Smart grids, Micro-grids and the Modern Grid:

Safe and reliable electrical distribution through defense in depth

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ELECTRICITY IS A FLEXIBLE AND IMPORTANT ENERGY CARRIER WHOSE EFFECTIVE USE IS CENTRAL TO A MODERN SOCIETY

A century old technology – the grid is being transformed by the movement to the "Smart Grid"

- There are definitions of the "smart grid" – the grid is already pretty smart and the question is, "what is changing to make it smarter?"
  - Primarily changing through the increase in information collected and the application of decision support tools to use that information …
- Resulting in:
  - improved reliability/resilience,
  - efficiency,
  - reduced cost,
  - more rapid recovery,
  - greater customer empowerment
  - …and more effective renewable integration …

INCREASING THE SMARTNESS OF THE GRID IS ALSO ENABLING A RETHINKING OF GRID ARCHITECTURE

Introduction to Next Generation Microgrids

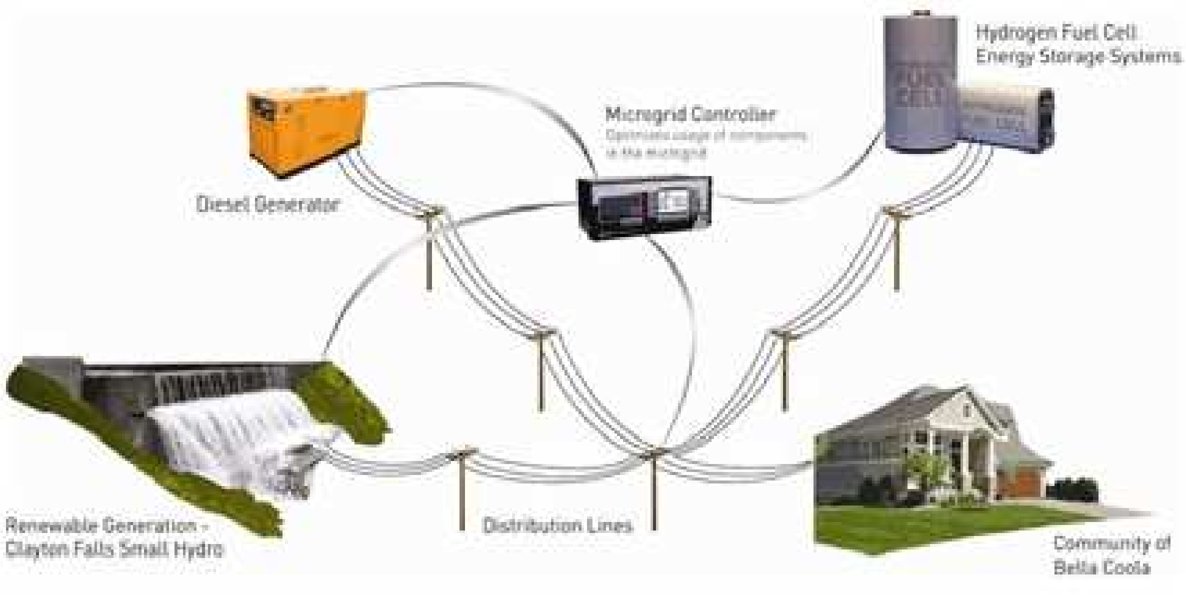
- The concept of a microgrid is an old one in which a customer can separate itself fro the grid an provide basic energy services with its own generation - this concept is being generalized in practice in many places.

- The Next Generation Micro-Grid can be defined as a portion of the grid capable of being independently managed to achieve greater resilience in operations, optimized for reduced losses, leverage all sources of generation under the right circumstances to deliver an improved customer experience.

- There are a core set of configurations of differing intent:
  - Classic separable micro-grid
  - Defensive micro-grid
  - Demand response micro-grid
  - Controlled Separation Island
  - Recovery island
  - Island like feeder (or dependent muni/coop)
  - Real Islands

Key Considerations for Micro-grids

- Degree of Isolation
- Nature of the Local Power
- Operating Margin
- Load Capacity Factor
- Size of the Control Area
- “Permanence” of the Boundaries
- Regulatory Complexity “Seams”

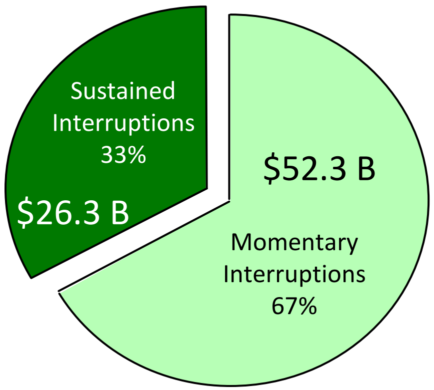


Example microgrid

Two classes of microgrid are generally customer controlled

- **Classic separable micro-grid** – in general the goal of this class of microgrid is reliability of power – it is growing in popularity as a mechanism for ensuring that critical infrastructure – hospitals, fire and police stations, gasoline stations, grocery stores – retain power during emergencies.
  - In the US this class of microgrid is spreading as a post hurricane Sandy response

- **Defensive micro-grid** – a specialized need of particular industries (e.g. semiconductors) where power quality (freedom from power transients and brief interruptions) is critical to operation. Power protection and storage technologies (e.g. Superconducting magnetic energy storage – SMES) are deployed to protect key processes.



US Costs

LaCommare & Eto, Energy 31, 1845 (2006)

THE WALL STREET JOURNAL.
WSJ.com

ASIA TECHNOLOGY | DECEMBER 9, 2010, 11:15 A.M. ET

Brief Power Outage Threatens Toshiba Chip Shipments

0.07 second outage → 20% chip reduction for 2 months

Micro-grids can also provide a mechanism to help utilities manage peak load

- **A demand response micro-grid** allows a utility to "call on" customers to curtail their use of electricity in order to meet peak demand without adding (generally more expensive) generation.
  - There are many variants of this approach of which a micro-grid is the most sophisticated
  - For example – a classic microgrid owner could be called on to curtail their demand for energy to the utility and could meet this "call" by using their own local generation.
    - Within this class of microgrid "smart technologies" are also used to mange building systems, such as HVAC and water heating to reduce load.
    - These systems are becoming sufficiently automated that "demand response" is becoming a dispatchable resource just like generation.

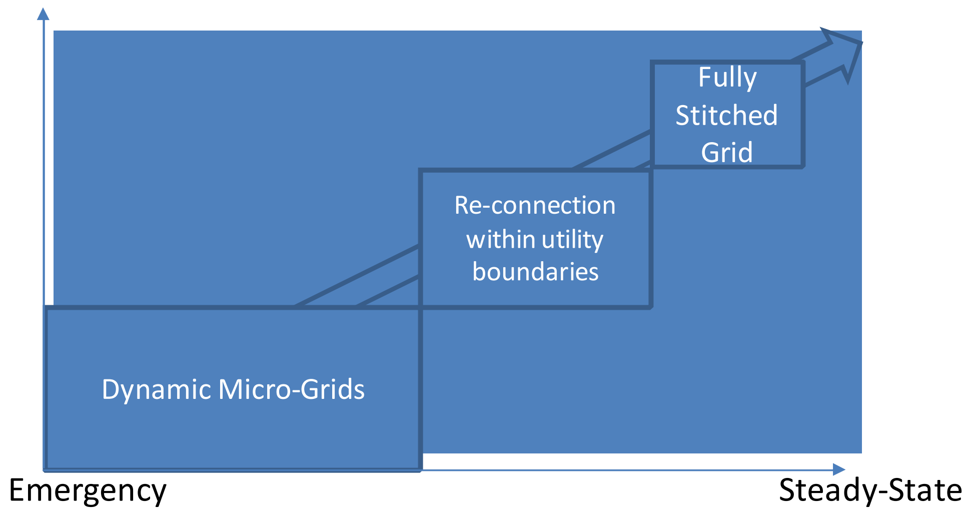
WHILE THE FOREGOING EXAMPLES PROVIDE PROTECTION TO CUSTOMERS AND AND TO THE UTILITY THROUGH CUSTOMERS – THERE ARE WAYS THE MICROGRID CONCEPT CAN BE EXTENDED.

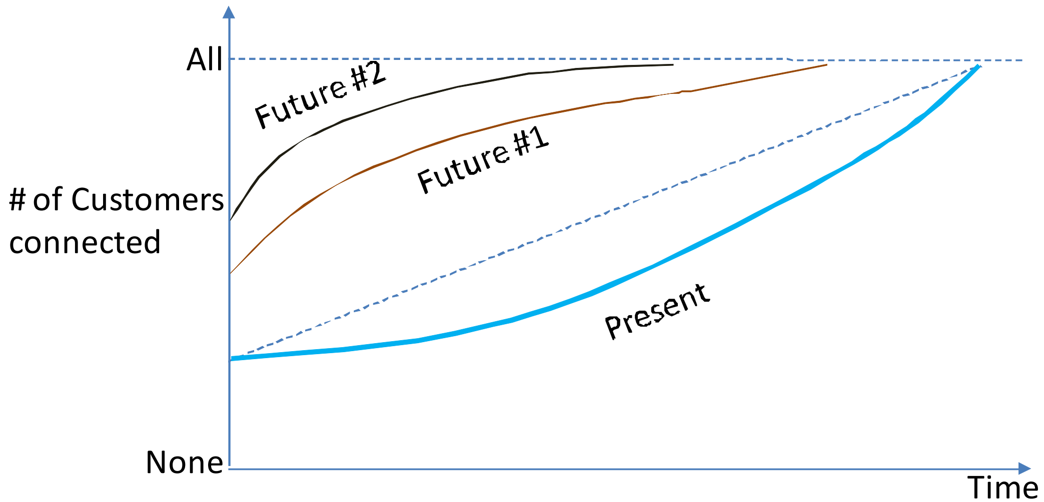
Much grid resilience comes from integration of large areas – but events can cause disintegration …

- **Controlled Separation Islands** – Cascading failure of the system is one of the major causes of widespread grid failures – e.g. US in 2003 and July 2012 in India – these can have both natural and human causes. One technique suggested for halting the cascade – and maintaining service – is controlled separation …
  - Basically a portion of the grid is disconnected from the broader grid and supply and demand is managed on this scale – matching supply and demand. This is a tremendous control challenge but it may become increasingly possible as distributed generation becomes more widespread.

- **Recovery islands** – large scale meteorological events – typhoons, hurricanes and snow storms can cause widespread damage to the distribution and transmission structure.
  - While difficult to reconnect the whole backbone – local generation resources can be used to power limited parts of the grid, without benefit of the whole system.
  - These recovery islands are basically dynamic micro-grids brought into being to return service to customers as quickly as possible -

Dynamic microgrid path to restoration for Long Island (US)





Goal of dynamic microgrid approach is to both decrease the number of initial outages and to accelerate the return of service to customers.

Ahead of storm – activate locational capacity and create isolatable micro-grids.

Driven by local failures dynamically create and manage smaller grids.

Post storm, re-stitch the micro-grids back together …

FINALLY – THERE ARE SPECIAL CIRCUMSTANCES WHERE MICROGRID PRINCIPLES APPLY OR THAT CAN INFORM HOW WE THINK ABOUT MICROGRIDS.

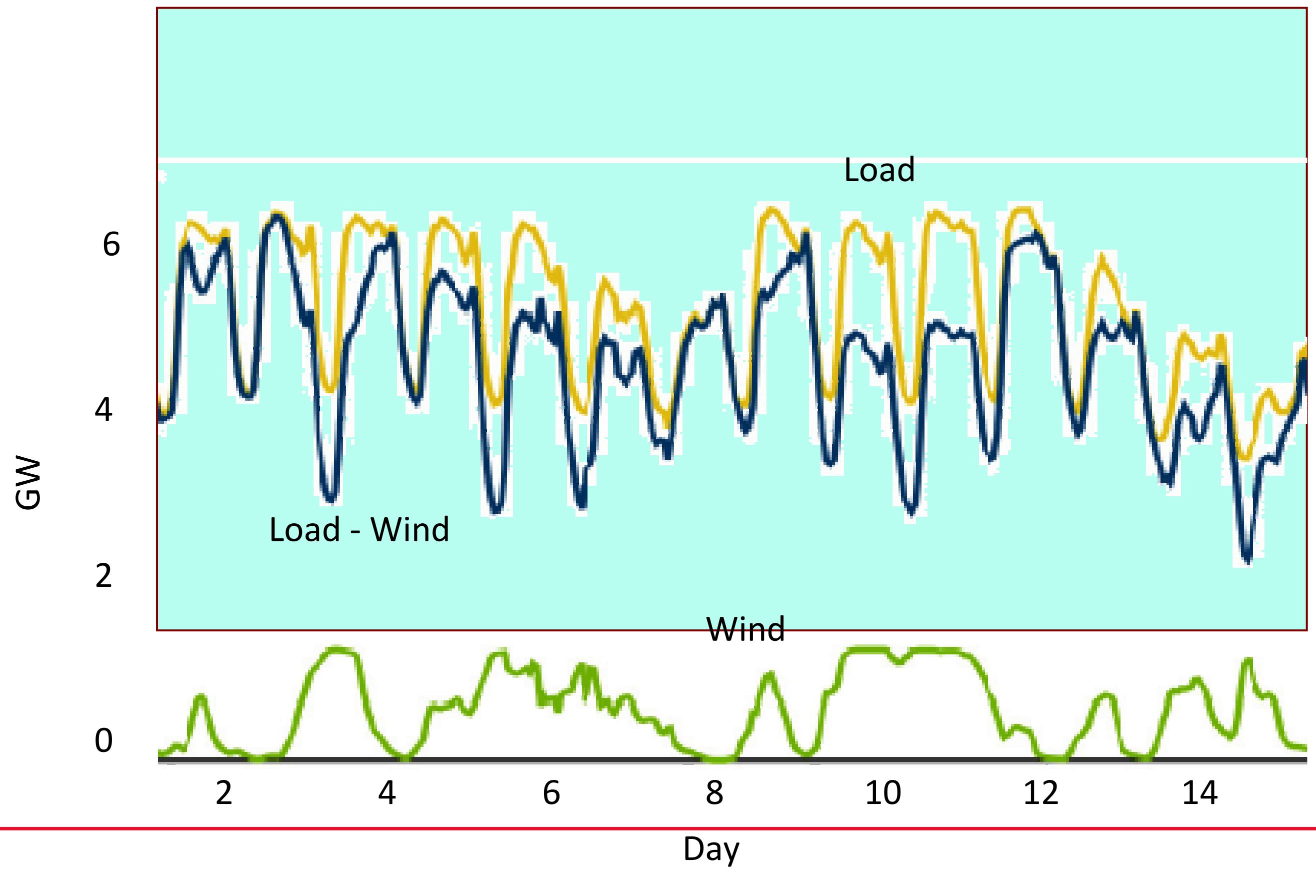
Microgrid – like enterprises

- **Island like and isolated feeders**– some parts of a larger grid are operated independently (e.g. cities or in the US co-operative utilities) and while they do not have large scale generation, they do have distributed generation (many times renewables) and have special geographical needs – peninsulas for example.
  - These situations can have special needs that may not be able to be managed from a central control room – sometimes simply because of control speed.
  - Increasing penetration of distributed renewable energy – solar and wind – will necessitate more sophisticated local control and the ability to manage things like two way power flow, previously primarily a transmission level issue.
  - Local control of these feeders – similar to that provided for microgrids will increase reliability.

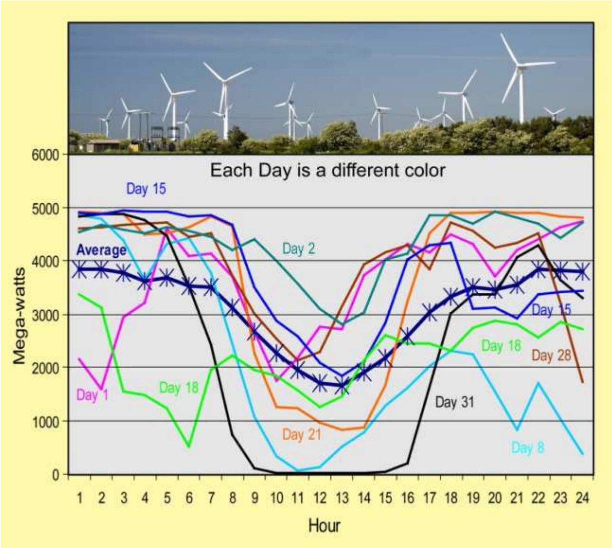
- **Real Islands** – these are in reality microgrids that lack the benefit of having the ability to connect to a larger grid. There are important lessons they can teach us …
  - The cost of power on an island is almost always higher that on a large continental grid (e.g. US Virgin Islands > $.5/kWh
  - Renewable integration desirable but difficult just as it is for conventional microgrids.

Matching supply and demand in time – renewables – have to forecast supply as well as demand

Xcel Wind Farm, Minnesota
1.5 GW Wind in 10 GW Peak System

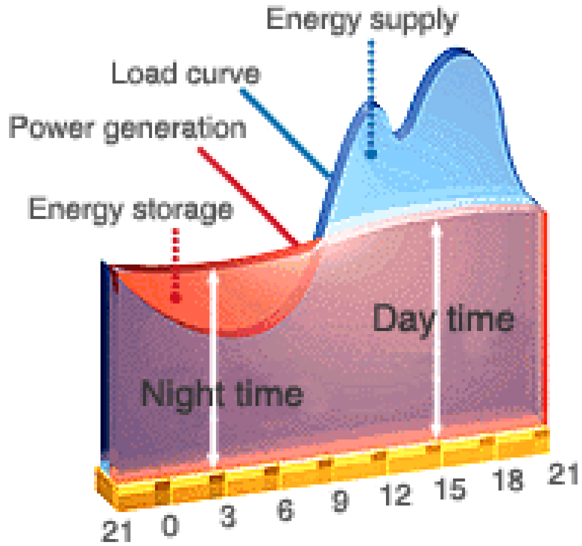


Energy storage is critical for renewable penetration
<u>and benefits grid stability and reliability</u>

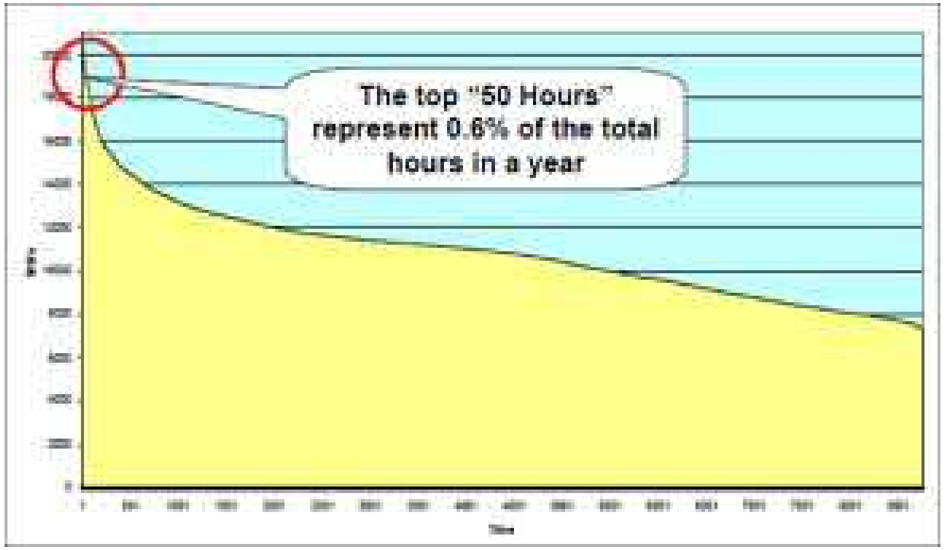


Drivers for Large Scale Energy Storage

- Renewable Generation
- Grid Reliability Management
- Power quality
- Load leveling, shifting



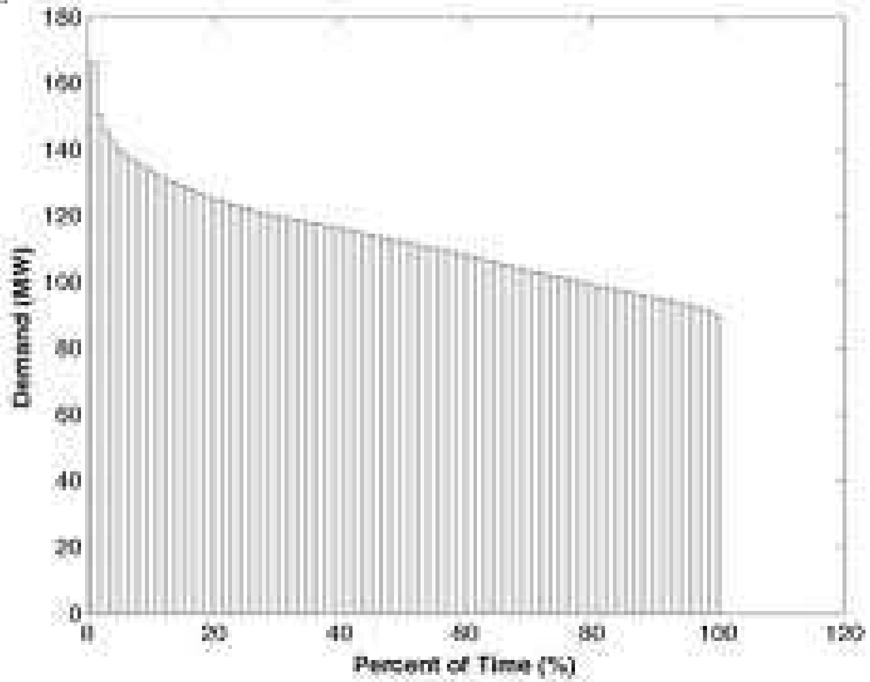
Finally – generation is expensive and meeting peak demand is always a challenge.



Load duration curve: for how long do you have meet what load?

In general: one seeks to use one's least expensive generation as much as possible … therefore most expensive resource is used to satisfy peak … … However not always true …

Which makes storage even more valuable for a microgrids and islands



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The bottom line -

- Electricity and the grid are important for society …
- There are microgrid practices and concepts than can make the service to customers better and at the same time increase the robustness of the overall system
- The system’s robustness is thereby enhanced in depth
- The new measurement and control technologies from “smart grid” developments are making this all possible