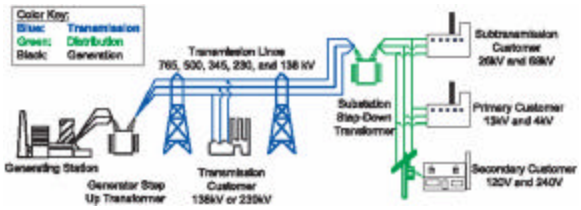
"Distinguished Lecturer" program

Green Power & the Modern Grid

Jerry Ramie
ARC Technical Resources, Inc.

The Existing Power Grid



Power and information flows <u>one-way</u>

PNNL began work on modern grid in 2000

Develop understanding of new technologies

Distributed energy resources

Load management & control

Automated power diagnostics

Solid-state controls

IT was the "key enabler" for transformation

GRIDWISE™ at PNNL

April 2003, representatives first met

Utilities, equipment makers, IT providers, Regulators, interest groups, universities, labs.

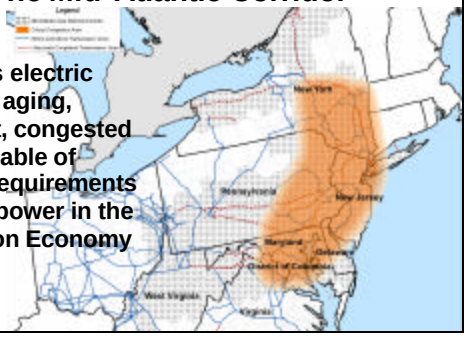
"Roadmap" for the future

***<u>Grid 2030</u>* from DOE**

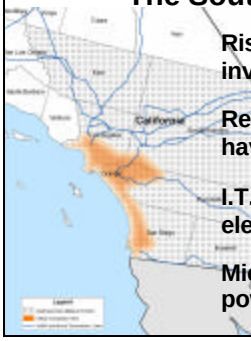
Their major findings:

The Mid-Atlantic Corridor

America's electric system is aging, inefficient, congested and incapable of meeting requirements for clean power in the Information Economy



The Southwest Corridor



Risk & uncertainty have driven investment an to all-time low

Regulations for competition have fallen short

I.T. has not transformed the electric industry yet

Microprocessors require better power quality & reliability

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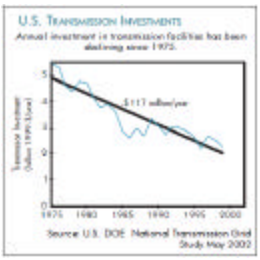
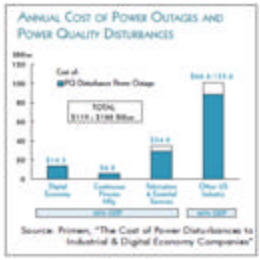
The Power Grid Problems

Increasingly difficult to site transmission lines





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The Power Grid Problems

"Grid 2030"

A National Vision for Electricity's Second 100 Years

- "Technology readiness" needs to be improved
- "Political logjam" should be eliminated
- "Research & Development" should be expanded
- "Technology roadmap" needs to be developed

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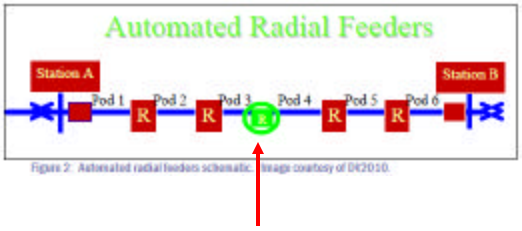
The Power Grid Problems

DOE "Smart Grid"

Self-healing from power disturbances



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The Power Grid Problems

DOE "Smart Grid"

Motivates & includes the consumer

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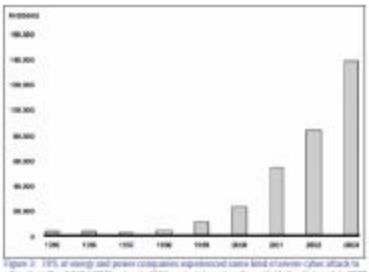
The Power Grid Problems

DOE "Smart Grid"

Resilient against physical or cyber attack



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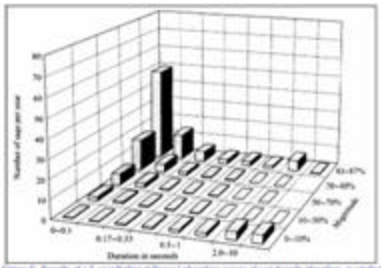
The Power Grid Problems

DOE "Smart Grid"

Provides power quality for 21st century needs



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The Power Grid Problems

DOE "Smart Grid"

Accommodates generation and storage options

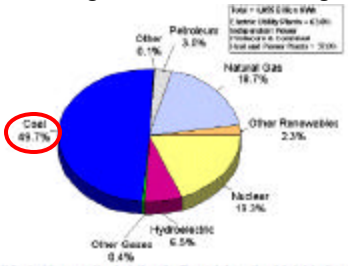

Figure 3: U.S. electric generation fuel diversity (Energy Information Administration, Form EIA-860, "Electric Power Annual" 2006: www.eia.doe.gov/cneaf/electricity/epa/figes1.html)

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The Power Grid Problems

DOE "Smart Grid"

Enables new products, services, and markets

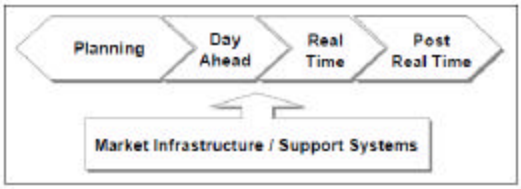

Figure 2: Time frames for market operations and their supporting infrastructure define the concept of enabling markets.

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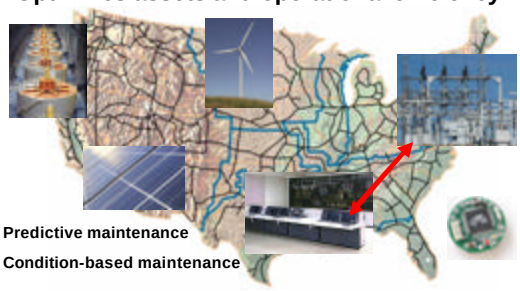
The Power Grid Problems

DOE "Smart Grid"

Optimizes assets and operational efficiency



Predictive maintenance

Condition-based maintenance

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The Power Grid Problems

DOE "Smart Grid"

Standardized designs stimulate developments

IEEE 1547 series of Standards for DER

Four key Technology Areas:

- **Architecture & Communication Standards**
- **Monitoring & Load Management Technologies**
- **Advanced Components & Operating Concepts**
- **Modeling & Simulation**

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The "Roadmaps"

EPRI ELECTRIC POWER RESEARCH INSTITUTE

***Intelligrid*™ architecture links communications and the power grid for the first time**

Basic technologies available today, integration (interoperation) is the challenge

Deploy equipment in this order:

- Automatic Meter Reading (AMR)
- (SCADA) uses the AMR infrastructure for control
- Remote-controlled distribution devices

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The "Roadmaps"

Modern Grid Strategy

Milestone Sequence

AMI

AMI empowers the customer and establishes communications to the loads

Communications is critical!

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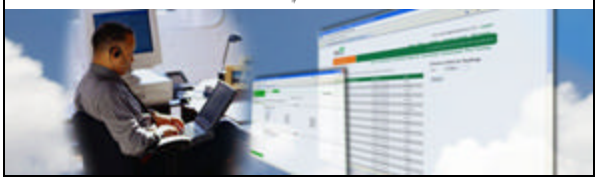
The "Roadmaps"

Modern Grid Strategy

Milestone Sequence

- **AMI** — *AMI empowers the customer and establishes communications to the loads*
- **Distribution (ADO)** — *ADO enables self healing*



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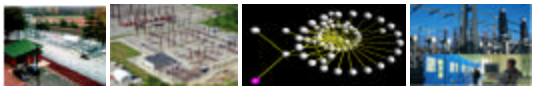
The "Roadmaps"

Modern Grid Strategy

Milestone Sequence

- **AMI** — *AMI empowers the customer and establishes communications to the loads*
- **Distribution (ADO)** — *ADO enables self healing*
- **Transmission (ATO)** — *ATO addresses congestion*



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The "Roadmaps"

Modern Grid Strategy

Milestone Sequence

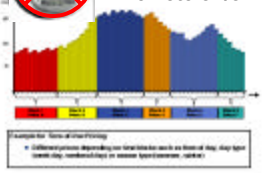
- **AMI** — *AMI empowers the customer and establishes communications to the loads*
- **Distribution (ADO)** — *ADO enables self healing*
- **Transmission (ATO)** — *ATO addresses congestion*
- **Asset Management (AAM)** — *AAM greatly improves the performance of today's asset management programs*

Green Power & the Modern Grid

The Technologies

AMI Systems

- Time-based pricing
- Data exchange
- Network metering
- Loss & Restoration
- Remote on/off
- Load limiting
- Pre-payment
- P.Q. monitoring
- Tamper & theft
- Communicates



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The Technologies

Home Area Networks

- In-home display
- Responsive to price signals
- Set points to limit control
- Control of loads
- Consumer over-ride capable

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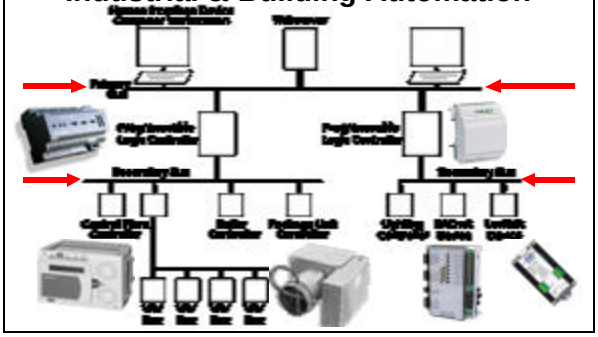
The Technologies

Industrial & Building Automation



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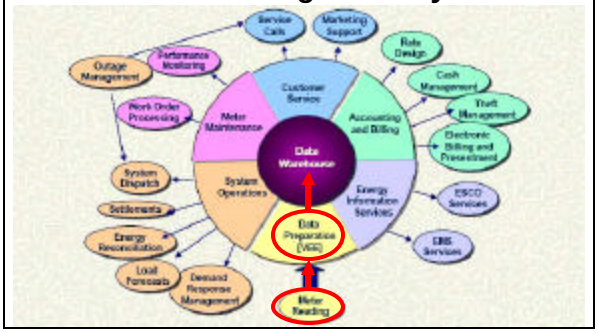
The Technologies

Meter Data Management Systems



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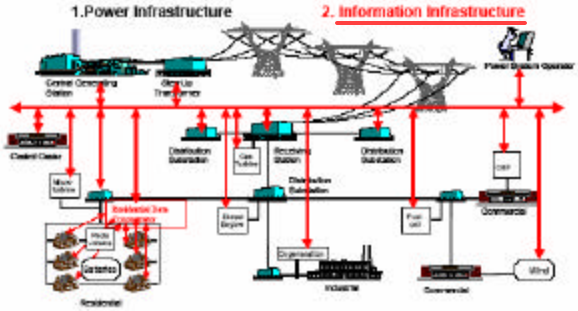
The Technologies

Integrated Communications



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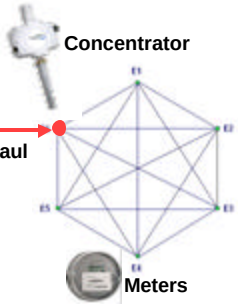
The Choices in Media

Typical Architecture

Network Operations

Backhaul

Concentrator



Meters

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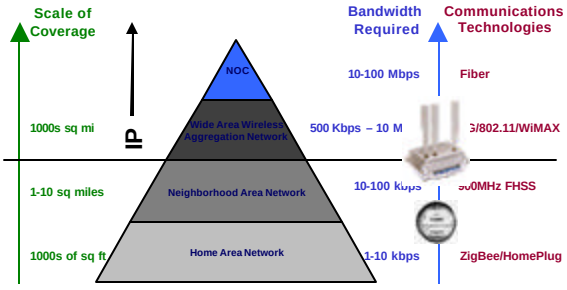
The Choices in Media

Typical Architecture



Typical "Smart Grid" Communications Hierarchy

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The Choices in Media

Wireline Technologies

Power Line Carrier (PLC)

- Substation versions for AMI
- Residential versions for HAN
- Communicate over power lines
- Long distances achievable
- Low cost, reliable, two-way
- Passes through transformers
- Slow speeds, point-to-point

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The Choices in Media

Wireline Technologies

Broadband over Power Lines (Access)

- More bandwidth than required
- Sell to customers over MV & LV
- 2G products can notch -35dB
- Make-ready & keep-ready work
- Gap noise erodes performance
- Limited distances & speeds
- EMC/emissions are site-variable

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The Choices in Media

Wireline Technologies

Broadband over Power Lines (In-Premises)

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The Choices in Media

Wireline Technologies

Copper UTP (telephone)

- Widely available
- Analog modem speeds
- DSL speeds, T1 speeds
- Co-located convenience
- Not owned by power company
- Continuing expense

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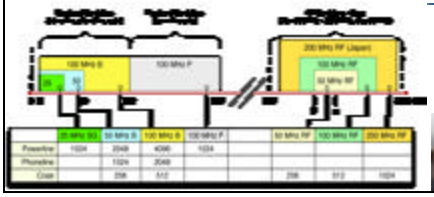
The Choices in Media

Wireline Technologies

G.hn

ITU began work in 2006 on a unified wireline networking standard for powerline, phoneline, & coax.

OFDM Carriers/media type



HomeGrid FORUM, Panasonic, 2wire, DS2

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The Choices in Media

Wireline Technologies

Optical Fiber

- Very high speed
- Secure
- Point-to-Point
- High installation costs

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The Choices in Media

Wireless Technologies

Multiple Address System Radio

- Unlicensed & licensed bands
- Point-to-Point or Multipoint
- SCADA & DA applications now
- Ethernet speeds (typically)

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The Choices in Media

Wireless Technologies

Paging Networks

- Short messages
- Small mobile terminals
- One-way is low cost
- Some Standards exist
- Not owned by power company
- Two-way messaging costly
- Most systems are proprietary

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The Choices in Media

Wireless Technologies

Spread Spectrum Radio

- Unlicensed 902-928MHz
- Point-to-Multipoint
- Short distance (last mile)
- Hopping consumes overhead
- Line-of-sight required

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The Choices in Media

Wireless Technologies

Wireless Fidelity (WiFi)

- Open Standards
- 802.11b & 802.11g
- 5-54Mb/s achievable
- High market penetration
- Short range <100m
- Poor reception
- Stucco mesh
- Other reflectors

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The Choices in Media

Wireless Technologies

ZigBee

- Low cost, low power usage
- IEEE 802.15.4 Standard
- Wireless control & monitoring

- Operates in ISM radio bands
- Limited adoption (currently)

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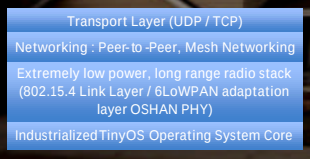
The Choices in Media

Wireless Technologie

OSHAN

- Average home size in the U.S. was 2,330 sq. ft. (2004)
  - The National Association of Home Builders
- PAN with 30 - 40' indoor communication ran[illegible]ay be insufficient for reliable wireless connections in the home



- 900 MHz implementation
- Lower data rate
- Spectrum is also crowded

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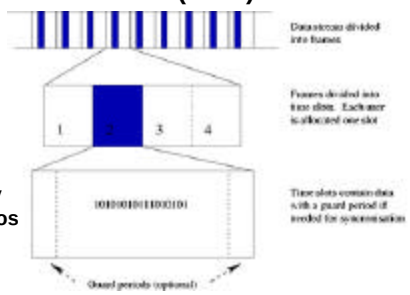
The Choices in Media

Wireless Technologies

TDMA Cellular (GSM)

- IS-136 Standard
- Several users share channel
- Unique time slot for each user
- Network capacity limits active radios
- Future is CDMA



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The Choices in Media

Wireless Technologies

CDMA Cellular

- IS-95 Standard
- Widely available
- Unique code for each user
- Short message length not for control
- Coverage can be spotty

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The Choices in Media

Wireless Technologies

3G Cellular

Third generation

Modem service for monitoring only

Short message length not for control

Intended for smart phones

Cost effective

Quickly implemented

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The Choices in Media

Wireless Technologies

WiMAX

Fixed operation to IEEE 802.16d

Mobile operation to IEEE 802.16e

75Mb/s over 10-30 miles

Different vendors work together

Poor market penetration

High cost (currently)

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The Choices in Media

Wireless Technologies

VSAT Terminal

Satellite ground station

Antenna <3 meters

Data rates up to 4Mb/s

Mesh or star configurations

Suitable for control

Wide coverage & quick implementation

Severe weather affects reliability

High cost?

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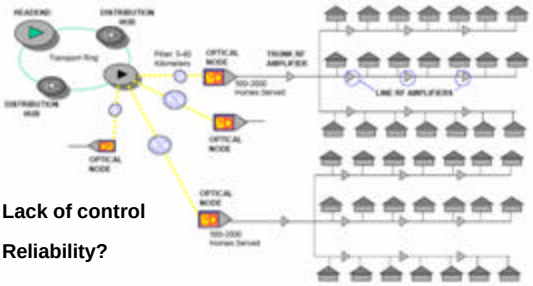
The Choices in Media

Other Technologies

Hybrid Fiber Coax (HFC)



Lack of control

Reliability?

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The Choices in Media

Other Technologies

Fiber to the Home (FTTH)

verizon FiOS Internet

Very fast speeds

Not owned by utility

Recurring costs

Lack of control

at&t U-verse

50Mb/s downstream

20Mb/s upstream

18Mb/s downstream

1.5Mb/s upstream

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The EMC Threat

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The EMC Threat

Indian Point, NY 3/23/08

Emergency shutdown caused by camera

RFI from Kodak C340 Digital Zoom

Boiler pump controller affected

"All that had to happen was for the camera to be on."

Similar incident at Haddam Neck, CT in 1997

Insufficient "compatibility margin"

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The EMC Threat

EMC & Vulnerability

Equipment reliability will be impaired by EMC problems

EMC validation through testing assures reliable operation

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The EMC Threat

EN 50178

Electronic Equip. used in power installations

For equip. not covered in Product Standards

Electric shock, testing, systems integration

Contains IT, power electronics, non-electronics

Covers stand-alone & sub-assemblies

EMC requirements at box or system level

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The EMC Threat

IEC Generic Standards

	Emissions	Immunity
Conducted	EN 55011 EN 55022	IEC 61000-4-6
Radiated		IEC 61000-4-3
Power-line	IEC 61000-3-2 IEC 61000-3-3	IEC 61000-4-8 IEC 61000-4-9 IEC 61000-4-10 IEC 61000-4-11 IEC 61000-4-13 IEC 61000-4-16 IEC 61000-4-17
ESD		IEC 61000-4-2
EFT		IEC 61000-4-4
Surge		IEC 61000-4-5
Surge Withstand		IEC 61000-4-18

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The EMC Threat

Substation Immunity Standards

Types of Equipment	more < < < < < < < < Severity < < < < < < < < less					
	IEC 60870-2-1 Tele-control equipment	IEC 60255-26 Relaying equipment	IEC 61000-6-5 Generic Substation	IEC 60439-1 Switchgear & Controlgear	EN 61326 Process Measurement	EN 55024 Computers & Telecoms
Microwave control	x					
Relays & assoc.		x				
Sensors			x		x	
Switchgear				x		
PC's						x
Power devices			x		x	
Power controls			x		x	
Metering					x	
2-way COM						x
Test Equipment					x	
Networking equip.						x
Wireless equip.						x

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The EMC Threat

EMC Standards for Protective Relays

	Emissions	Immunity
Conducted	IEC 60255-25	IEC 60255-22-6
Radiated		IEC 60255-22-3 → IEEE C37.90.2
Power-line	IEC 61000-3-2 IEC 61000-3-3	IEC 61000-4-8 IEC 61000-4-9 IEC 60255-11 IEC 60255-22-7
ESD		IEC 60255-22-2 → IEEE C37.90.3
EFT		IEC 60255-22-4
Surge		IEC 60255-22-5
Surge Withstand		IEC 60255-22-1 → IEEE C37.90.1

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The EMC Threat

Distributed Resources IEEE - 1547

USA Federal Energy Policy Act of 2005, Section 1254: ***"Interconnection services shall be offered based upon the standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources With Electric Power Systems, as they may be amended from time to time."***

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The Remaining Challenges

Trends in Hardware

- Miniaturization of devices, smaller gaps
- Lower power (< voltage swing)
- Higher clock speeds (above 3 GHz)
- Wider bandwidth I/O ports
- Increasingly vulnerable digital products

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The Remaining Challenges

Trends in Compatibility

- Increasing number of Radiators
- Increasing number of Receptors
- Increasing susceptibility of Receptors
- Increasing dependence on the Internet
- Increasingly vulnerable infrastructure

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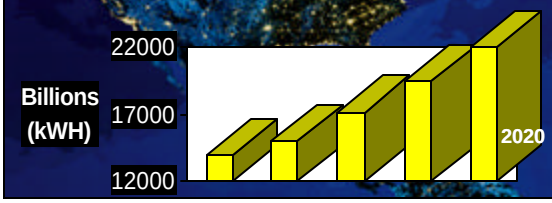
The Remaining Challenges

Conclusions

Demand for electric power will increase

Worldwide Electricity Consumption



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The Remaining Challenges

Conclusions

- Access to World markets is crucial
- Standards Testing enables this access
- Reliability is threatened by device physics
- Testing for Immunity validates Reliability
- Reliability is the ultimate Quality indicator

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Acknowledgements

Electric Utility Communications, Applications and Smart Grid Technologies© – American Radio Relay League (2008)

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