THE SMART ELECTRICAL GRID

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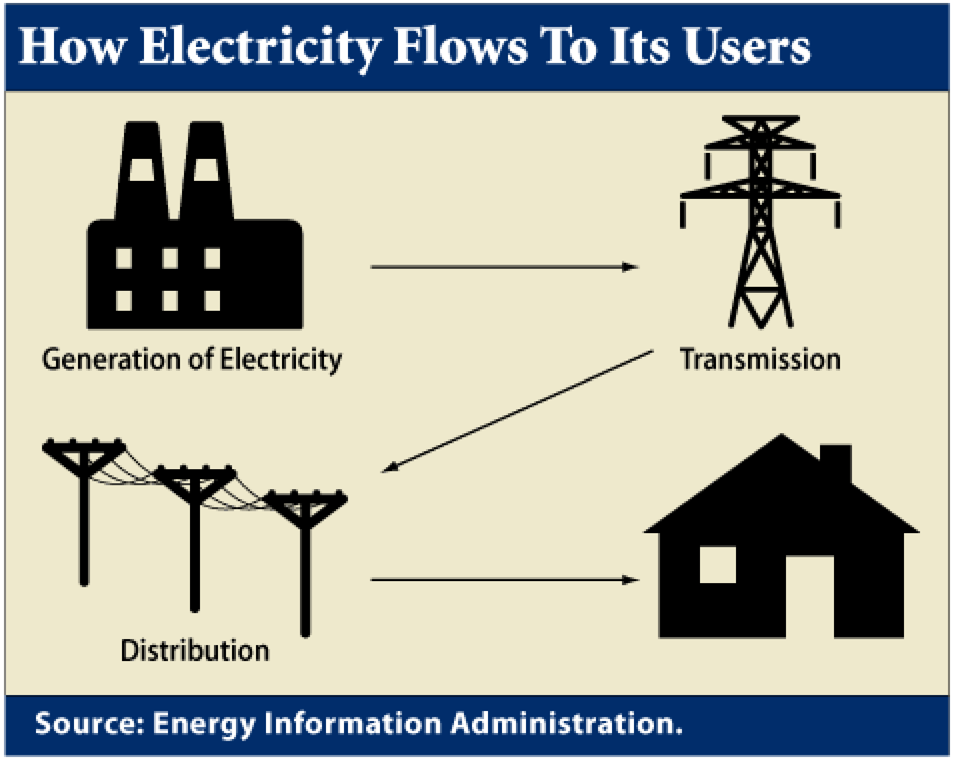
BACKGROUND

- Hierarchical
  - Generation
  - Transmission
  - Distribution
- Over-engineered
  - Designed to meet maximum peak load



MOTIVATIONS

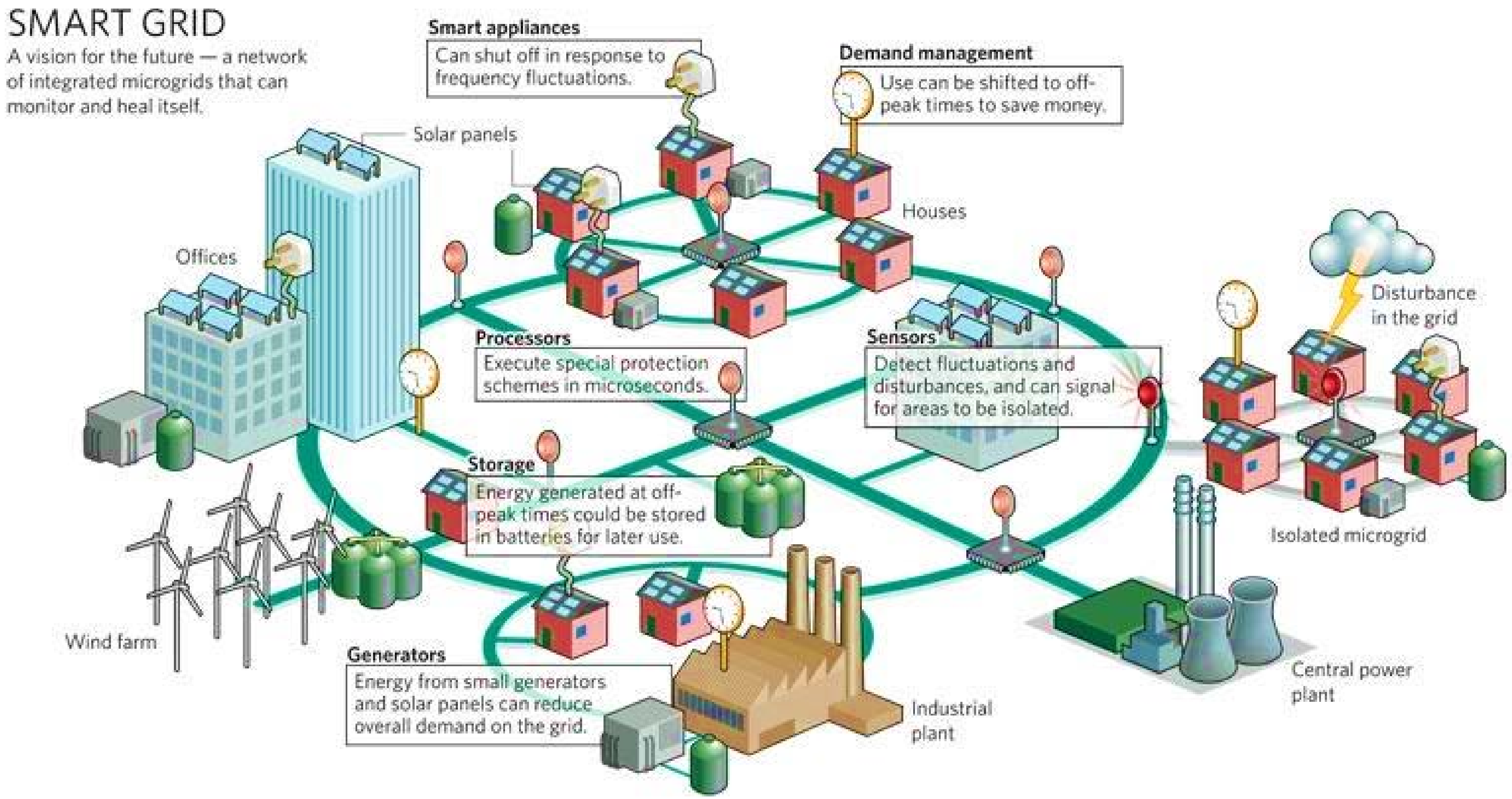
- Estimated that power outages and power quality disturbances cost the economy $25-$180 billion a year
- Northeast Blackout cost $4-$10 billion
- Consumption and production are changing
  - 20% renewables by 2030
  - National Research council estimates that by 2030 4-13% of light vehicles will be plug in electrics

Event	People Affected (Millions)	Location	Date
India Blackout 2012	670	India	July 30-31, 2012
Java-Bali Blackout 2005	100	Indonesia	August 18, 2005
Brazil Blackout 1999	97	Brazil	March 11, 1999
Brazil & Paraguay Blackout 2009	87	Brazil, Paraguay	November 10-11, 2009
U.S. & Canada Blackout 2003	55	the United States, Canada	August 14-15, 2003
Italy Blackout 2003	55	Italy, Switzerland, Austria, Slovenia, Croatia	September 28, 2003
U.S. & Canada Blackout 1965	30	the United States, Canada	November 9, 1965

INTRODUCTION

- "The term 'Smart Grid' refers to the **modernization of the electricity delivery system** so that it **monitors**, **protects**, and **automatically optimizes** the operation of its interconnected elements–from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations, and to end-use consumers, and their thermostats, electric vehicles, appliances, and other household devices."
  - -EPRI 2011

INTRODUCTION



http://www.consumerenergyreport.com/smart-grid/

REQUIREMENTS

- Reliable
- Flexible
- Efficient
- Sustainable
- Market-Enabling

EFFICIENT & MARKET ENABLING

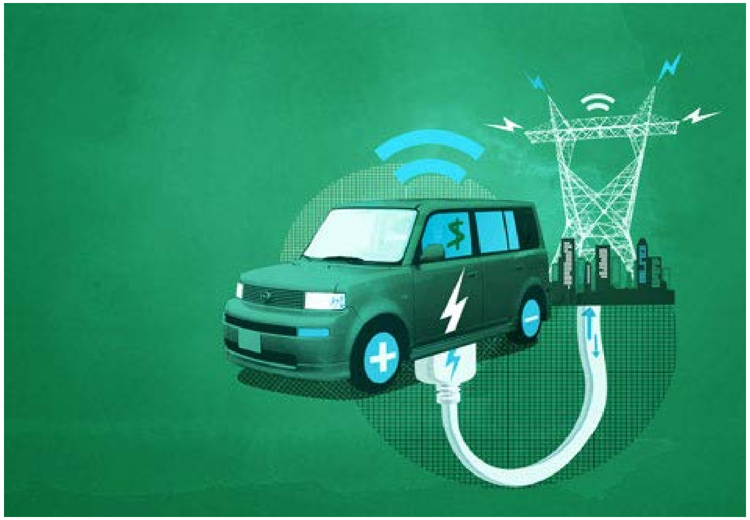
- Advanced Metering Infrastructure
  - Smart Meters
  - Demand Side Management
    - Time of Use (TOU)
    - Real Time Pricing (RTP)
    - Critical Peak Pricing (CPP)
  - Home Area Networking (HAN)
    - Google PowerMeter
    - Microsoft Hohm
  - Demand Response (DR)
    - Capacity Bidding (CBP)
    - Agricultural and Pumping Interruptible (API)
    - Emergency Demand Response (EDRP)

RELIABILITY

- Flexible Alternating Current Transmission (FACTS)
  - Control energy flow on the grid with more precision
  - Reduced transmission losses and fault currents
  - Improved power quality
  - Improved power transfer capability
- Phasor Measurement Unit (PMU)
  - Real time monitoring of line voltage or current phase angles
  - Transient phenomena are spotted sooner
- Active Thermal Monitoring
  - Measure the loading level of branches in the power network
  - Enable 5-15% higher line loading

FLEXIBLE & SUSTAINABLE

- Renewables
  - Wind and solar are intermittent sources
  - Can cause stresses on local distribution feeders where they are installed



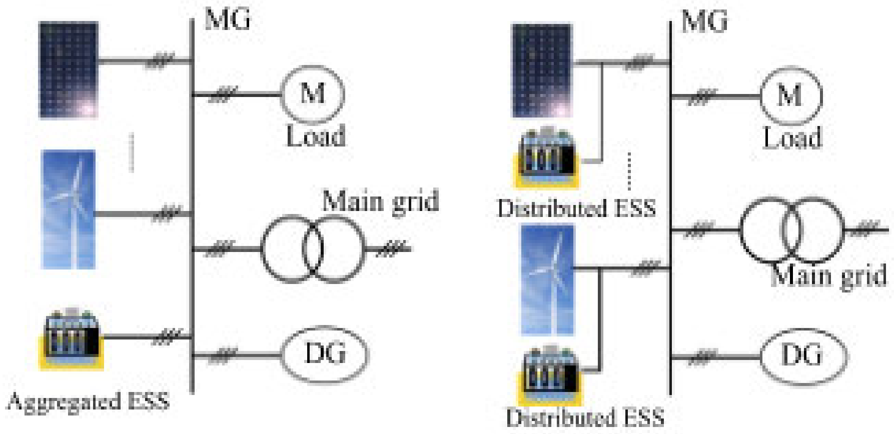
- Micro-grids
  - “interconnected networks of distributed energy systems that can function whether they are connected to or separate from the grid”
- Vehicle-to-grid and Grid Storage

Flexible & Sustainable

- Sodium Sulfur Batteries (NaS)
  - 4 times the energy density of lead-acid
  - 2500+ cycles at 10% depth of discharge
  - 15 year life
- Flywheel Energy Storage (FES)
  - Very efficient ~ 95%
  - $380-2500 $/kW.h
  - Disadvantages include large size, low energy density and high standby loss
- Supercapacitor
  - Longer cycles than lead-acid
  - Lower energy density than lead-acid

Flexible & Sustainable

- Energy Storage Configuration
  - Aggregated
    - All ESSs are aggregated as one ESS and connected to the MG terminal
    - Superior performance to distributed ESS at same capacity
    - Can be used to soothe power flow fluctuations
  - Distributed
    - ESS are directly coupled to individual DERs
    - Can be made simpler since each storage system has to deal with a single type of source
    - Disadvantage is that the power produced by DERs has to be carried the transmission lines before being stored



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