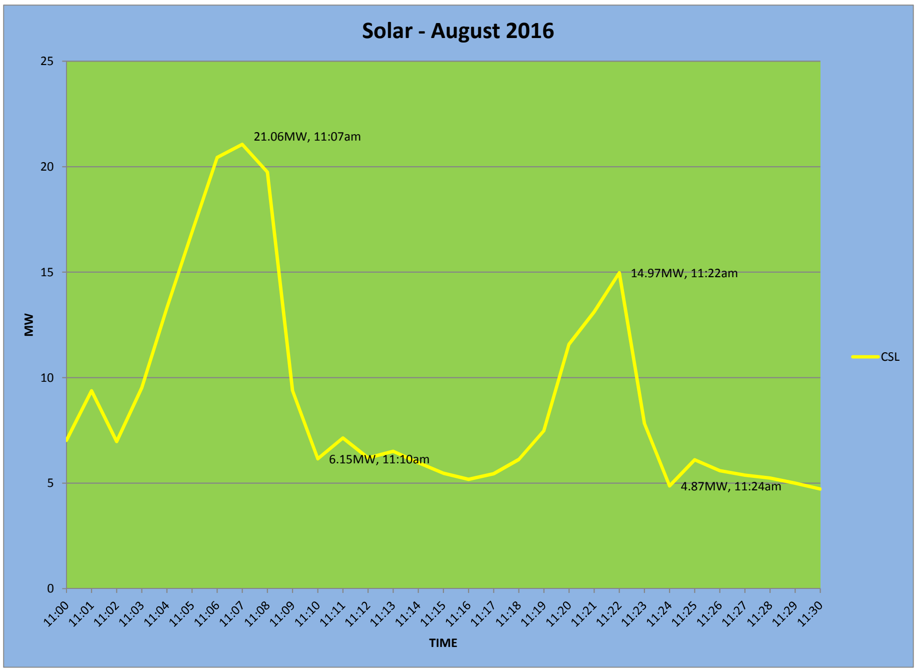
18:15
Time
MW


AGGREGATED WIND POWER OUTPUT (MW)
(Example of Wind Power Variability)
MW
WIND-3
WIND-2
WIND 1
Total-Wind (MW)
40
35
30
25
20
15
10
5
10:20
10:22
10:24
10:26
10:28
10:30
10:32
10:34
10:36
10:38
10:40
10:42
10:44


Solar - August 2016
21.06MW, 11:07am
14.97MW, 11:22am
6.15MW, 11:10am
4.87MW, 11:24am
CSL
MW
TIME
25
20
15
10
5
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11:00
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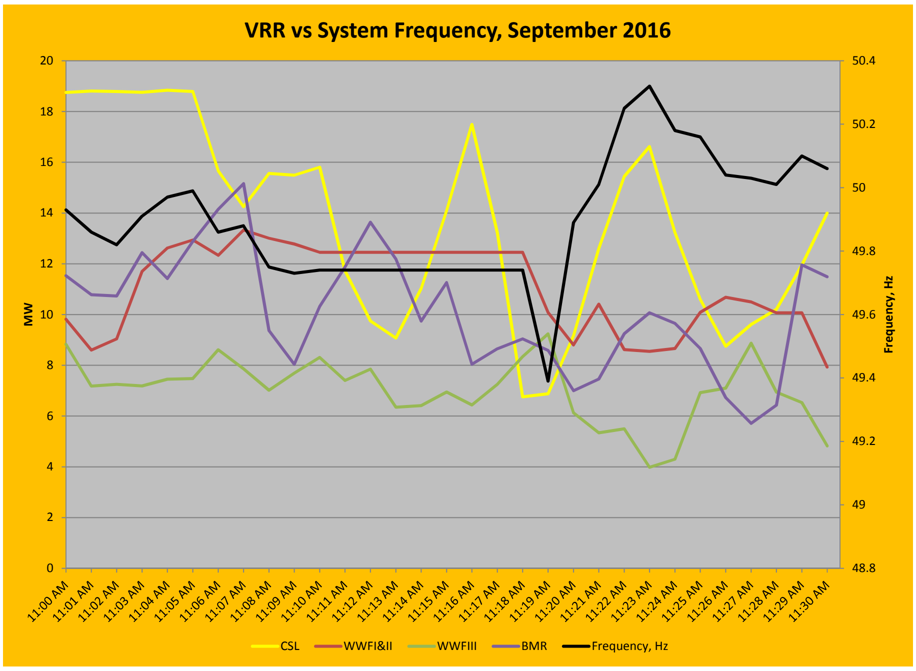
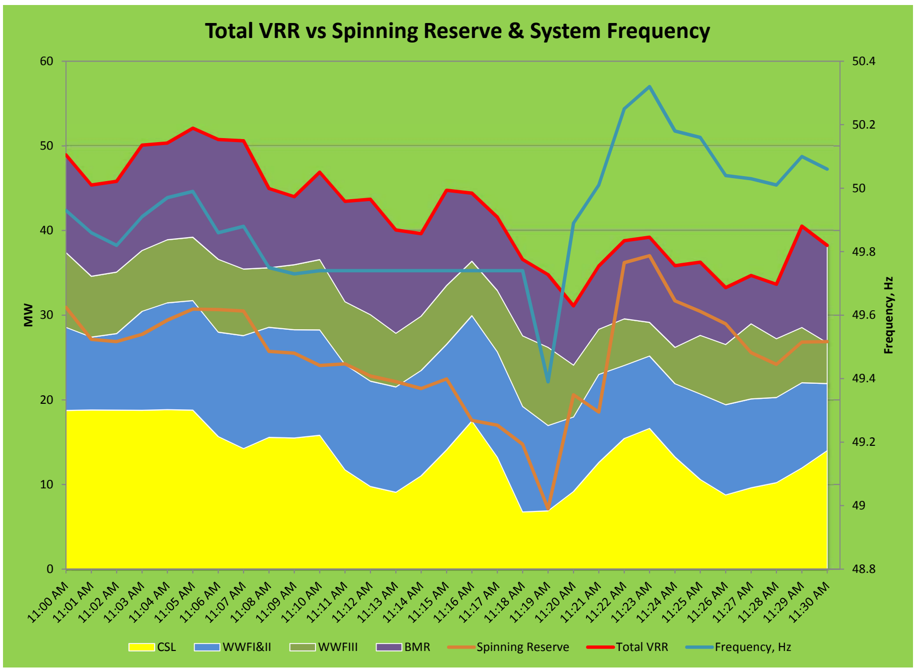
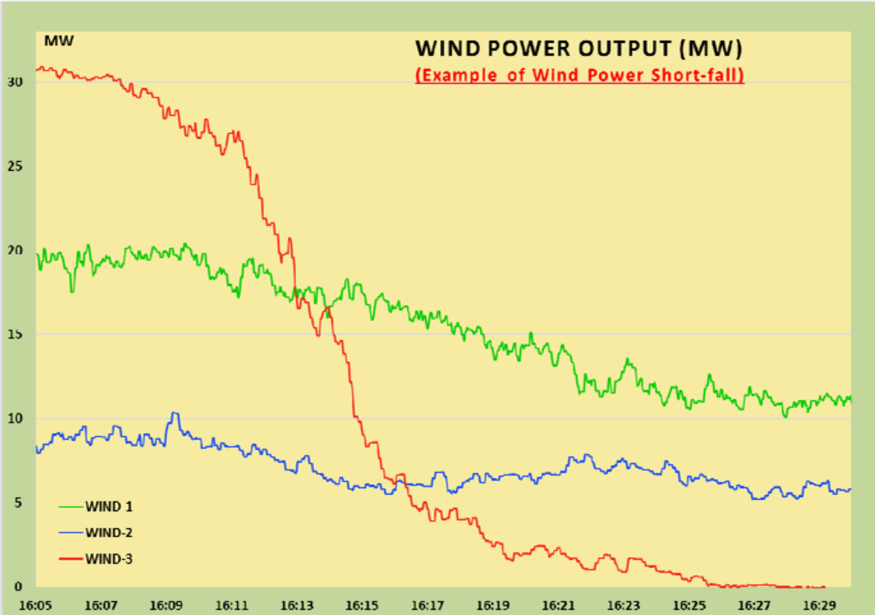
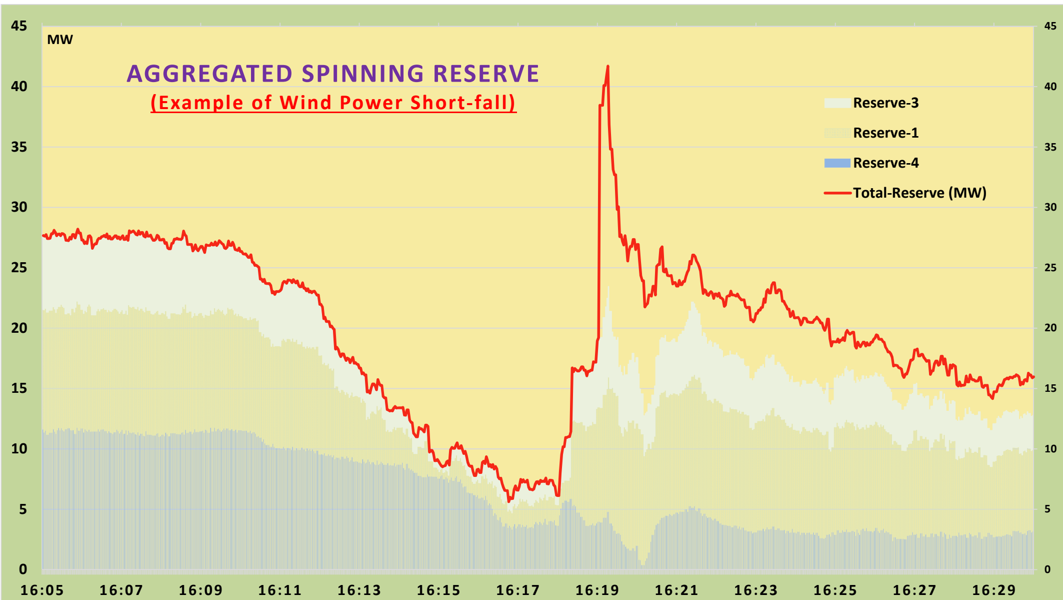


VRR vs System Frequency, September 2016
MW
Frequency, Hz
CSL
WWFI&II
WWFIII
BMR
Frequency, Hz

Total VRR vs Spinning Reserve & System Frequency
MW
Frequency, Hz
CSL
WWFI&II
WWFIII
BMR
Spinning Reserve
Total VRR
Frequency, Hz

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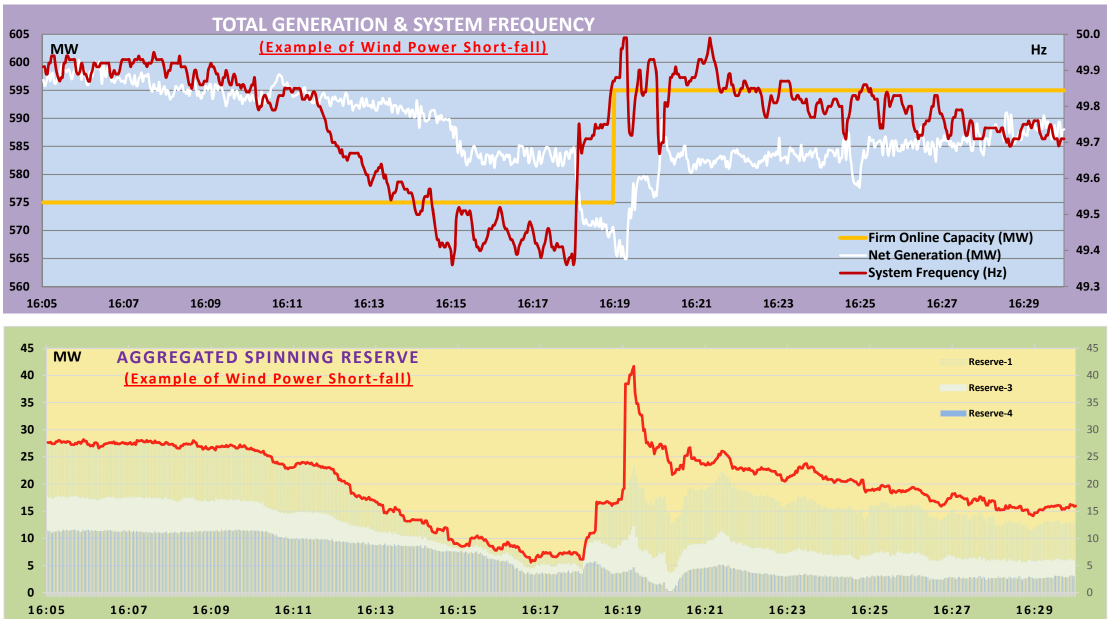


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# CONCERNS:

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- What **levels of Spinning Reserve** need to be maintained to buffer the effects of such high variability?
- How many generators online are capable of **adequate Governor response**?
- What to do if the **Wind suddenly stops** blowing or Wind units go offline?
- What is the balance between a policy of **Shed and Restore** and **High Spinning Reserve** Levels?

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## Short Term Measures from 2016 onwards

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- **Declaration of Machine Availability for Spinning Reserves**
  - Procedure to ensure compliance with GPCR requirement
  - Machine "testing" twice daily on AGC units carrying SR
  - Real time declaration of Units availability and ramping capabilities
- **Rate of Change alarm for Renewables on the Grid, Renewable Forecasting Improvements**
  - Site specific data, week ahead sub-hourly (small resolution) projections
  - Real time comparison between actual output and forecast
- **Improve Ramp Response of Machines**
  - Performance based maintenance programme for machine governor tuning
- **Review of Load Shedding Scheme**
- **New tools /skills for dynamic stability modeling**
- **Spinning reserve adjustments**

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## Medium to Long term Measures From 2016 onwards

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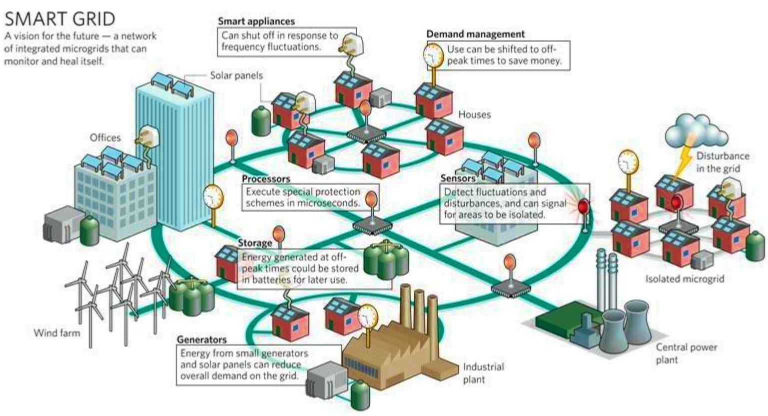
- Storage
- Smart Grid

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# Long term Measures
# From 2016 onwards



**Energy Storage**
As renewable generation grows it will ultimately overwhelm the ability of conventional resources to compensate renewable variability, and require the capture of electricity generated by wind, solar and other renewables for later use.

**Demand Response**
Demand-side flexibility can also aide in the integration of variable renewable generation, particularly in cases of fast ramps or extreme events.
Demand response can be used to supply reserves as well as peak reduction



# Storage



**Energy Storage**

## Grid-Scale Energy Storage Economical Benefits for JPSCo.

Time-Shifting

- Store Cheaper Electricity generated during off-peak hours and dispatch to much higher demand peak.
- Store excess energy that would otherwise be cut back to avoid reliability issues.

Regulation and frequency Response

- Can replace generation units used to increase or decrease voltages as needed.
- **Used to respond to variations in frequency.**

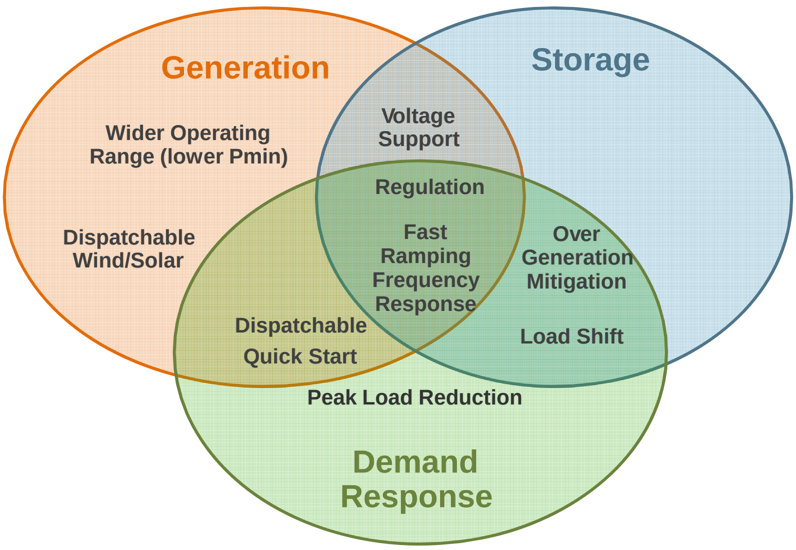
Spinning, Non-Spinning, Supplementary Reserves

- Can provide all three

Increased Penetration of Renewable Sources

- Crucial for eliminating weather-induced fluctuations in electricity production from wind and PV systems.

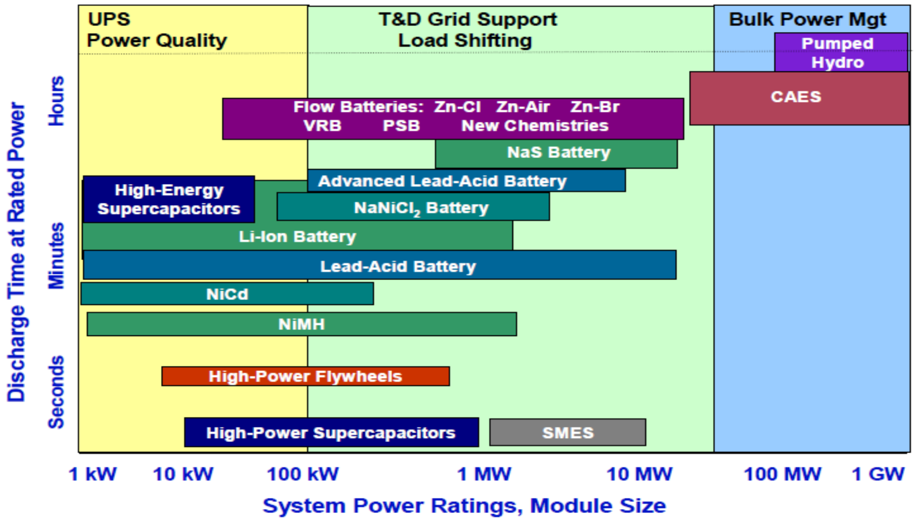
# Grid-Scale Energy Storage Reliability Factors




## Other Performance Factors

- Self generation (with RES) (Micro grids)
- Reliability improvement
- Demand Charge management
- Volt/VARS management
- Demand side management
- Electric Vehicle Charging

# Position of Energy Storage Technologies

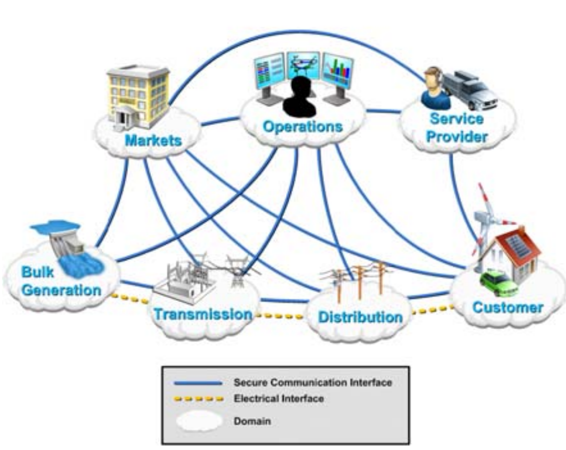



Source: http://www.iec.ch/whitepaper/energystorage/

Key Lesson: Energy storage systems are designed effectively to address different needs. Avoid one size fits all solutions.

# The SMART GRID

***"A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies"*** *– European Technology Platform Smart Grid (ETPSG)*




NIST Conceptual Reference Model

## The Smart Grid

A **SMART GRID** is an electric power delivery system stretching from generation to the point of consumption

Key Characteristics are:

- Integrated with advanced IT systems
- A communication network that supports real time bi-directional communication
- Connected sensors and control end point devices
- Advanced Grid Management Systems (SCADA/DMS)

These systems work together:

- To optimize power resources
- Reduce costs
- Increase the stability and quality of power supply.
- The smart grid also better supports renewable energy integration and distributed power generation



## Smart Grid can help

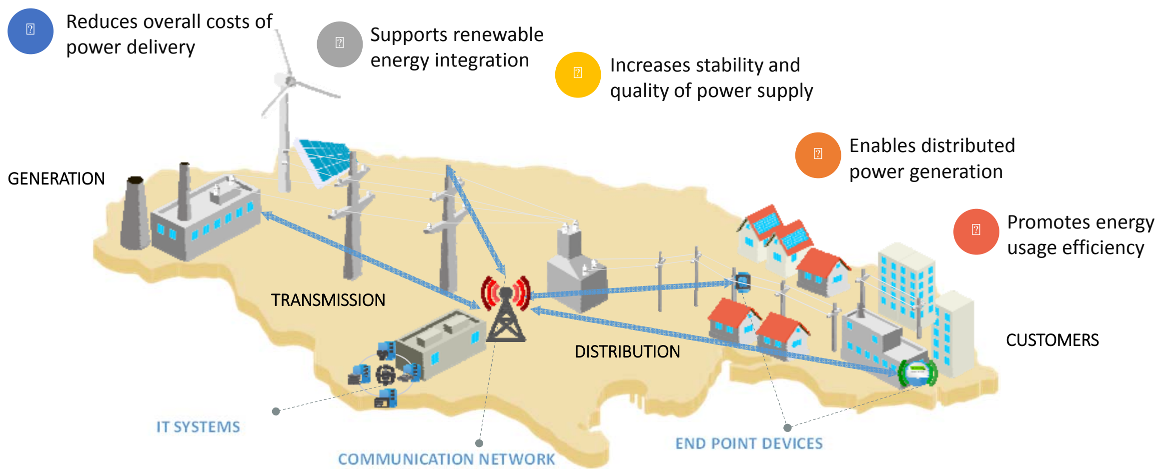
***Better forecasting.*** Widespread instrumentation and advanced computer models allow system operators to better predict and manage RE variability and uncertainty.

***Demand response***. Smart meters, coupled with intelligent appliances and even industrial- scale loads, can allow demand-side contributions to balancing.

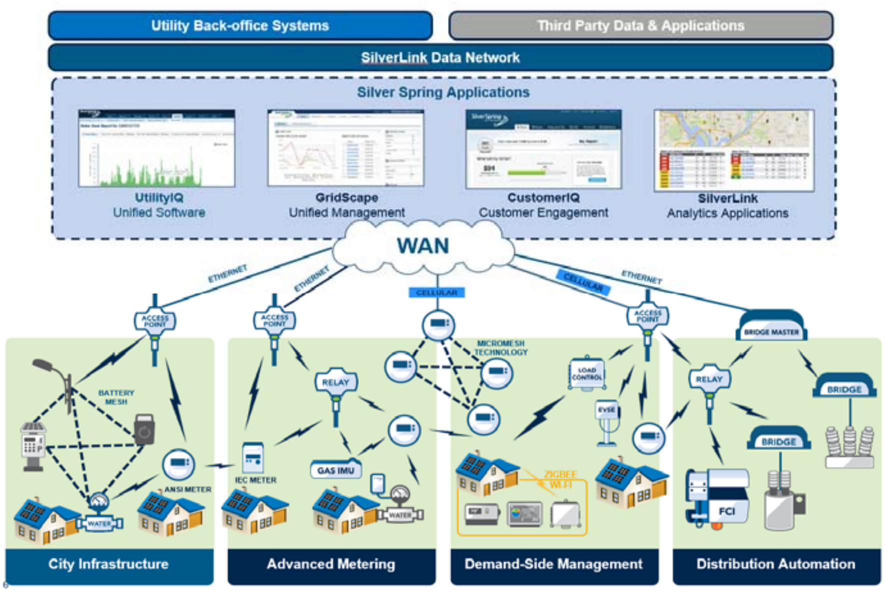
***Integrated storage***. Storage can help to smooth short-term variations in RE output, as well as to manage mismatches in supply and demand.

***Real-time system awareness and management***. Instrumentation and control equipment across transmission and distributions networks allows system operators to have real-time awareness of system conditions, and increasingly, the ability to actively manage grid behavior.

# Smart Grid




# Communications network is a key enabler

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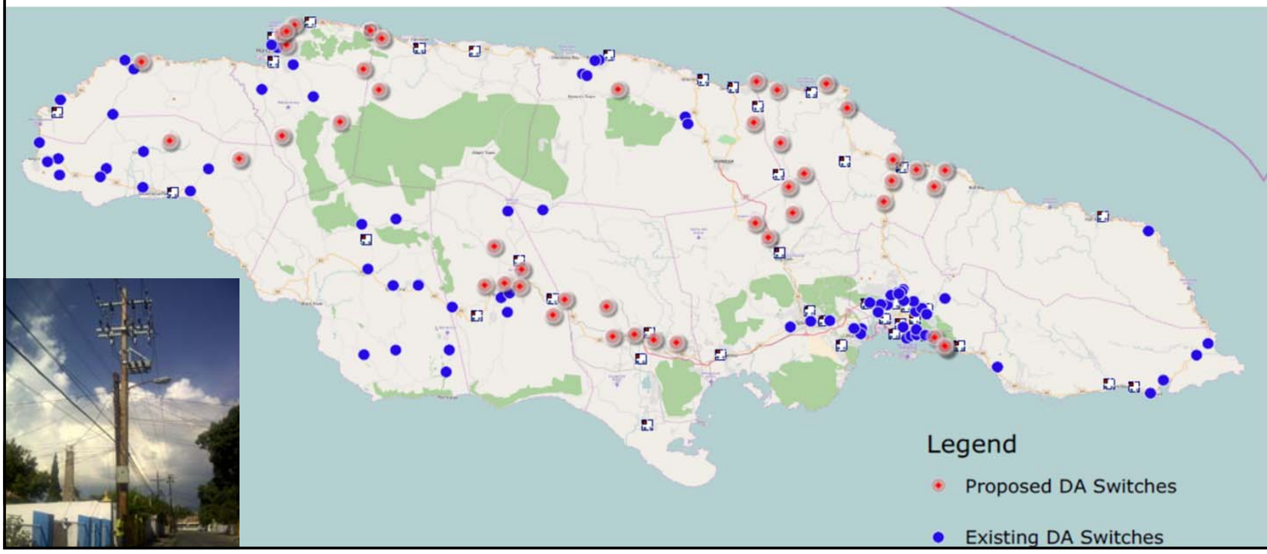
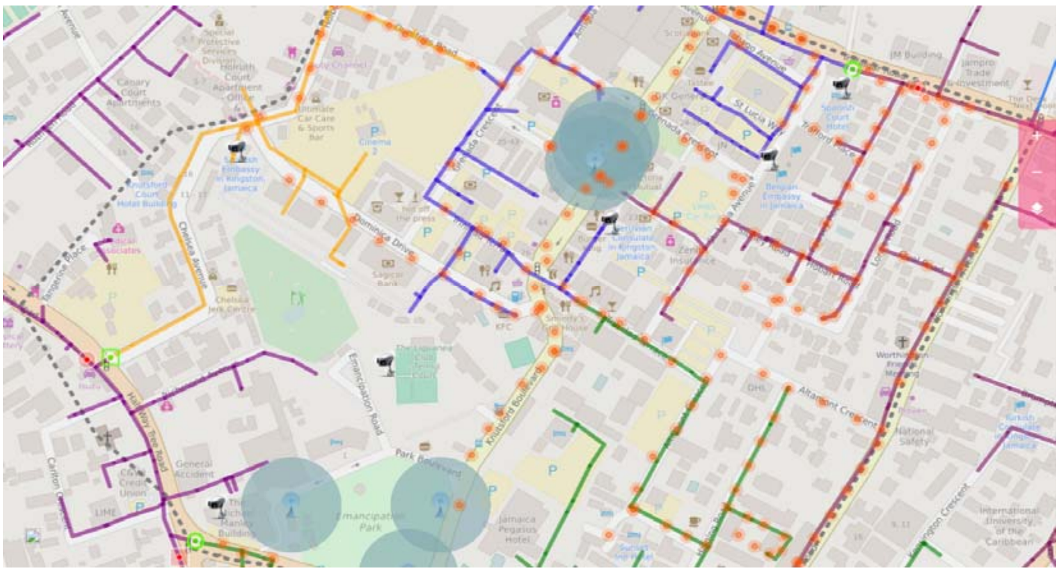
## Smart Devices installed in JPS grid-outage frequency and duration decreased significantly in 2015




## New Kingston –First Smart City-2017



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# Smart Grid and VRR's

- What share of VRR is possible with more effective use of existing flexible resources? **No one size fits all**, careful studies and simulations are necessary.

- Integrated Resource Planning using, for example, the Flexibility Assessment (FAST) method developed by the IEA( International Energy Agency) Grid Integration of Variable Renewables (GIVAR) project.

- IEA identifies four technical flexibility resources that can aid in the integration challenge:
  - **Dispatchable plants**: Load-Following Generators with ramp-up/ramp-down and short start-up/shut-down times
  - **Storage**: batteries, pumped hydro, compressed air, flywheels
  - **Interconnection**: to neighbouring utilities/systems
  - **Demand-Side measures**: Customer participation in power system operation – load shifting, load shedding etc., **SMART-GRID Technologies are integral components**

## SMART GRID- towards a self healing network

01

**01** Large number of fast acting sensors throughout the , protection devices, fast communication network, linking each node in real-time, fast acting algorithms, intelligent processors optimising power flows

**02** Constantly looking for problems that can trigger larger and cascading disturbances on the network. Similar to Real-Time Contingency Analysis, computers would assess trouble signs and possible consequences and automatically adjust grid characteristics to avert or minimise any disturbances

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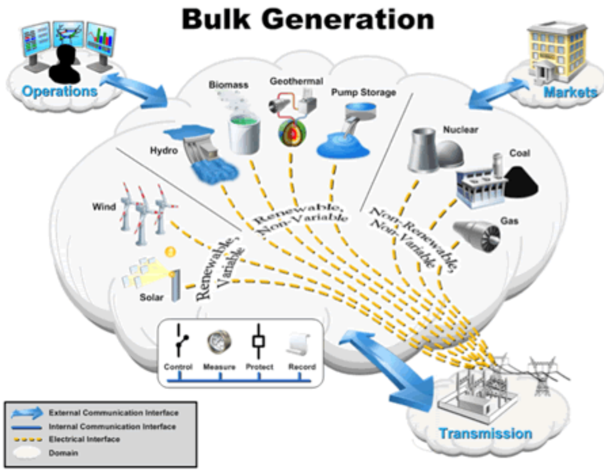
# Flexibility is the Answer!

- Flexibility expresses the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise
- Curtailing the VRR output when necessary to prevent surplus
- Achieving Near-Instantaneaous Ramp Rates




NIST Conceptual Reference Model

# Control Room Improvements

- High resolution visualization of grid status and health
- **Automated Demand Management**
- Algorithms that identify intermittency events and look-ahead
- Integrated forecasting software that allows for more accurate dispatch
- Ability to manage the connection or disconnection of micro-grids
- Work force demographics and skills

# Conclusion

- **All electric grids are different and the optimal solutions for addressing integration vary accordingly. The least-cost options available to individual grids depend on the overall flexibility of the grid because of the generation state and mix (including the renewable energy penetration), regulatory structure and operational practices.**

- **Integrated Resource Plan (IRP) is an absolutely necessary tool to understand and predict impact on Grid. Policy makers must see this as a critical tool in driving renewables penetration decisions**

  - Establish the existing flexibility of the grid to integrate new resources
  - Determine the optimal size and sites for renewable energy projects (resources)
  - Ensure grid sustainability through generation units with appropriate ramp and frequency stability capabilities
  - Facilitate better collaboration with customers in Distributive Generation, who are producing electricity and selling back to the grid

- **Policy makers must also consider whether the regulatory paradigm can be redesigned to best support the revolution taking place in the energy industry**

- **Storage Business cases are still immature and are very case specifics**