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A Study of Smart Grids Benefit for China's Wind Development

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Vision of China's Smart Grid

What is The Smart Grid?

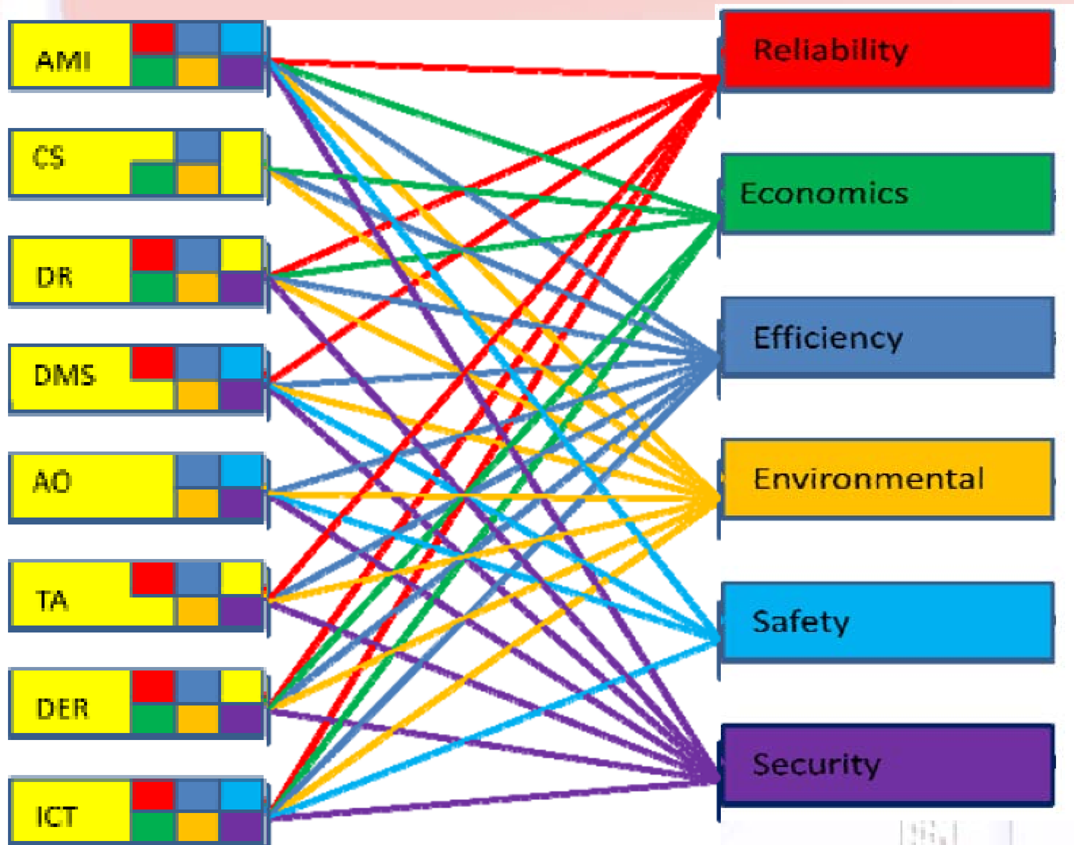
Many Definitions – But One VISION

- Enables active participation by consumers
- Accommodates all generation and storage options
- Enables new products, services, and markets
- Provides power quality for the digital economy
- Optimizes asset utilization and operates efficiently
- Anticipates and responds to system disturbances (self-heals)
- Operates resiliently against attack and natural disaster

MI

Interconnected by a Communication Fabric that Reaches Each Device

Benefits of Smart Grids



Advanced Metering Infrastructure (AMI)
Customer Side Systems (CS)
Demand Response (DR)
Distribution Management System/Distribution Automation (DMS)
Transmission Enhancement Applications (TA)
Asset/System Optimization (AO)
Distributed Energy Resources (DER)
Information and Communications Integration (ICT)


Policy
Operating Strategies
Physical Systems

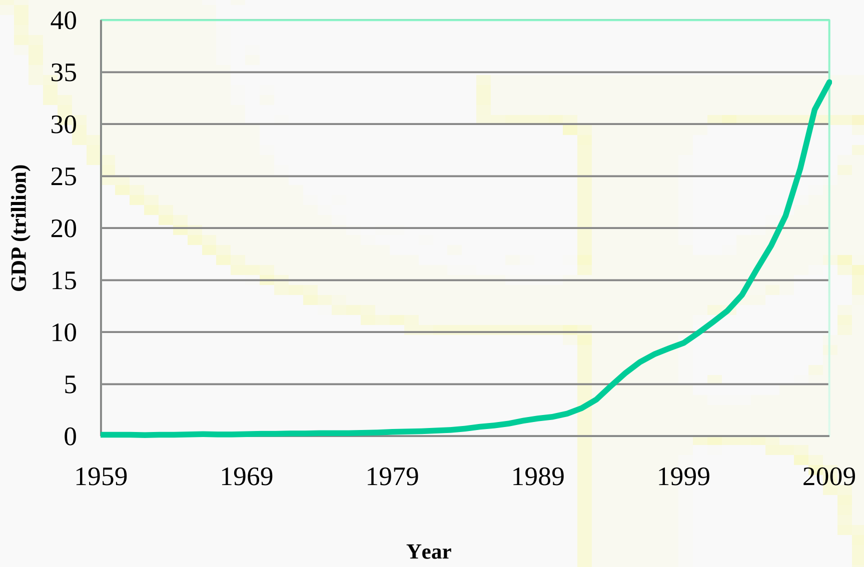
Vision of Smart Grid (China)

- Building an internationally-leading strong and smart grid, with an extra high voltage grid as its backbone and constructed with self-reliant innovation for its high level of information, automation and interaction.
- Smart Grid is based on a strong grid network, supported by an information-communication platform, with smart controllers covering aspects from generation, transmission, distribution, customer service to dispatching.
- Smart Grid is the carrier of power flow, information flow and work flow. It is a strong, reliable, economical, efficient, clean, transparent, and interactive integration

Motivation of China's Smart Grid: Renewables Integration

China's Economic Rise

- GDP 1959-2009



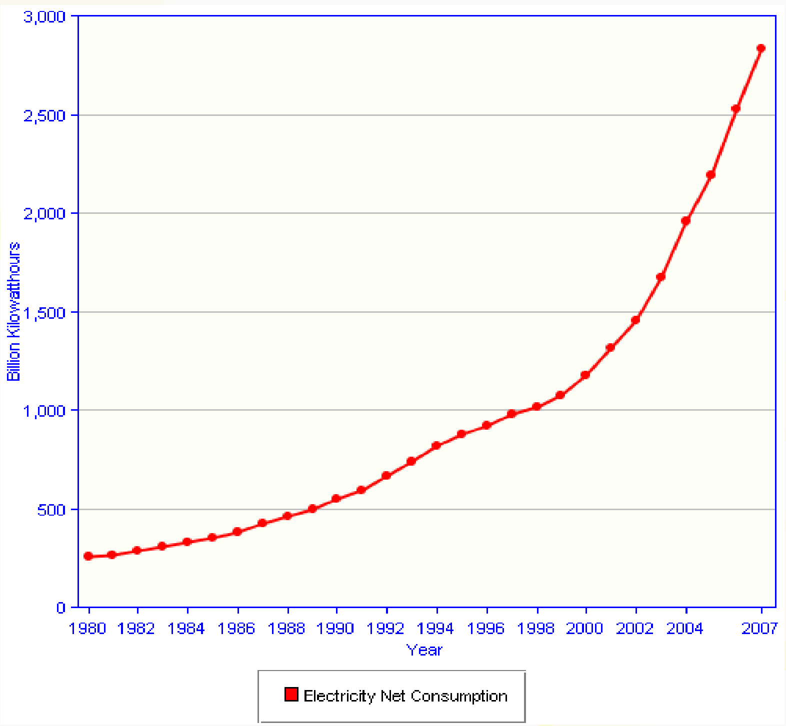
- Accompanied by growth in
  - Energy consumption
  - Environmental degradation

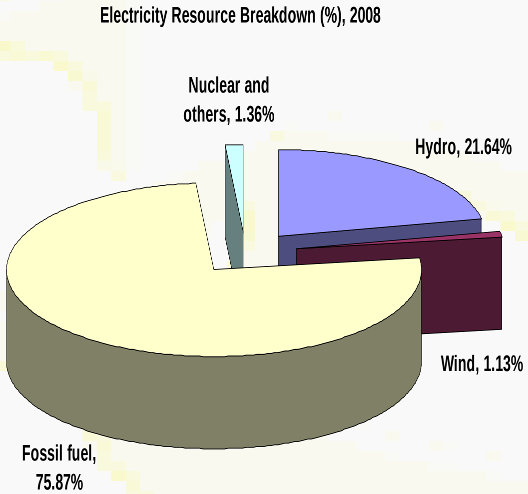
- 34 trillion RMB = 5.23 trillion US$ in 2009
- from 1979 to 2009, the average annual incremental reaches 9%.

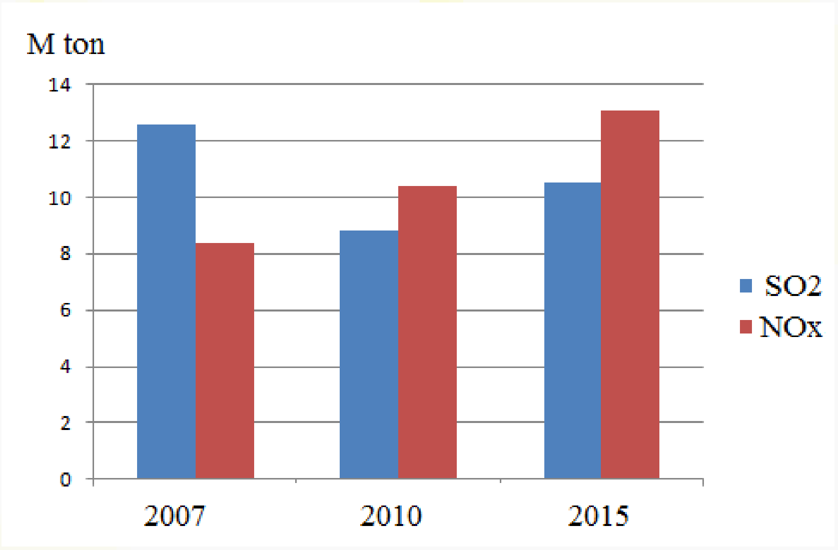
Copenhagen Promises

- China now ranks the second in terms of installed generation capacity and electricity consumption.
- 2009, the installed capacity has reached 874GW
- China 22.5 ton CO2/10k$, UK 2.5, India 14.3, US 4.5, Japan 2.9, Germany 3
- Developing countries to adopt a low-emission path
- China promises to reduce carbon intensity 40-45% by 2020.

China's Electricity Sector







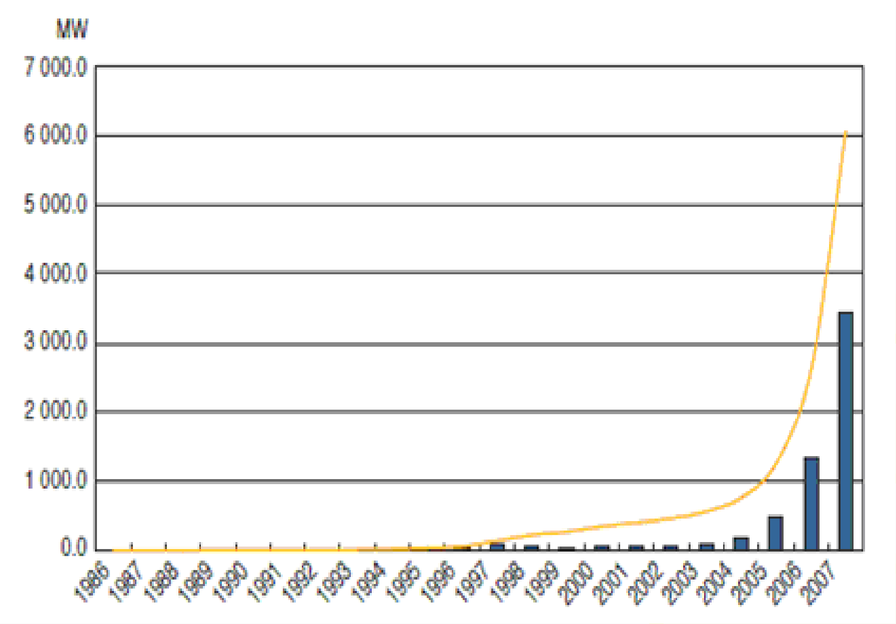
Installed Capacity: 792.5 GW (2008);

874 GW(2009)

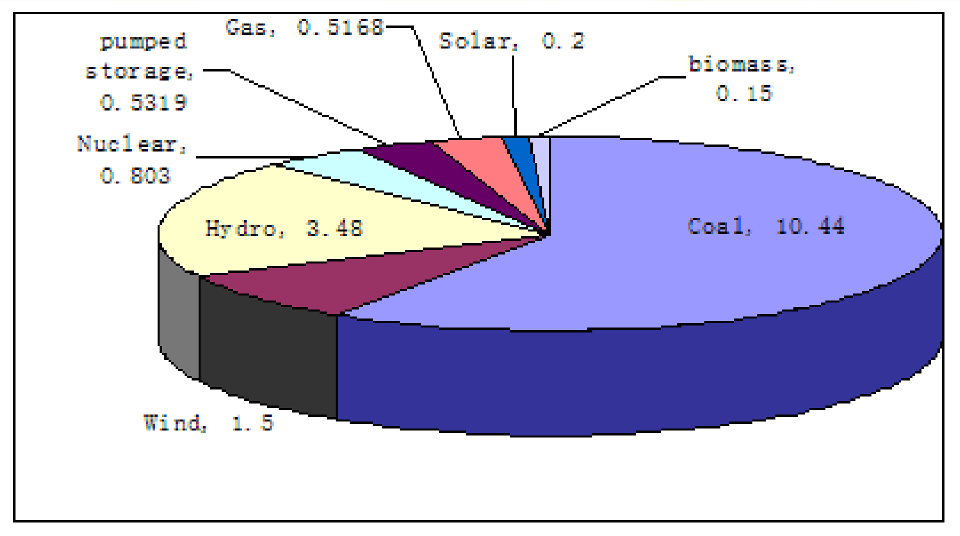
950 GW (2010)

From 2006 to 2010 annual incremental reaches 17%

Wind Power Development



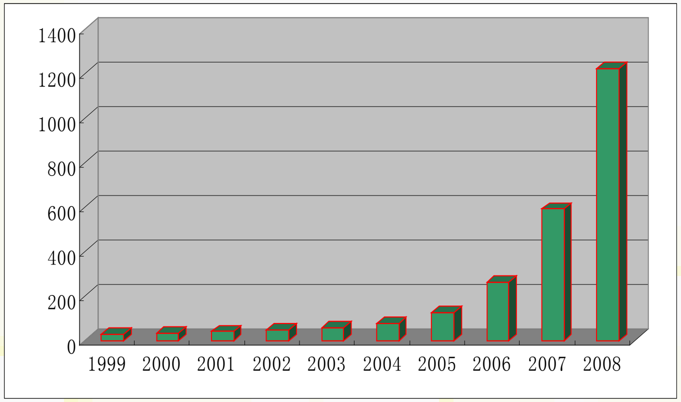
Installed Capacity of Wind Generation in China



Planned Power Source Structure in China by 2020

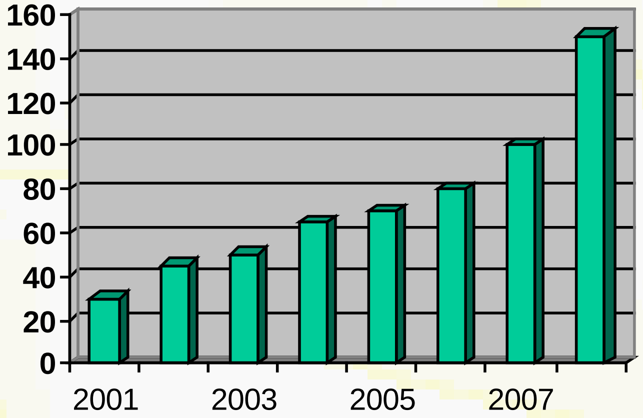
Development in Renewable Resources

- Wind development



- 2008: 12.17GW
- 2009: 25.1GW

- Solar development



» 2008

PV gen = 150 MW

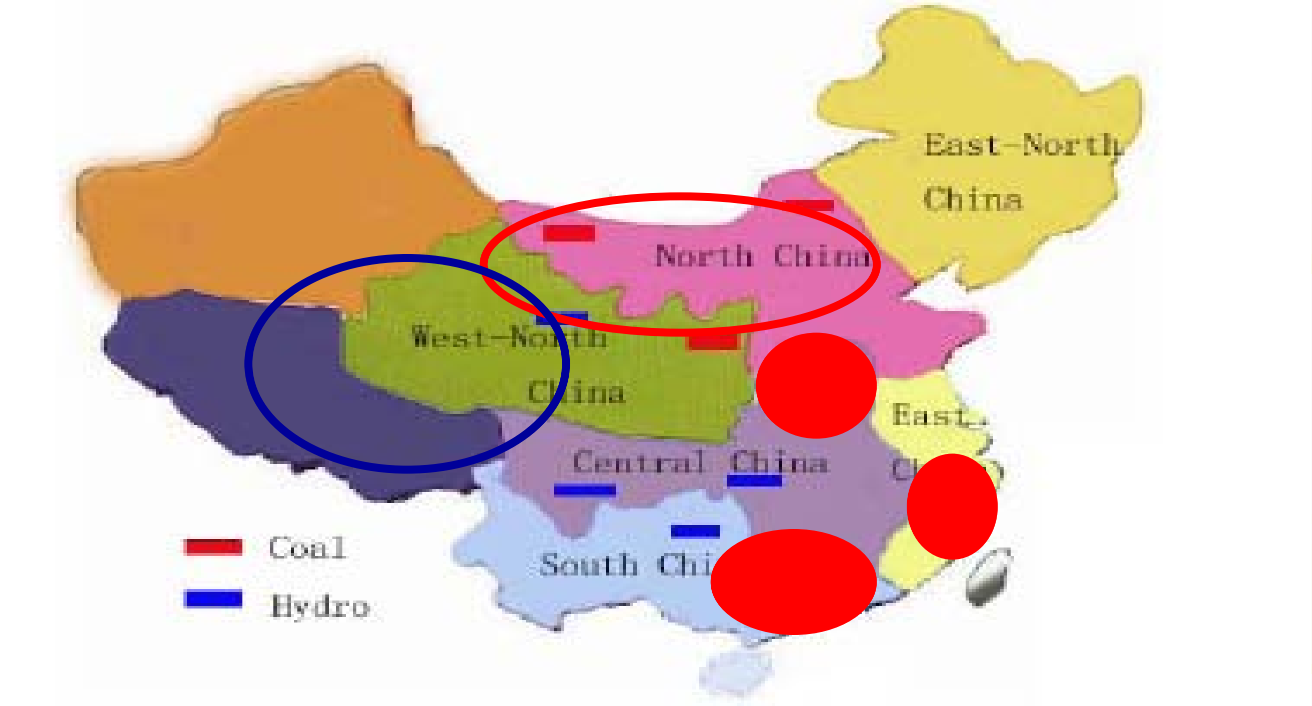
PV production = 2.6GW

Bottleneck of Wind Integration

- 2008: installed capacity 12.17GW, only 8.94GW is connected with system (70%)
- 2009: installed capacity 25.1GW, only 16.13GW is connected with system (64.2%)
- Bottleneck: network, regulation capacity

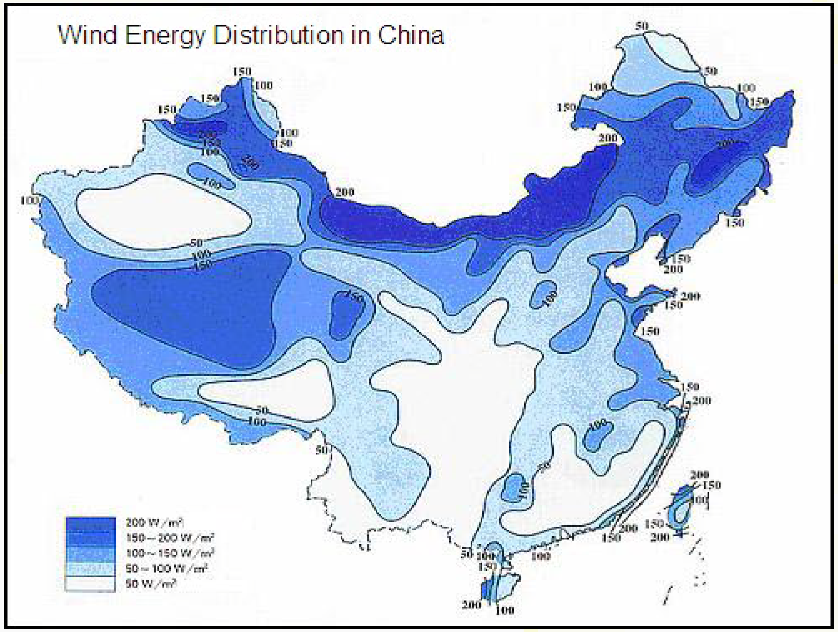
China's Smart Grid: Requirements for Network Construction

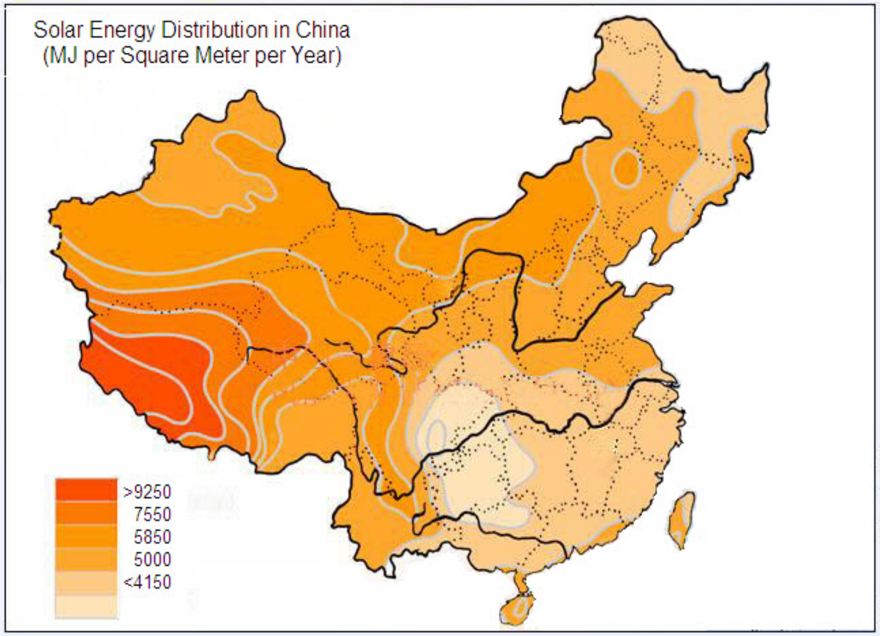
Electricity Supply in China



- **Uneven distribution of energy sources**
  - ➢Coal: 82% in the north and northwest regions
  - ➢ Hydro: 67% in southwest region
- **70% of consumption in the east, south and a part of central region**
- **Long distance electric transmission is necessary**

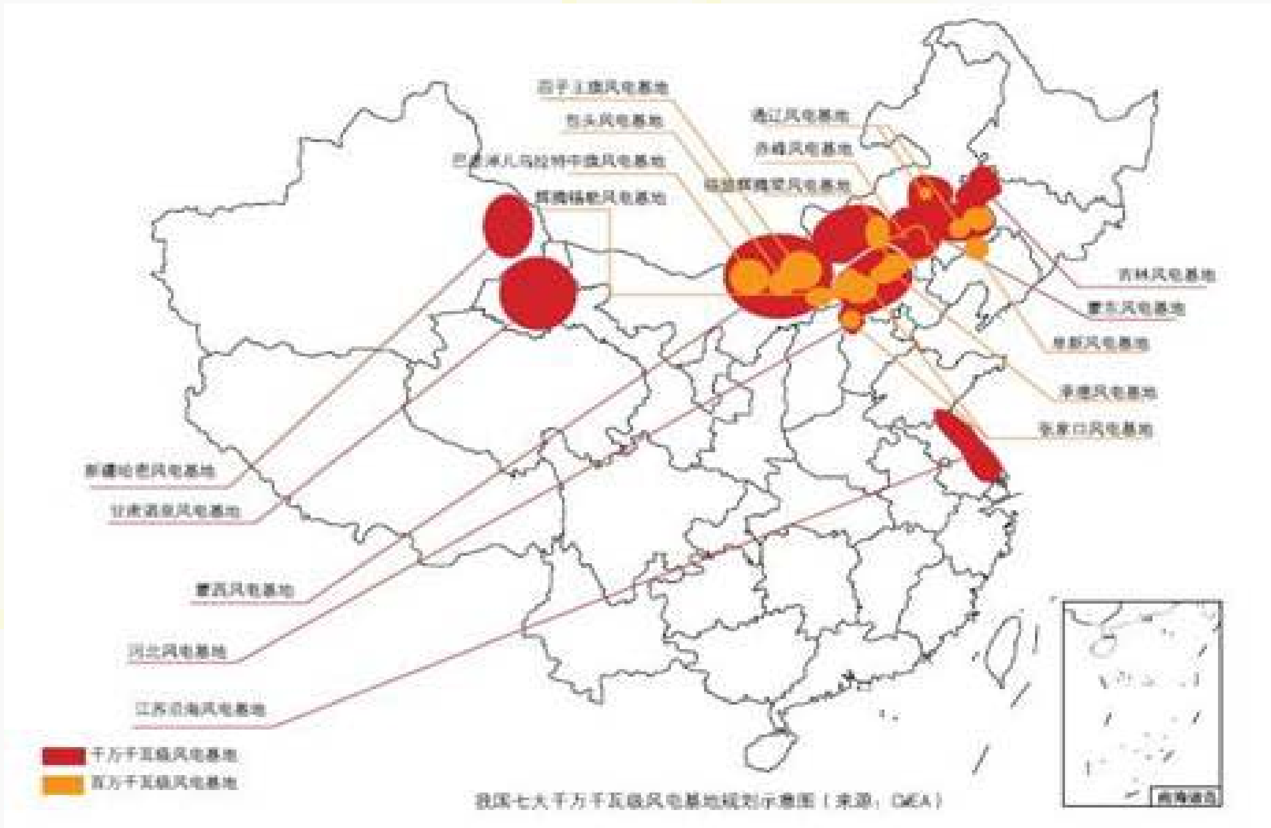
Wind and Solar Resources





- Resource are more in the north, northwest and southwest.
- Demand are more in the east, south and central.

7 Huge Wind Farms (>10GW each)



- Installed Capacity: 2015: 58.08GW, 2020: 90.17GW.
- Interconnected: 2015: 22GW, 2020: 41.63GW
- Regulation capacity; Strong network

Regulation Capacity of Different Areas

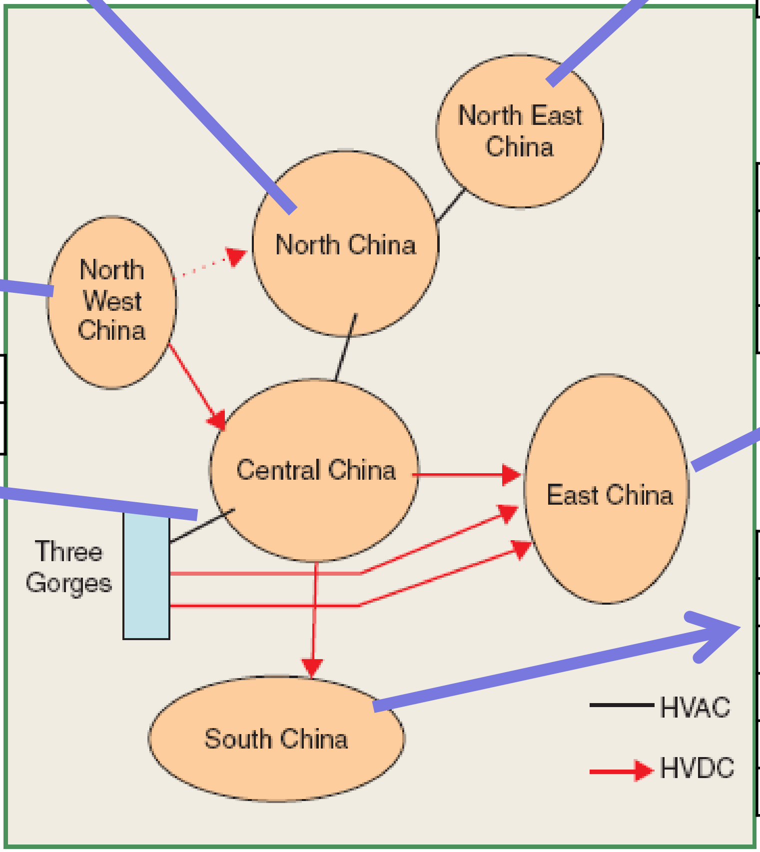
Capacity	183.79GW	100%
T	178.28GW	97%
H	5.51GW	3%

Capacity	71.41GW	100%
T	58.27GW	81.6%
H	6.65GW	9.3%
W	6.49GW	9.1%

Capacity	63.49GW	100%
T	43.56GW	68.6%
H	17.37GW	27.35%

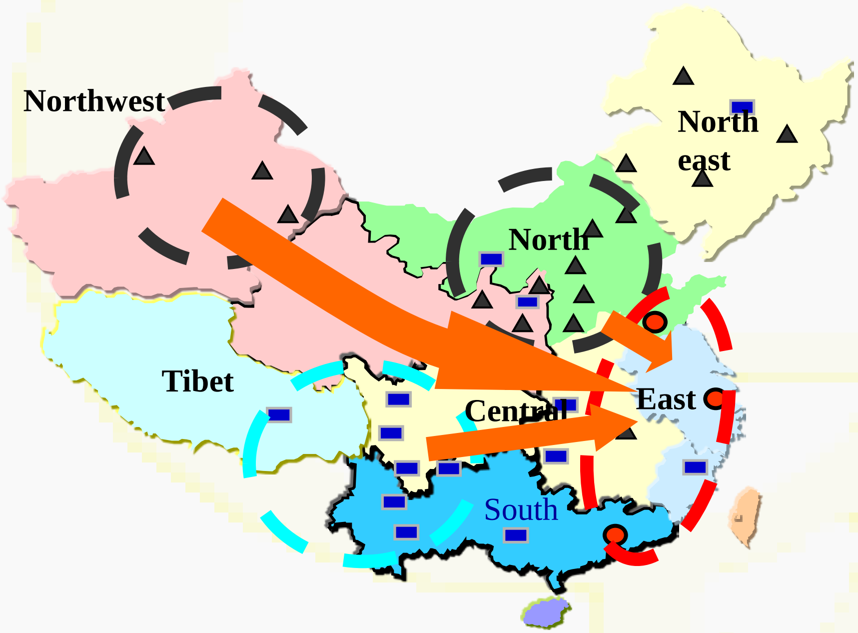
Capacity	164GW	100%
T	129GW	87.86%
H	16.1GW	9.79%
HP	3.86GW	2.35%

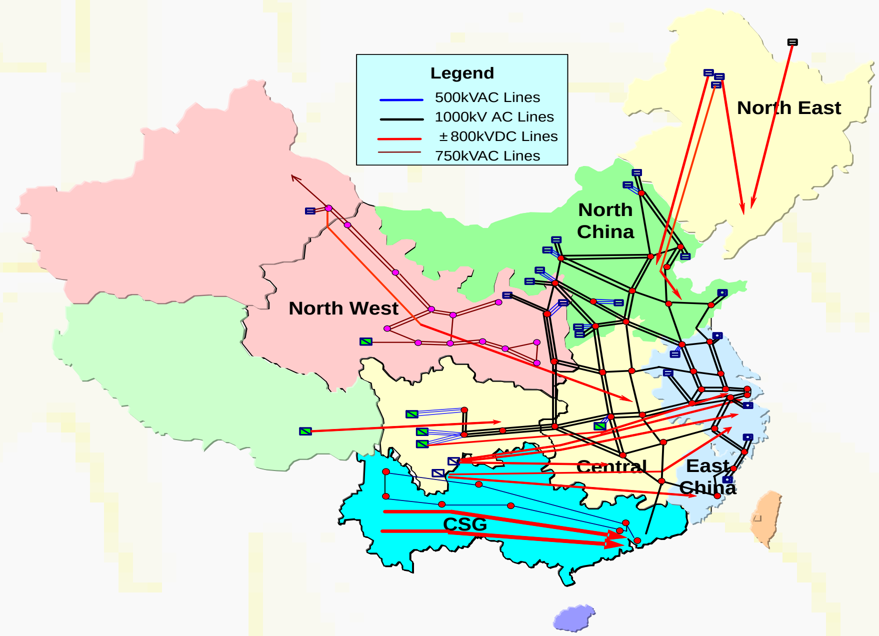
Capacity	182.26GW	100%
H		40%



Capacity	135GW	100%
T	84.05GW	62.25%
H	43.71GW	32.37%
N	3.95GW	2.92%
W	0.59GW	0.43%
HP	2.7GW	2%

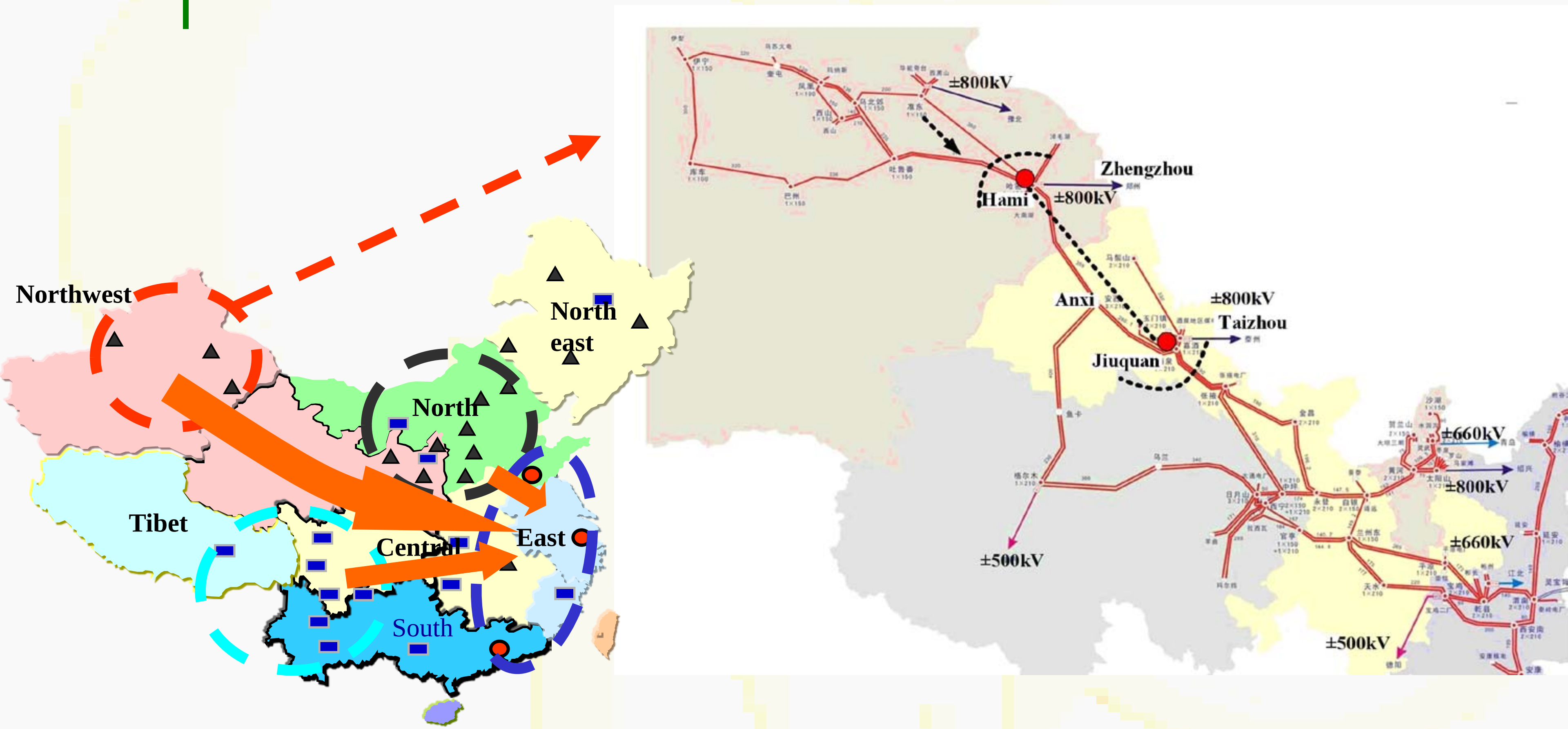
Transmission Requirements





- Large-scale deployment of renewable resources requires a strong grid to transport power from west to east.
- Management of renewable resources and conservation measures (efficiency improvement, demand response) require a smart grid.

Network Structure for Wind Integration

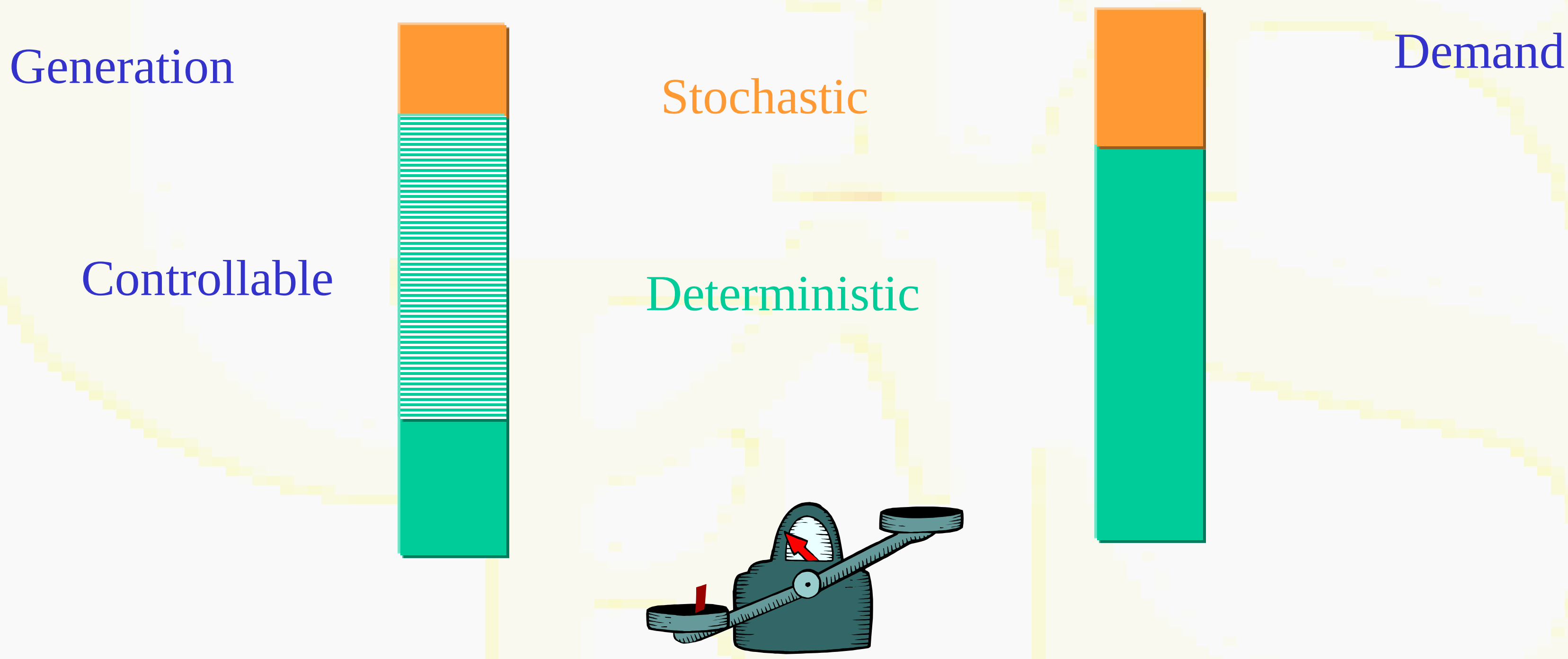


Northwest Grid HVDC projects planning for 2015

China’s Smart Grid: Smart Operation

Traditional Power System

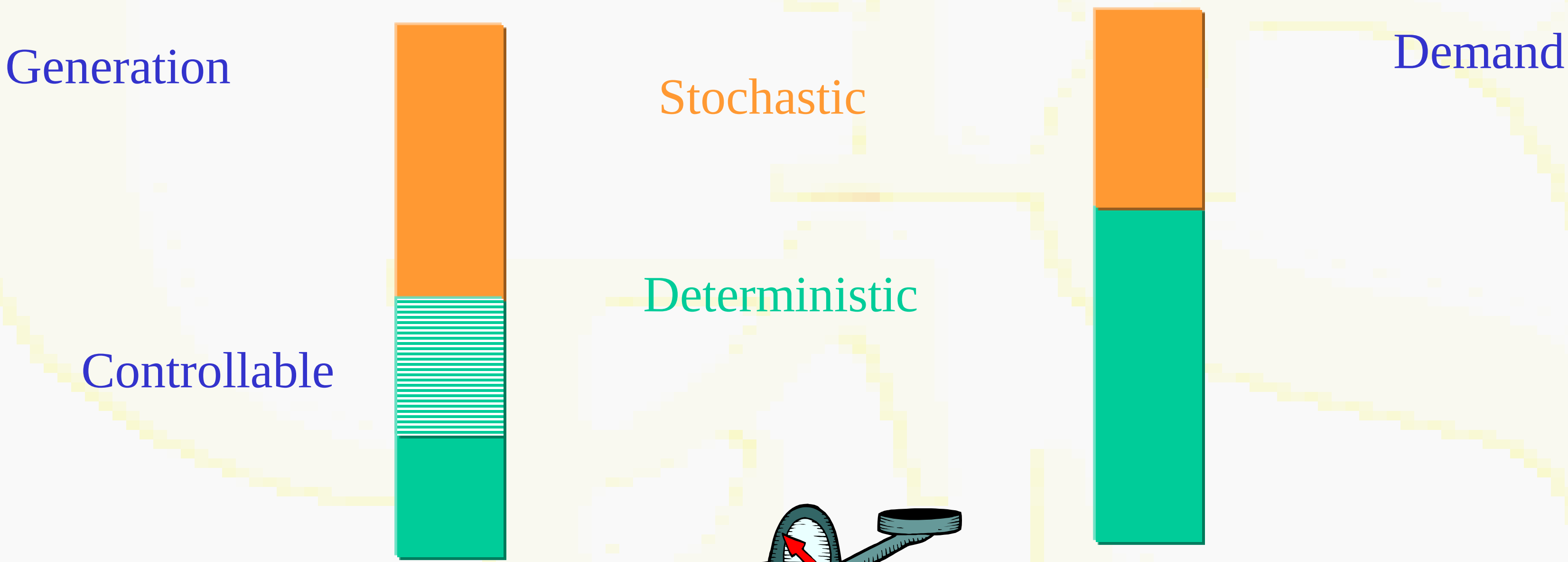
- Enough deterministic and controllable generation



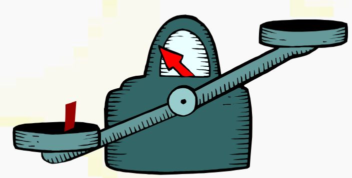
Generation follows the load

Strategies in Smart Grid Environment

- Increase in (stochastic) renewable generation



Increase
energy storage

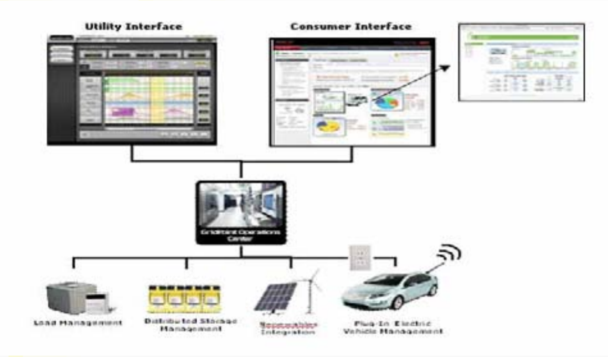


Load
follows generation

Tighter control

Smart Operation of Smart Grid

- Objectives
  - Enabling renewables & EV
  - Engaging consumers
  - Enhancing efficiency, reliability
- Tools
  - Real-time information from sensors and communication networks of smart grid
  - Enhanced analysis and control capabilities of smart grid
- Smart operation
  - Distributed and coordinated
  - Risk-based (vs. worst-case)
  - Self-healing
  - Control and communication architecture
  - Laboratory experiment

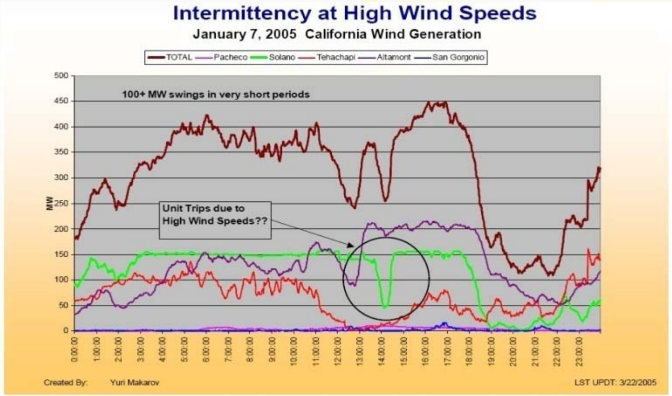


Flexibility Requirements

- Inertial response: cycles to 1-2 seconds
- Primary frequency response: cycles to 5-10 seconds
- Regulation:10 seconds to several minutes
- Load following/ ramping: several minutes to few hours
- Contingency spinning/non-spinning reserve
- Replacement reserve
- Variable generation tail event reserve

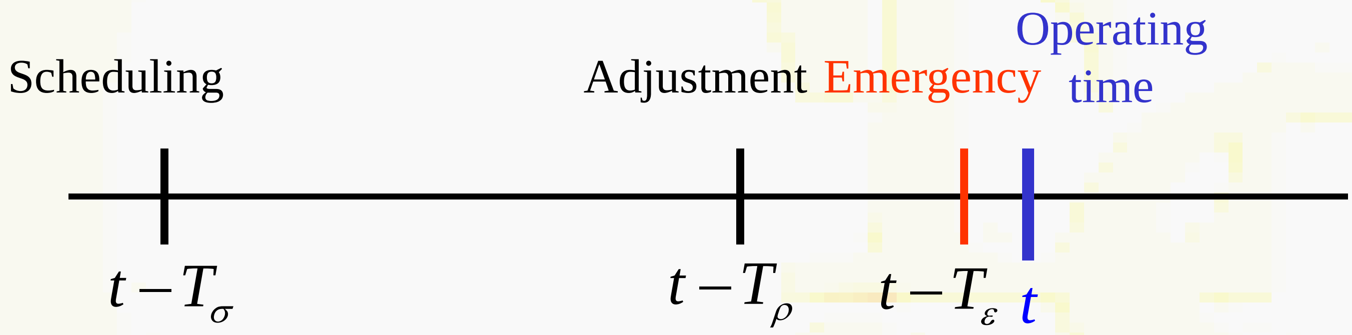
Risk-limiting Dispatch

- Motivations
  - Renewable resources (wind and solar) are intermittent and highly variable.
  - Demand response and EV make load more stochastic.
  - Smart grid (sensors, communications, controls) provides more accurate real-time measurements, tighter feedback and more refined control.



- Operating principle
  - Optimizing objective (max social welfare or min cost)
  - Subject to the constraint that the risk of not meeting operating constraints is small.
- Methodology
  - Sequential stochastic decisions
  - Probability distributions are conditioned on updated measurements from the smart grid.

Optimal Dispatch

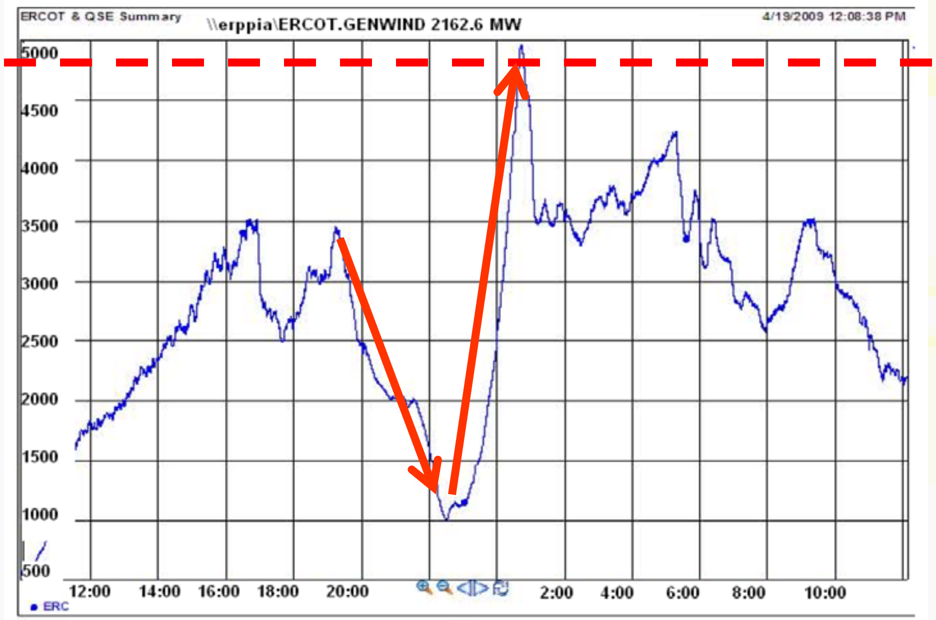


- The overall optimization problem for system operation:

$$
\begin{aligned}
\max \quad & f(\mathbf{x}(t), u_\sigma, u_\rho, u_\varepsilon) \\
s.t. \quad & \Pr\{g(\mathbf{x}(t), u_\sigma) = 0, h(\mathbf{x}(t), u_\sigma) \le 0 \,|\, \mathbf{y}_{t-T_\sigma}\} \ge p^* \\
& \Pr\{g(\mathbf{x}(t), u_\rho) = 0, h(\mathbf{x}(t), u_\rho) \le 0 \,|\, \mathbf{y}_{t-T_\rho}\} \ge p^* \\
& \Pr\{g(\mathbf{x}(t), u_\varepsilon) = 0, h(\mathbf{x}(t), u_\varepsilon) \le 0 \,|\, \mathbf{y}_{t-T_\varepsilon}\} = 1
\end{aligned}
$$

Operation Strategy: Coordination of Thermal Units & Wind Power

Figure A-6: 3,039 MW increases (18-Apr-09 23:39 to 19-Apr-09 00:39)



- Capacity
- Fast ramping of wind generation
- Minimal output of thermal(coal) units

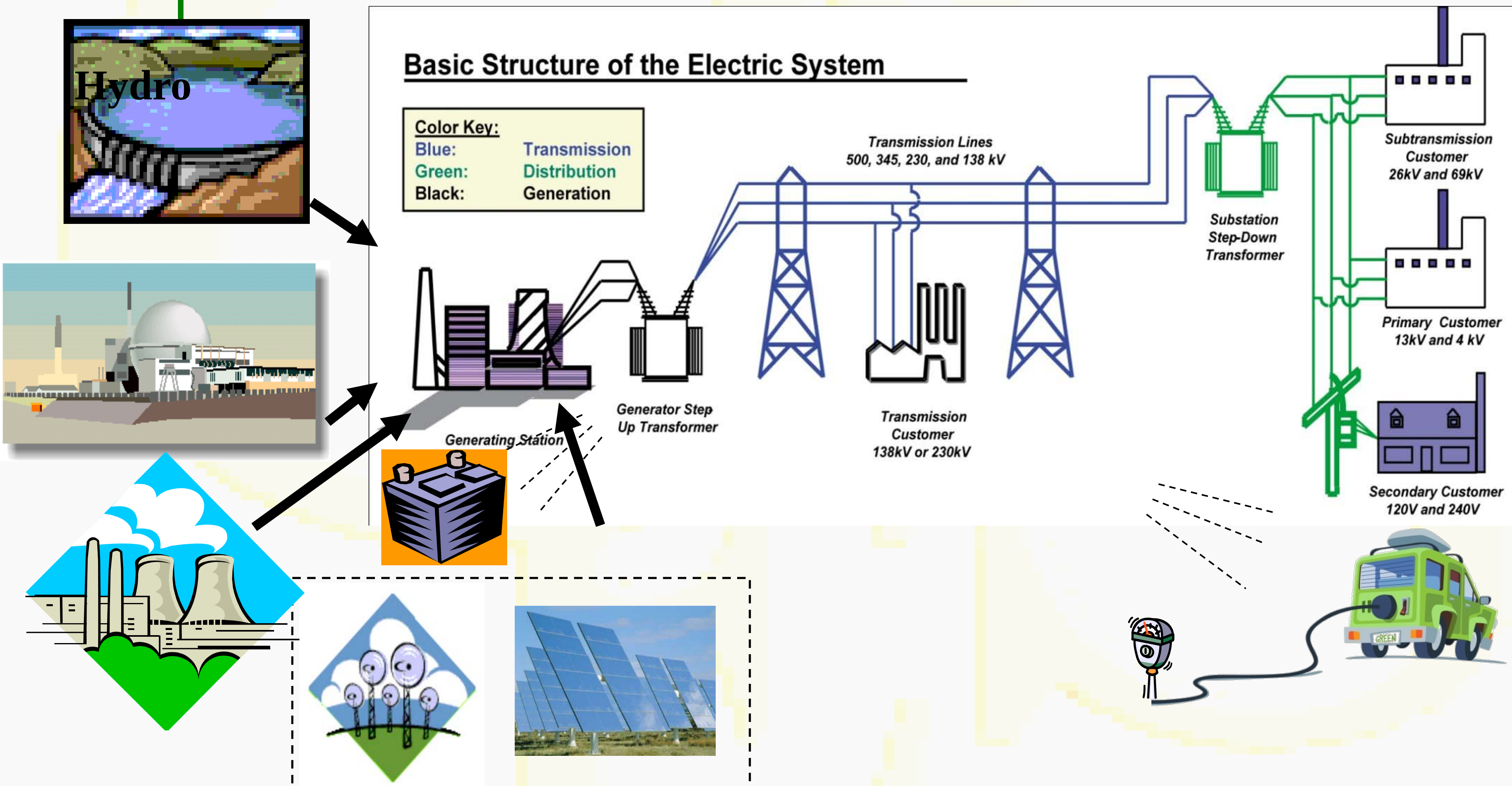
$$C_{Th} = C_W$$

$$C_{Th} < (3 \sim 5) \times C_W$$

$$2C_{Th} = C_W$$

Introduction of responsive load is acceptable approach

Power Systems operation with high Percentage Renewables Penetration

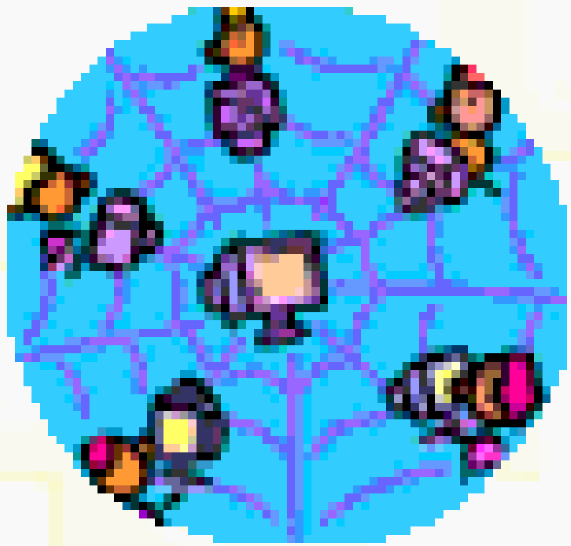


Balance capacity as well as ramping

Summary

- Smart grid of the future
  - Brings information and communication technology, as well as power electronics, into electric grid.
  - Promises better utilization of renewable resources and demand participation.
  - Will unleashing innovation for new sensors, smart appliances, new devices, new products, etc.
- Smart operation of smart grid
  - To realize full potential of a smart grid, smart operation must be developed for all grid participants.
  - Research in new operational paradigm and system integration is needed. Examples of risk-limiting dispatch, design of future control centers and self-healing grid, as well as a testing laboratory, are given.

Thank You



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