Renewable Energy and Distributed Power Generation

Overview & Scope in USA
Past, Present and Future

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Presentation Outline

- Historical Perspectives
- DG Fundamentals
- Renewable Energy and Distributed Generation
- DG & Renewable Technologies
- Challenges and Problems
- Conclusions
- Q and A?

Hi-Lights and Snapshots

Historical Perspectives in USA

- Inception - 1930
- 1931 - 1950
- 1951 - 1985
- 1986 - Present

Brief US History of Electric Power Industry: Important Milestones

History

Early Days (Inception – 1930): (~50 Years)

- (1879) Light Bulb Invented by Edison
- (1882) Pearl Street Generating Plant (DC)
- (1882) Poly-Phase Induction Motor (AC) Invented by Tesla
- (1883) Transformer Invented by Stanley
- (1884) Steam Turbine Invented by Parsons
- (1885 - 93) Westinghouse, Edison, Tesla (DC Vs. AC)
- (1895) Niagara Falls Power Station (3-Phase, AC)

- Small and Regional Utility Companies, Little Interconnection and Transmission Facilities
- Technological Improvements in Generation and Transmission followed by Load Growth
- Competition, Consolidation, and Monopoly
- "Formation of Holding Companies" and Their Abuses
- Federal Government Intervention

1931- 1950

(~20 yrs.)

High Load Growth, Technological Development, Government Participation & Intervention

Brief US History of Electric Power Industry: Important Milestones

Growth of Electric Power Industry (1931 - 50) (~20 yrs.)

1

- (1935) Public Utilities Holding Company Act (PUHCA) – Reorganized Electric Utility Industry and Created Effective Regulation (State and Federal)
- (1936) Federal Power Act (FPA) and Creation of Federal Power Commission (FPC)

- Tremendous Growth of Hydropower (US Government) and Use of Electricity
- Rural Electrification Program

1951- 1985

(~35 yrs.)

Modernization of Electric Power Industry, Technological Development, Extensive Interconnection, Government Regulation

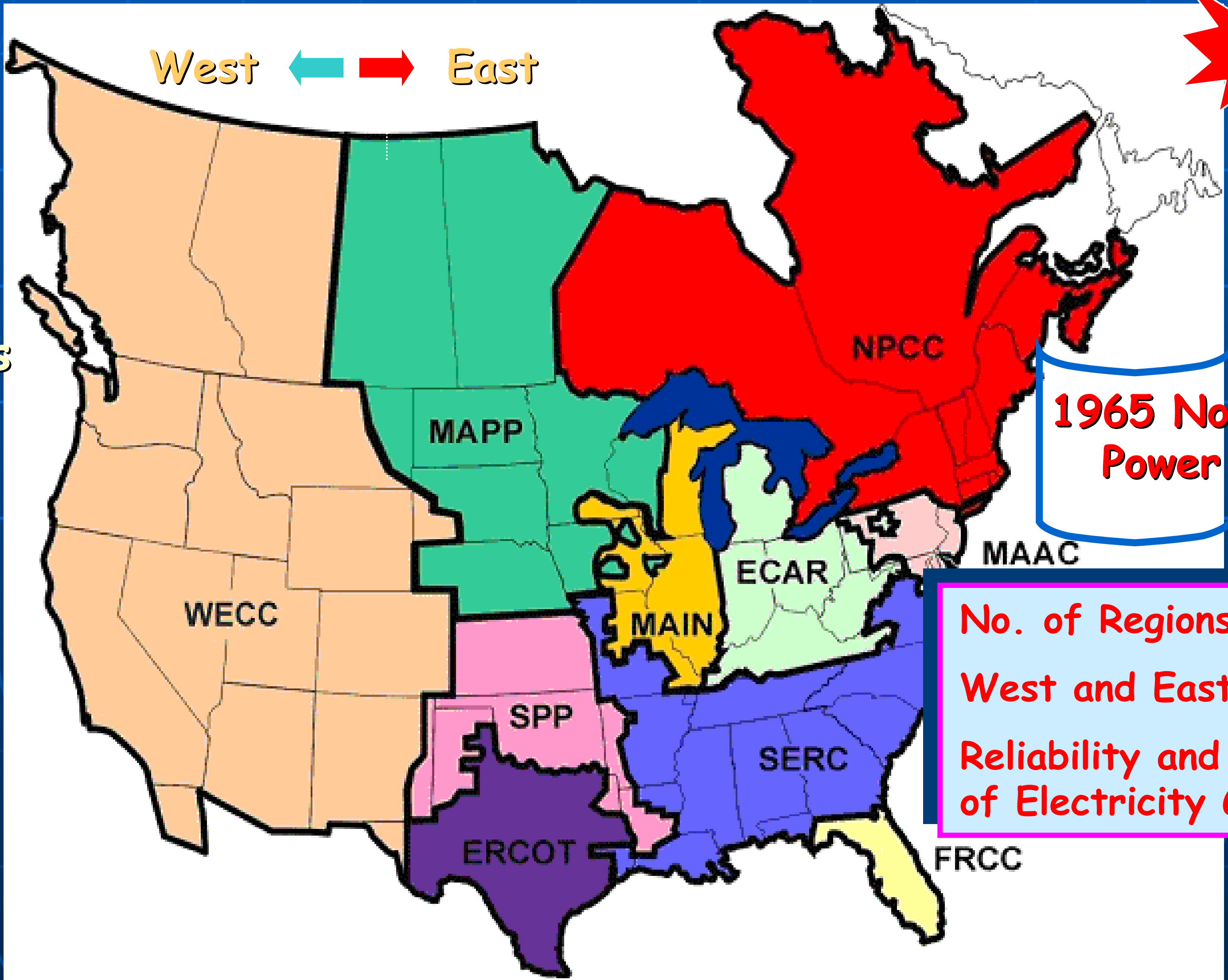
Modern Days Electric Power Industry USA and Canada (1951-85):

(1965) North East Power Failure

(1968) North American Electric Reliability Council (NERC)

2

Tremendous Growth of Electric Power Industry



1965 North-East Power Failure

No. of Regions (9)

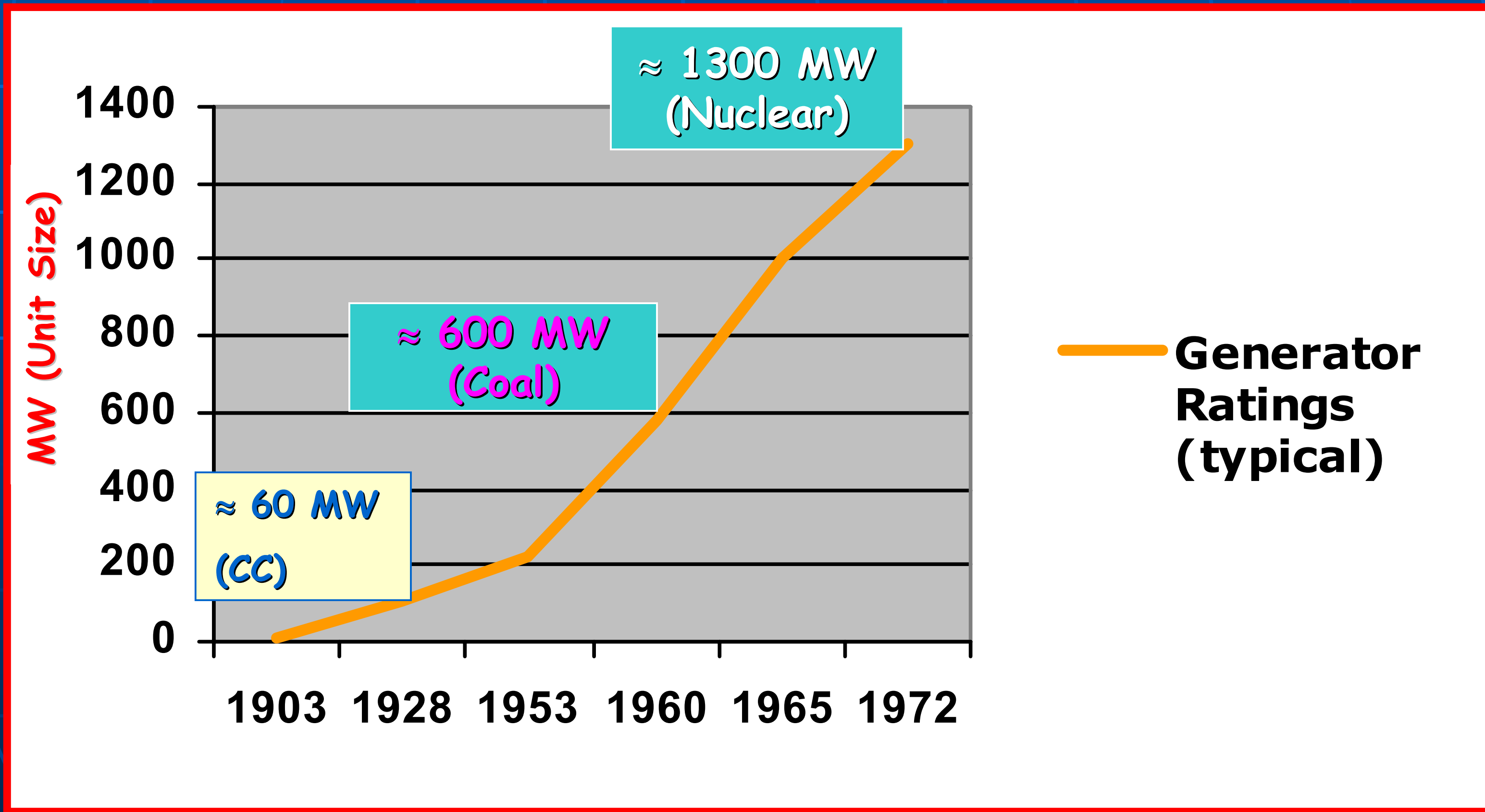
West and East/Texas

Reliability and Security of Electricity Grid

Technological Improvements: Generation (1920s-1970s) → 50 yrs.

Larger (the "Better") Units are more efficient - produce cheaper electricity.

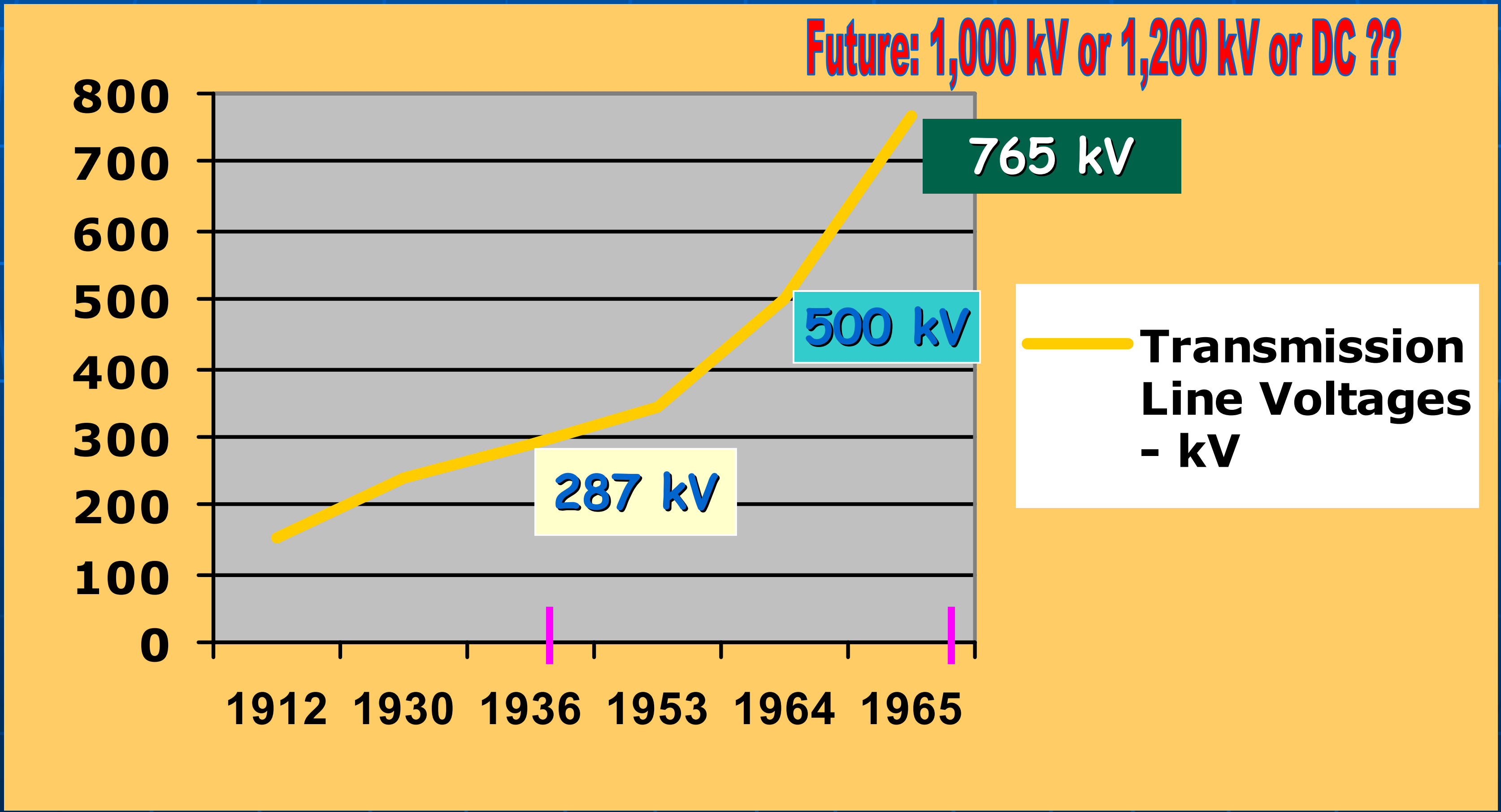
"Central Power Plants"



Technological Improvements: Transmission (1920s-1970s)

50 yrs.

Higher Voltage Reduces Losses, it is cheaper to transmit electricity long distances. Interconnection for Reliability, Resource Sharing and Cost Minimization



Brief US History of Electric Power Industry: Important Milestones

Modern Days Electric Power Industry (1951-85):

- (1973) Oil Embargo and Energy Crisis
- (1976) Formation of the "Department of Energy" (Split Department of the Interior)

(1977) Federal Energy Regulatory Commission (FERC) Created, "FPC (1935) Abolished", FERC had more Authority and Broader Responsibility

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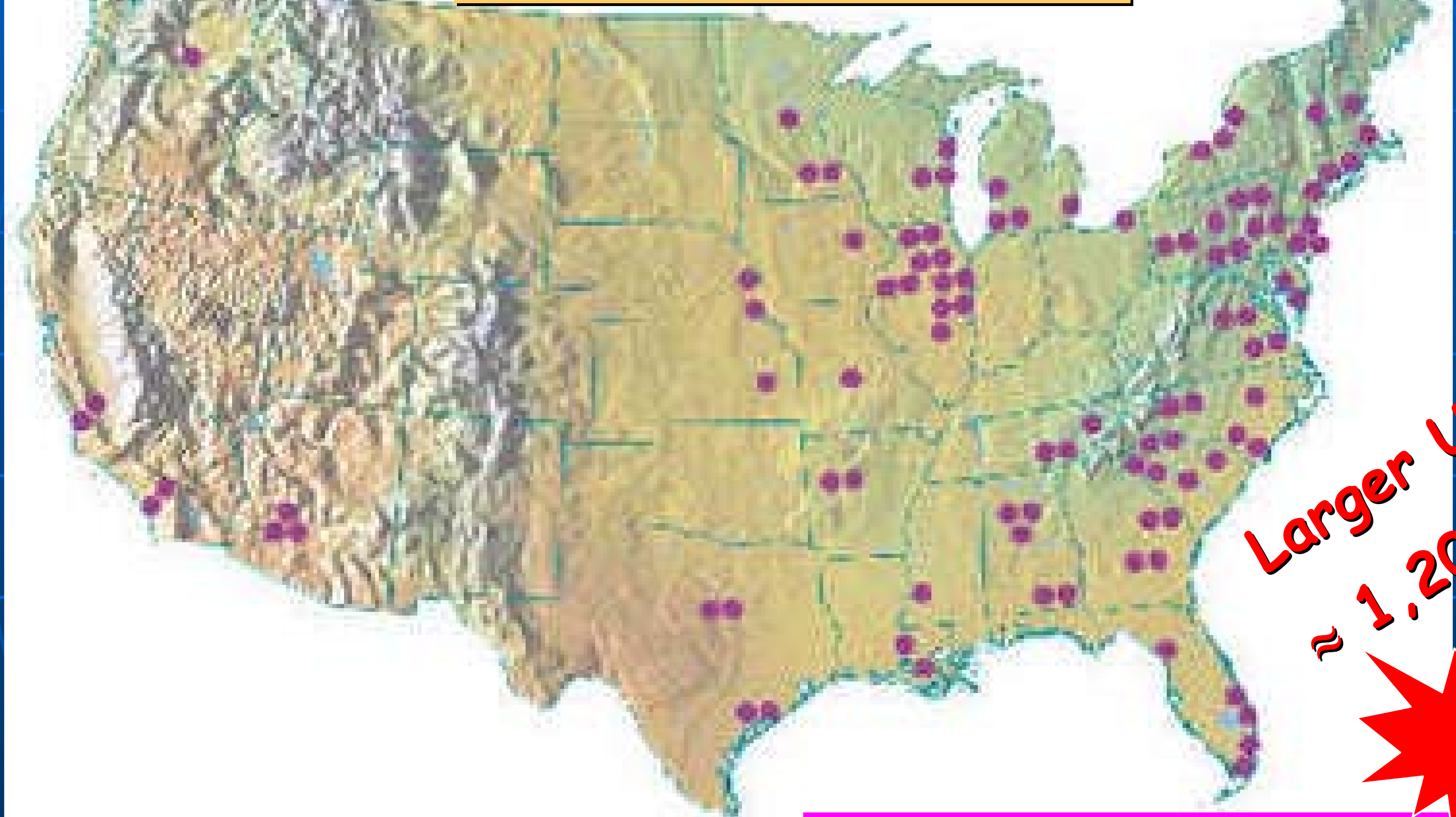
Brief US History of Electric Power Industry: Important Milestones

Modern Days Electric Power Industry (1951-85):

- Little Development in Hydro Power (Already Mostly Developed)
- Growth of Nuclear Power
- Coal Fired Power Plants Growth – Larger Sizes
- Growth (~7%) of Electricity Demands Continues
- Higher Bulk Transmission Voltage and Tremendous Growth of Interconnected Power Network

Nuclear Power in USA

("Base" Load Plants)



Larger Units
≈ 1,200 MW

4

Two Very Important Events:

(1979) Three Mile Island Accident

(1986) Chernybal Nuclear Power Plant Accident

Demise of Nuclear Power Growth in USA!!!

(1974) Energy Reorganization Act

Nuclear Regulatory Commission (NRC)

Historical Perspectives of Deregulating Electric Power Industry in USA

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PURPA (1978): Public Utility Regulatory Policies Act

PURPA was a broad statute aimed at expanding the use of cogeneration and renewable energy sources. It created a new class of power producers called Qualifying Facilities (QFs), which are basically independent (non-utility-owned) power generators (NUGs, IPPs) who meet certain stipulations. The PURPA requires utilities to buy power from these non-utility generators at each utility's avoided cost – a price equal to the incremental cost that particular utility would incur to produce the power itself (i,e., what the utility saves or avoids spending by not generating that same amount of power with its own generators).

De-Regulation & Restructuring

1986 – Present

(most recent ~20 years)

Slower Growth, Higher Prices, Growth Restriction, More Government Intervention, Use of Renewable Energy

Brief US History of Electric Power Industry

Modern Days Electric Power Industry

- Very Few New Power Plants (Mostly Coal) by the Investor Owned Utility (IOU)
- Little Expansion on EHV (Bulk Power) Transmission System
- Long and Expensive Process for New Power Plants and T&D Expansion (Environmental Impact Assessment and Permitting)
- Energy Growth (Slower Rate, ~3-4%)
- Energy Conservation (Demand Side Management or "DSM")
- Very Little Expenditure on "Infrastructure"
- Independent Power Producers (IPPs) – Built Power Plants (Combined Cycle Gas Turbine: 50-150 MW Range)and sold Power to Large Utilities (IOUs)
- Cogeneration - many smaller industrial type power plants (1 – 30 MW Range): PURPA and QFs
- Low Head (and Small) Hydros (100 kW - 5 MW Range)

Brief US History of Electric Power Industry

- Reserve Margin Depleted from Approx. 30% in Early 70's to about ≈ 6-8% at Present.
- Reserve Margin is the amount of generating capacity over and above the peak load, allowed to cover maintenance and contingency (failure) needs. Generally, 12-15% is considered a good rule of thumb.
- Spinning Reserve is the actual amount of plants kept running.
- Standby Reserve is that available on short notice (say 30 mins.).

Depleted Reserve Margin

US Historical Perspectives of Deregulating Electric Power Industry

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EPAct (1992): Energy Policy Act

This comprehensive Bill had over 30 titles (sections) covering more than just electric power. In that sector, it addressed many important issues, including nuclear plant licensing, environmental impacts, energy efficiency, electric vehicle technology applications, and more. The most sweeping impact on the electric power power industry was the fundamental changes it mandated by creating Open Access for Transmission. Any wholesale generator or buyer can petition FERC to mandate wheeling over any electric utility transmission facilities.

Role of US Government and Government Interventions

- (1935) Public Utilities Holding Company Act (PUCHA)
- (1936) Federal Power Act and Federal Power Commission (FPC) – Later Replaced by Federal Energy Regulatory Commission (FERC)
- (1968) North American Reliability Council (NERC)
- (1974) Energy Reorganization Act / Creation of Nuclear Regulatory Commission (NRC)
- (1976) Department of Energy
- (1977) Federal Energy Regulatory Commission (FERC)
- (1978) Public Utility Regulatory Policies Act (PURPA)
- (1992) Energy Policy Act (EPAct)
- (1996) FERC Orders 888 and 889
- (2000) FERC Order 2000 and More

FERC Orders

- Public Utility Commission (PUC) - State

US Historical Perspectives of Deregulating Electric Power Industry

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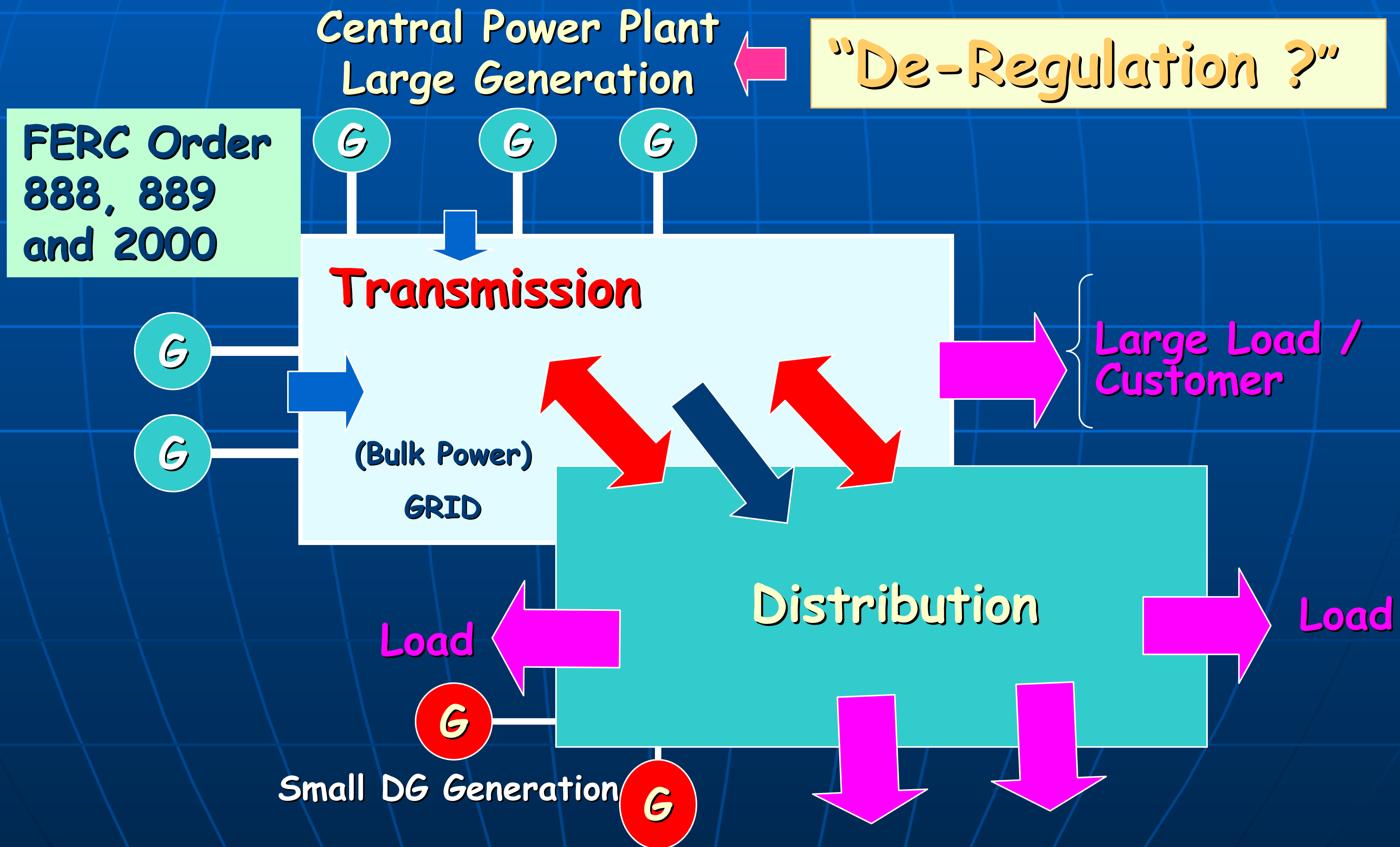
- FERC Orders 888 and 889 (1996) and More!!!
  While the EPAct introduced competition, it was up to the FERC to define the way it would be implemented. After two years of study following EPAct, FERC issued what was called the (Notice of Pending Ruling (NOPR)' which described its intended direction: toward full wholesale competition and open transmission access. FERC received over 20,000 pages of commentary on its rulings. FERC Order 888 orders all public utilities with transmission assets to offer non-discriminatory, open access and ancillary services to wholesale sellers and buyers of power. Order 889 details of how open access same time information system (OASIS) was to be developed.

Blackout 2003

- Reduced Reserve Margin
- Transmission Congestion
- Inadequate and Aging Infrastructure
- Reduced Operation and Maintenance
- Inadequate Training
- Decline in Educational Efforts
- Poor Engineering
- Very Little R & D Investment
- Corporate Greed
- Lack of Accountability and Quality, etc.

Summary

Basic Structure of Modern Electric Power System



Distributed Generation

&

Renewable Energy

Distributed Generation (DG):

- Traditionally, electric utility systems evolved with the central station concept because of significant economy of scale in power generation. Very large generators produced electric power and energy at less than one half the cost of small generator units. The bigger the generator, the more economical the power it produced.

- In the past 10 years, however, for numerous reasons, the traditional economic margin between the large and small units have decreased considerably.

What is "Distributed Generation (DG)" or Distributed Energy Resources (DER)?

- Small Generators and Storage Power Systems
- Typical Ranges: 1 kW to 50 MW or Larger
- Scattered throughout the Power Grid and Connected Primarily to Distribution System
- Provides Electric Power Needed by Electrical Consumers
- Located on the Utility System
- Stand-Alone - Isolated Site Not Connected to the Power Grid

Distributed Generation (DG)
(Other Characteristics)

- Recent Development
- Abundant Availability of Natural Gas ??
- CC Unit Size (50-60 MW very common)
- Real Short Time Construction Time
- Availability and Reliability of Power Supply
- Impact on Modern Power System
- Cost of Generation - $ 400/kW (combined cycle)
- Quick Fix, Short Term and Localized Solution

DG Includes

- Traditional (or Conventional) Power Generation
  - Diesel (5 kW-25 MW)
  - Combustion Turbine (10 MW – 50 MW)
  - Combined Cycle Turbine (50 MW – 150 MW)
  - Low-Head Hydro (10 kW – 5 MW)
  - Co-Generation Units (1 MW – 5 MW)
- Renewable Energy (and Non-Conventional Power Generation)
  - Wind (10 kW - 2 MW)
  - Solar Thermal (5 - 10 MW Range)
  - Photo-Voltaics (Small - 500 kW)
  - Low-Head Hydro (10 kW – 5 MW)
  - Biomass & Trash
  - Geothermal
  - Ocean Gradient
  - Tidal Power
  - Hybrid Systems
  - Fuel Cell

Relationships Between ?

- Standby Power Generation
- Emergency Power Generation
- Co-Generation
- Distributed Storage and Generation System (DSG)
- Dispersed Storage and Generation
- Dispersed Energy Systems (DES)
- Distributed Resources (DR)
- Independent Power Producers (IPP Plants)
- Non-Utility Generators (NUG)
- Hybrid Power Systems

All DG

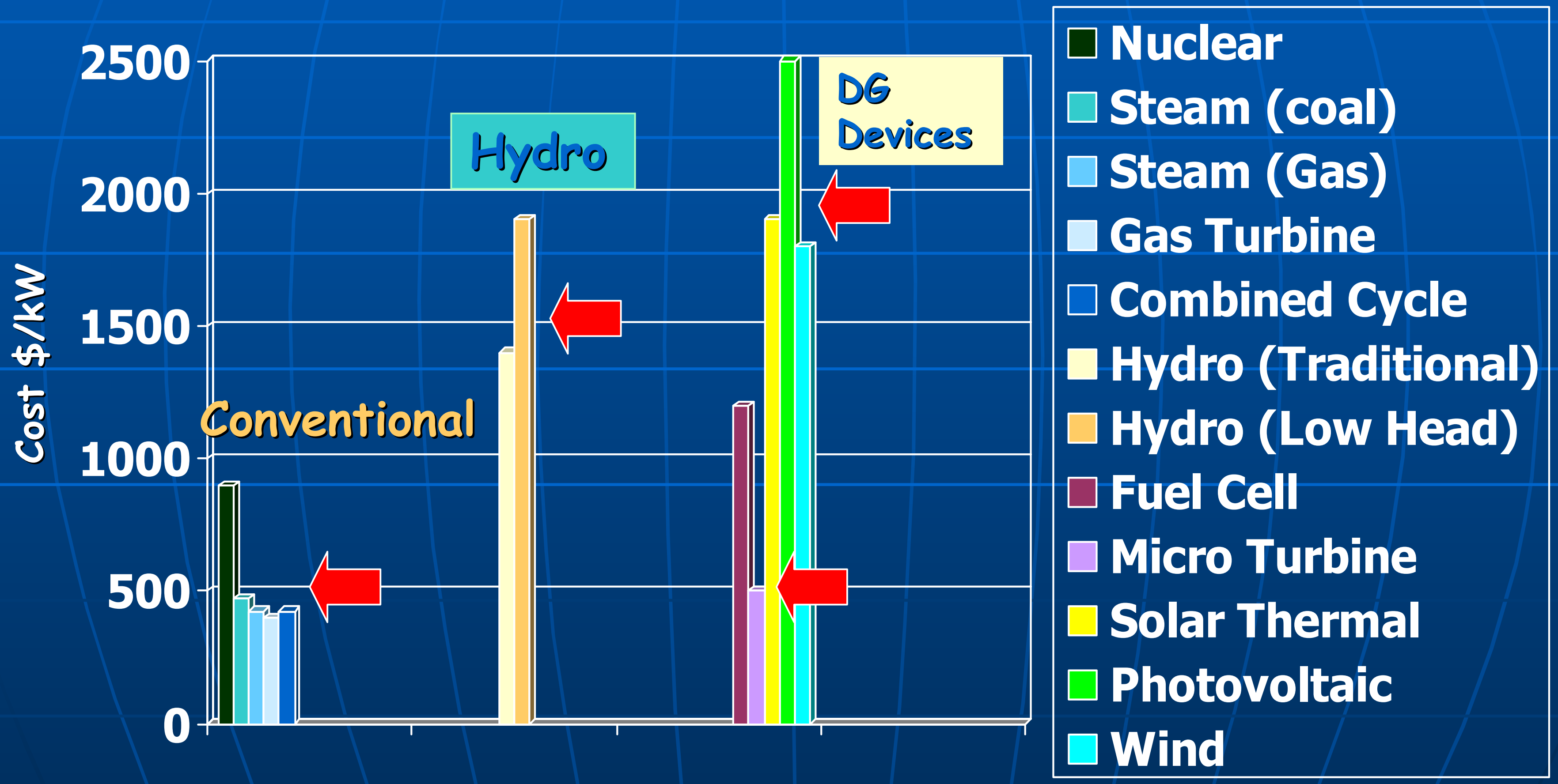
Renewable Energy (Non-Hydro): Role and Impacts

- Reasons for Recent Advancement and Research and Developments – Green House Effect and Global Worming, Sustainability, Less Dependence on Foreign Oil, Limited Resources of Usable Energy, Environmental Impact and Echo System
- Current Available Technology : Low-Head Hydro, Photovoltaic, Solar Thermal Storage Units, Wind, Fuel Cell, Ocean Thermal Gradient, Tidal Power, Geothermal, Trash Burning and Biomass, etc.
- Nuclear Fusion ??

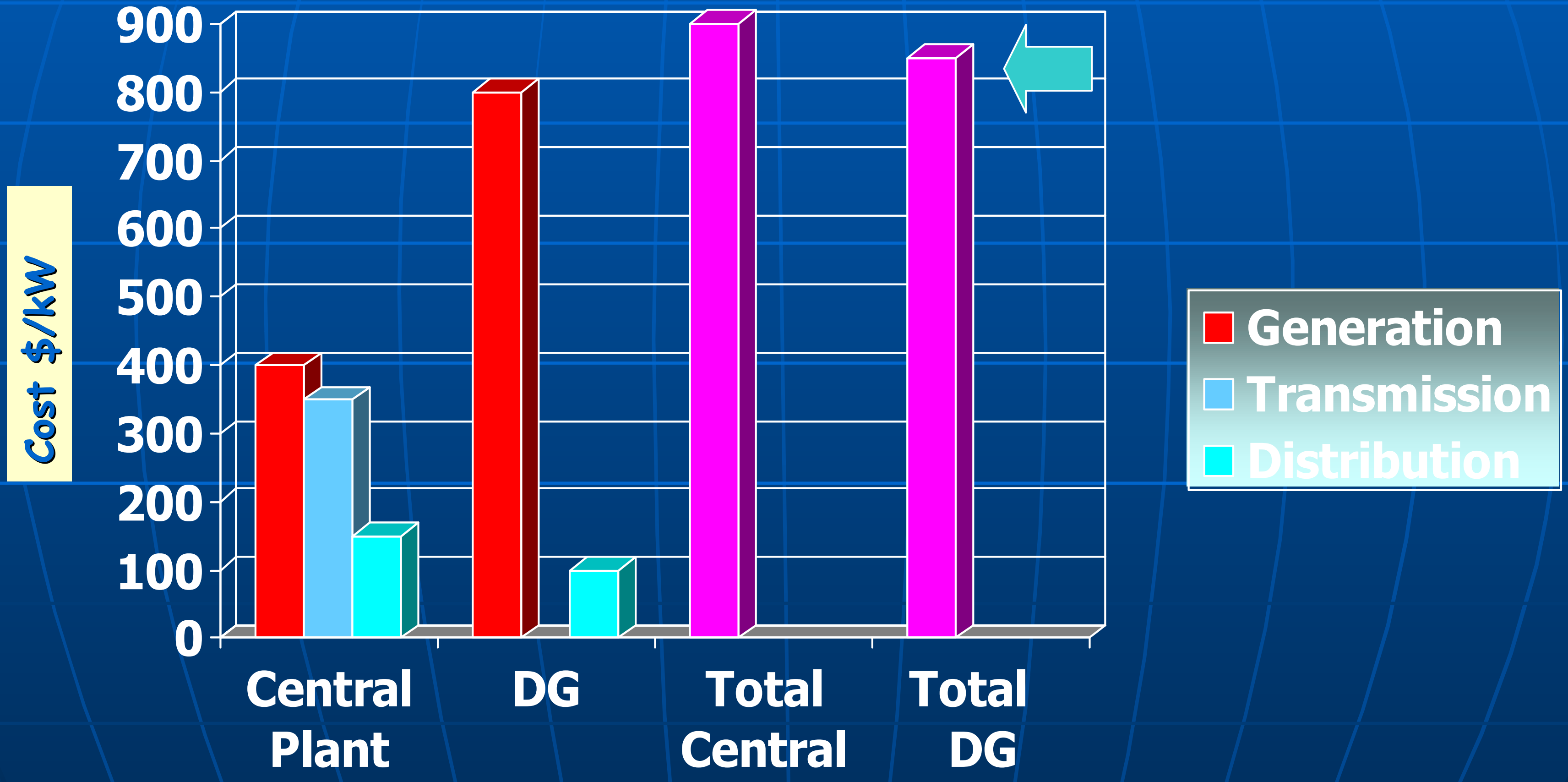
Renewable Energy (Non-Hydro): Role and Impacts

- Current Technological Development: Status – Cost of Generation ($/kW) and Comparison with the Existing Technology, Prediction, Environmental Impact and Aesthetics, Energy Density (Compared to Nuclear, Fossil Fuel, and Hydro Power)
- Base Load v. Special Application Considerations
- Incremental Load
- Practicality
- Reliability and Security of Power Systems (Unproven Technology, still in R&D Mode)

Capital Cost Comparison - DG Applications

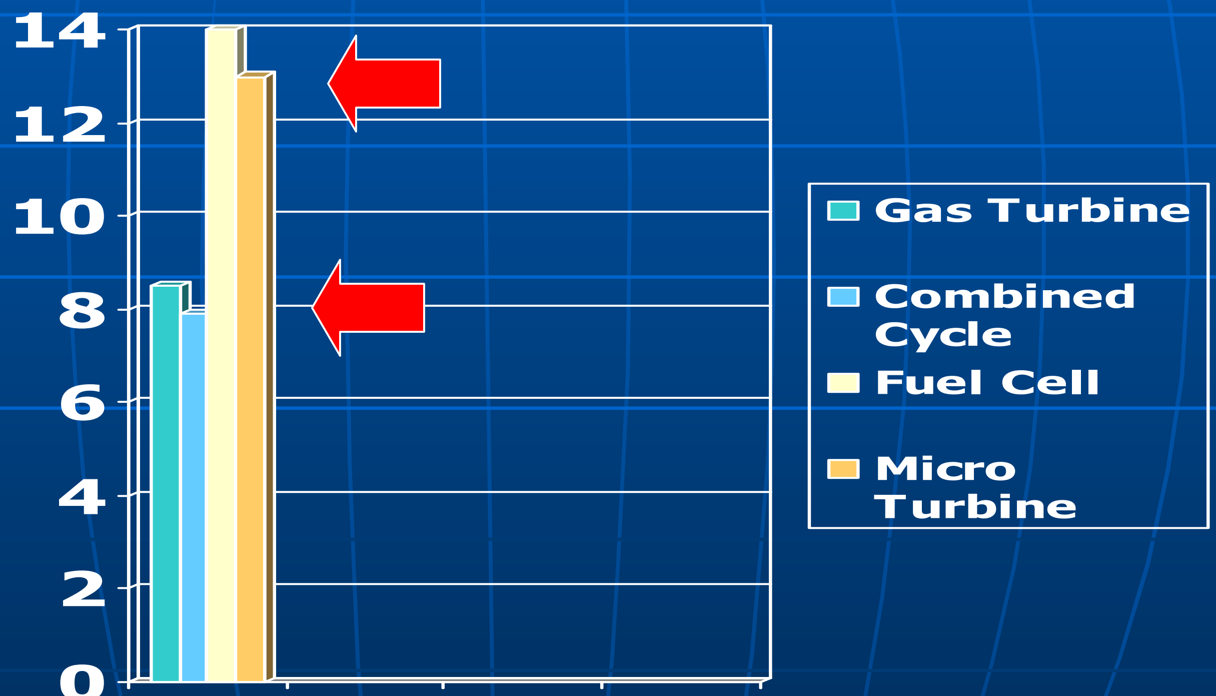


Typical Cost Analysis – DG Applications



Cost of Energy - DG Applications

Cents/kWh
Peaking Power



DG Technologies

Cost of Energy Trend

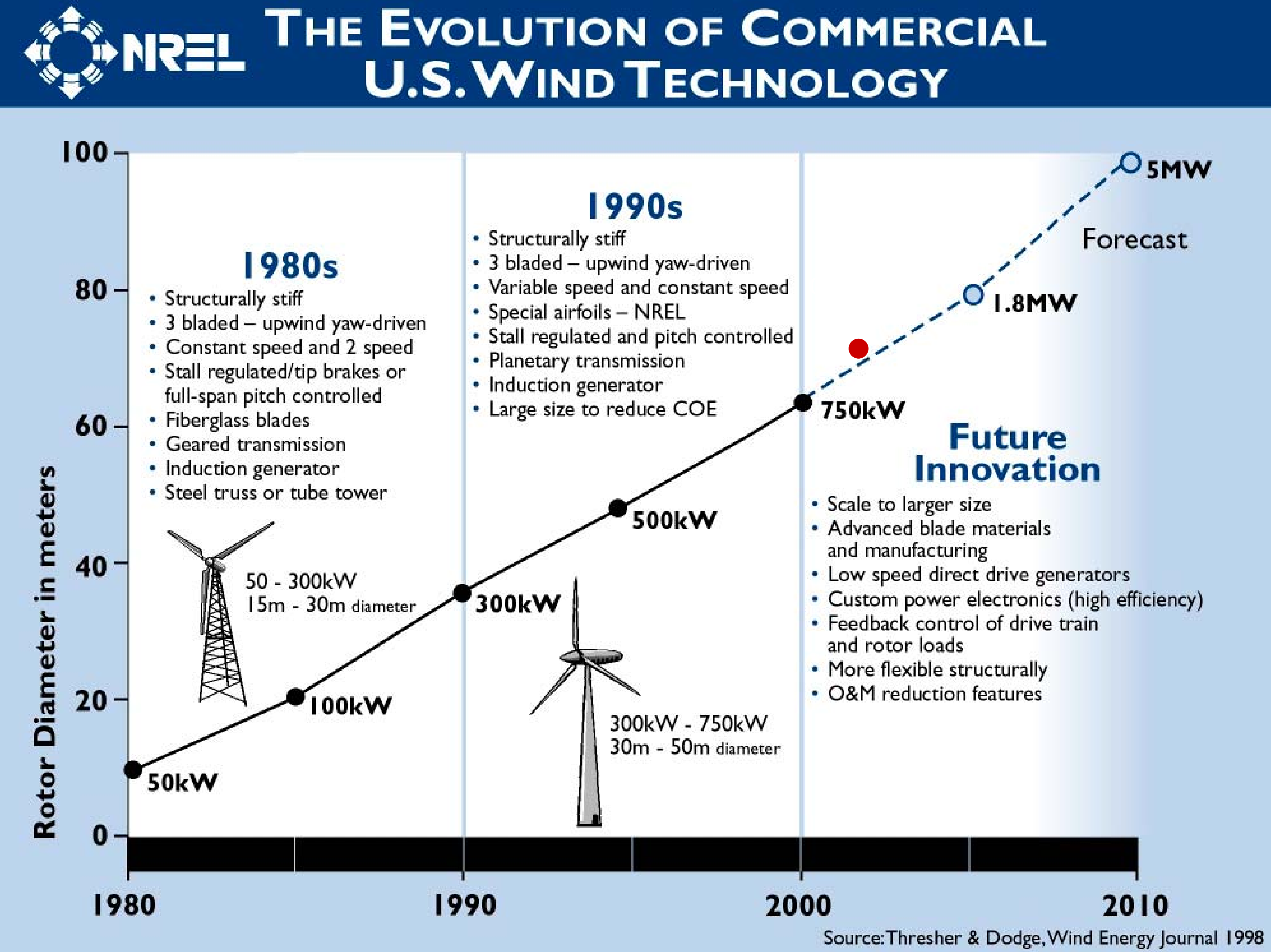
1979: 40 cents/kWh

2000:
4 - 6 cents/kWh

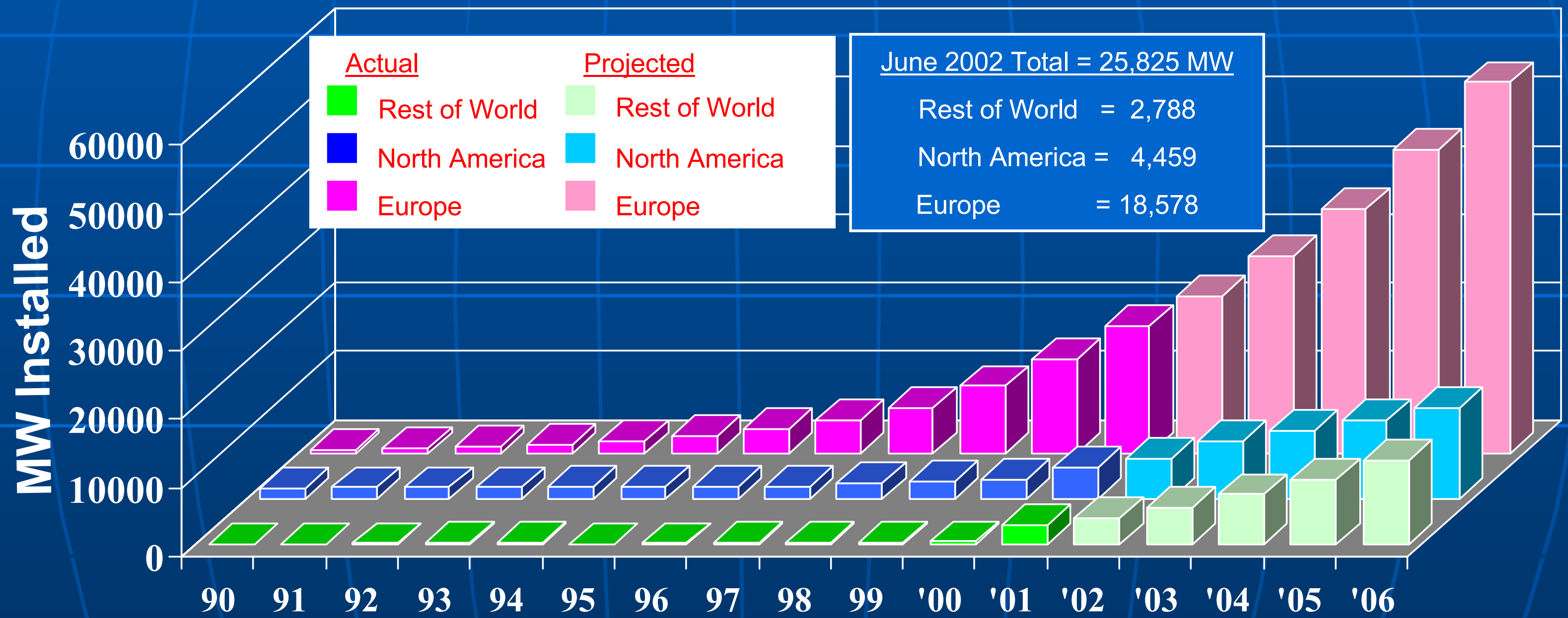
NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

- **Increased Turbine Size**
- **R&D Advances**
- **Manufacturing Improvements**

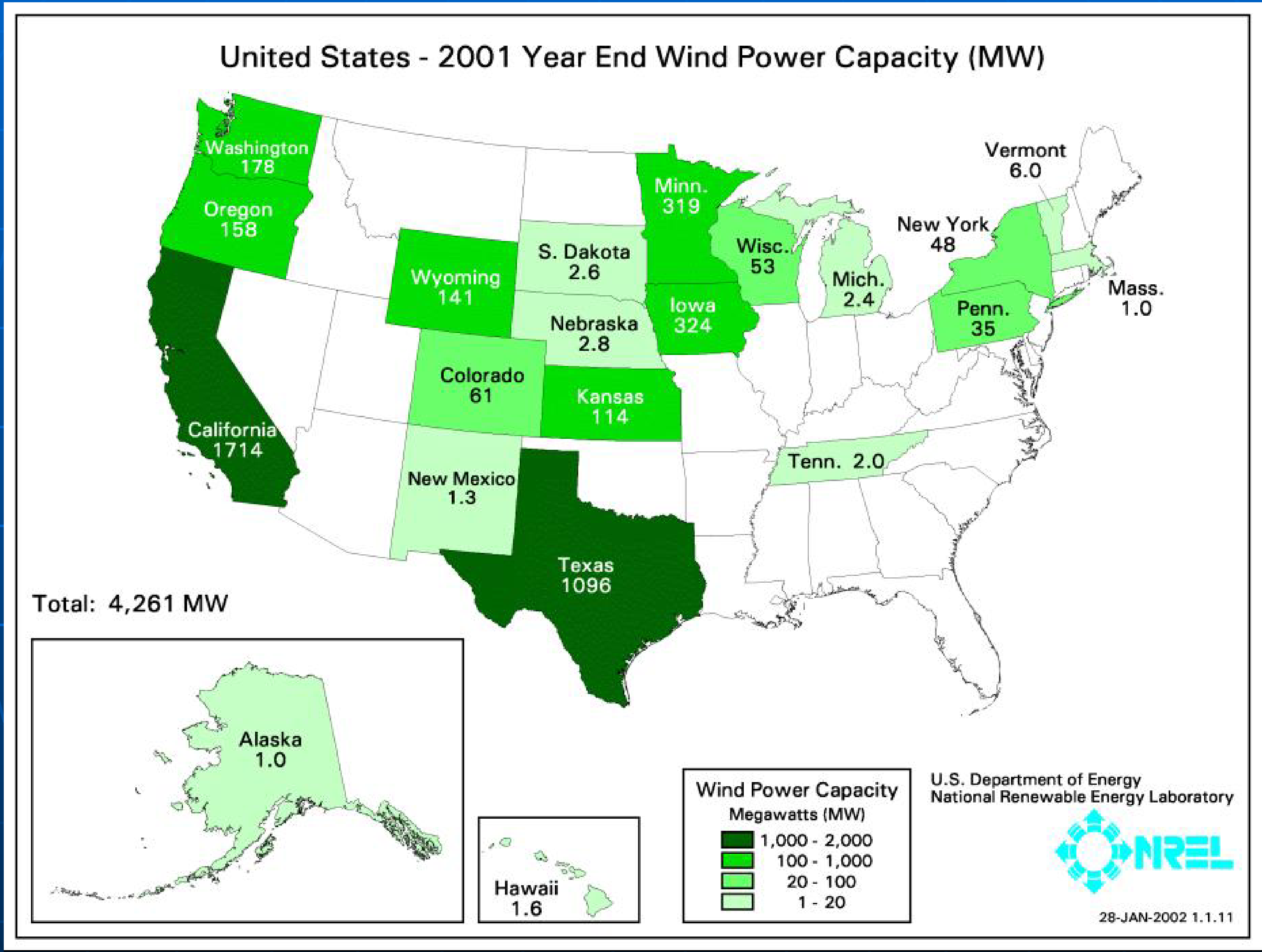
2004:
3 - 5 cents/kWh


NREL
THE EVOLUTION OF COMMERCIAL U.S. WIND TECHNOLOGY
Rotor Diameter in meters
100
80
60
40
20
0
1980
1990
2000
2010
1980s
• Structurally stiff
• 3 bladed – upwind yaw-driven
• Constant speed and 2 speed
• Stall regulated/tip brakes or full-span pitch controlled
• Fiberglass blades
• Geared transmission
• Induction generator
• Steel truss or tube tower
50 - 300kW
15m - 30m diameter
1990s
• Structurally stiff
• 3 bladed – upwind yaw-driven
• Variable speed and constant speed
• Special airfoils – NREL
• Stall regulated and pitch controlled
• Planetary transmission
• Induction generator
• Large size to reduce COE
300kW - 750kW
30m - 50m diameter
50kW
100kW
300kW
500kW
750kW
1.8MW
5MW
Forecast
Future Innovation
• Scale to larger size
• Advanced blade materials and manufacturing
• Low speed direct drive generators
• Custom power electronics (high efficiency)
• Feedback control of drive train and rotor loads
• More flexible structurally
• O&M reduction features
Source: Thresher & Dodge, Wind Energy Journal 1998

Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, March 2002
Windpower Monthly, January 2002


United States - 2001 Year End Wind Power Capacity (MW)
Washington 178
Oregon 158
California 1714
Wyoming 141
S. Dakota 2.6
Nebraska 2.8
Colorado 61
Kansas 114
New Mexico 1.3
Texas 1096
Minn. 319
Iowa 324
Wisc. 53
Mich. 2.4
Tenn. 2.0
New York 48
Penn. 35
Vermont 6.0
Mass. 1.0
Total: 4,261 MW
Alaska 1.0
Hawaii 1.6
Wind Power Capacity
Megawatts (MW)
1,000 - 2,000
100 - 1,000
20 - 100
1 - 20
U.S. Department of Energy
National Renewable Energy Laboratory
28-JAN-2002 1.1.11

International Market Drivers

- Europe
  - high mandated purchase rates (85-90% of retail, 10-12 cents/kWh)
  - strong government and public commitment to the environment, including climate change
  - population density & existing developments driving off shore deployment in Europe

- Developing World
  - huge capacity needs
  - lack of existing infrastructure (grid)
  - pressure for sustainable development (IDB's, climate change)
  - tied aid

Sizes and Applications

Small (≤10 kW)

- Homes
- Farms
- Remote Applications

(e.g. water pumping, telecom sites, icemaking)

Intermediate (10-250 kW)

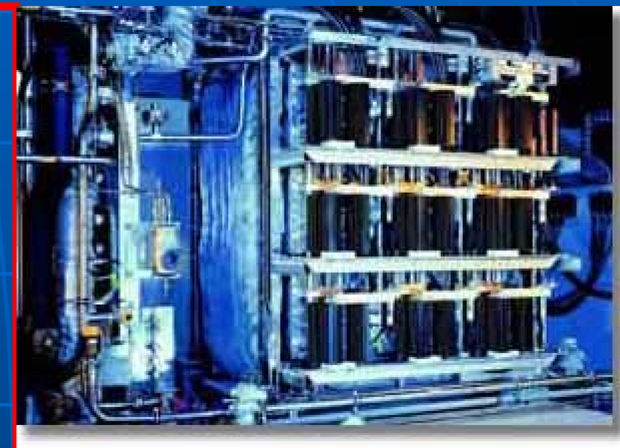
- Village Power
- Hybrid Systems
- Distributed Power

Large (250 kW - 2+MW)

- Central Station Wind Farms
- Distributed Power

DG Options (Fuel Cell)

- Generates DC with chemical reaction , requires an inverter
- No moving parts
- Power output of up to 2 MW (depending on type)
- High operating temperature



- Cost of 2,000 to 3,000 $/kW installed
- Additional cost of fuel and maintenance
- Low emission
- Difficult and polluting manufacturing process

- Fueled by hydrogen ideally but often reformed from other sources:
  - Natural gas
  - Water
  - Propane
  - Waste gas
- Hydrogen Storage
- Require pure fuel source

DG options (Microturbine)

- Generates high frequency AC, requires an converter /inverter
- Power output of 30 to 250 kW
- Output voltage of 480V to 4.16 kV
- Primarily uses natural gas as a fuel source but can be run on propane, waste gas or a variety of others

- Produces significant air pollution (still less that traditional sources)
- Produces large amounts of high temperature exhaust (CHP)
- Cost of 1,000 to 1,500 $/kW installed
- Additional cost of fuel and maintenance

DG Options (Photovoltaic)

- Generates DC, requires an inverter
- No internal moving parts (sun tracking)
- Power output is Scalable with size of array
- Not dispatchable - only available when the sun is shining

- Cost of 5,000 $/kW installed
- No additional fuel costs and low maintenance
- Environmentally friendly running

DG Options (Hydro)

- Power rating 1kW and up depending on type and application
- Normally synchronous or induction, no inverter necessary
- Cost 1,200 to 6,000 $/kW (heavily site dependent)
- Environmentally friendly

Biomass

Facts and Figures:

- Current Installed Capacity: ≈ 8,000 MW
- Conventional Steam Cycle (Low Efficiency)
- Economic Size: 10-30 MW Range
- CHP Design: 1-10 MW Range
- Small Scale and Very Selected (Economically Justified) Applications
- Economically Not Justifiable yet?

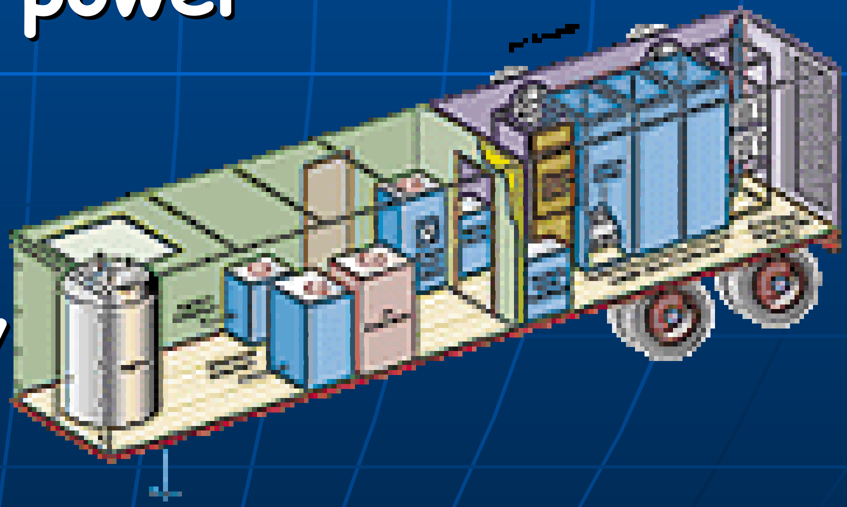
Storage Systems

- **SMES ($ 2,500 – 4,000 /kWhr)**
- **Battery**
- **Ultra- Capacitor**

- Fly Wheel
- Compressed Air
- Solar Thermal Energy Storage

DS Options (SMES)

- Can supply up to 3 MW and 18 MVAR of support per unit
- Can also supply large amounts of reactive power
- Very short term or instantaneous supply
- Very new technology



Power Systems and Interconnection Issues

Microgrid

DG Connection

- Distribution System (12.47 kV and Below) for Smaller Units
- Sub-transmission System (69 kV and 115 kV) for Larger Units

Electrical Machines & Systems

- Synchronous Generator
- Induction Generator
- Power Electronics: DC Power Output together with DC $\rightarrow$ AC Converter; Converter Technology; Control of Power

Why DG?

- Minimize Transmission and Distribution (T & D) Cost
- Increase Efficiency (40-55% Compared to 28-35% for Conventional Thermal Power Plant)
- DG Often Wins at Both Ends of the Reliability Spectrum
- Modular Design (Factory Assembled), Simplified Engineering Installations and Lower Cost
- Environmental Concerns

Why Not?

- Ownership and Operation
- Unproven Technology
- Aesthetics Concerns

T & D System Costs

- $ 50,000 / mile, Wood-Pole at 69 kV and 50 MVA ($ 1.00 / kVA-mile)
- $ 1,000,000 / mile for 500 kV, Double Circuit and 2,000 MVA ($ 0.50 / kVA-mile)
- Typical Distribution Substation: $ 20 – 40 / kW, 0.8 power factor, and Utilization Between 50-100%

- $ 150,000 / mile (Ranges: $ 50,000 – 300,000 / mile) – Typical 12.47 kV Distribution Line, 8-10 MVA, $10-15 / kVA-mile for Over Head Construction, and $ 30-50 / kVA-mile for Underground Construction
- Other Costs – Service Level Costs, O & M Cost, Cost of Electrical Losses

Guidelines for DG Applications

- Reducing Power Delivery (T & D) Costs
- Substitute for T & D Additions
- DG in Remote and Rural Locations
- DG Peak Shaving / Cost of Local utility Power
- Commercial and Industrial Applications

- Customer Applications
- Incremental Expansion Cost

Electric Power Systems, Machines, Power Electronics and Energy Research Focus and Overview