

2003 Energy *An Energy-Efficiency Workshop and Exposition*
Orlando, Florida

High-Availability Combined Heat and Power Systems for Critical Federal Facilities

Achieving Energy Security through Distributed Energy Resources

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2003 Energy *Securing Key Infrastructure*

Post 9/11 Initiatives to Secure Key Components

- Private Sector
 - Banking & Finance, Transportation, Oil & Gas, Information
- Public Sector
 - Government Services, Health Services, Law Enforcement

Top-down Approach: Backbone-level Systems

- Highways, grids, pipelines, airports, communications
- Focus on physical protection, manpower issues

Supporting Assets Addressed as Afterthought

- And no difference between concrete and reliable power

2003 Energy *Communication Infrastructures*

By Contrast, Datacom Addressed Like Y2K

- Recognized to be distributed, granular & ubiquitous
- Executive Order issued immediately after 9/11
 - Business, government and defense depend on information
 - Protection program to secure critical information infrastructure

Missing is a Y2K-like Perspective on Power

- Electricity is the critical fuel of information infrastructure
- Electrons are actually more essential than bits & bytes
 - They control electronically-operated analog infrastructure, too
 - Local power failures can propagate to cause widespread disruption
 - Line between physical and cyber blurred by digital control systems

2003 Energy *Critical Power Infrastructure*

"Blue Cascades" Project

- Federal, state and Canadian authorities
- Boeing, Pacific Gas & Electric, Verizon, Qwest
- Simulated terrorist attack on Northwest power grid
 - Attack could wreak havoc on nation's economy
 - Shutting down power and productivity in domino effect for weeks

Critical Power is Highly Distributed, Multi-Tiered

- Power is critical wherever it fuels a critical load
 - Nodes as large as a military base or small as a single pipeline valve
 - Some must be robust to run autonomously for weeks or longer
- Neither feasible nor economic to harden public grid

Responsibility falls on sector that owns nodes

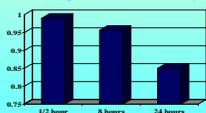
2003 Energy *Shortcomings of Backup Power*

Many Recognize Critical Importance of Power

- Military, telecom, hospitals, financial institutions
- Traditional protection involves emergency generators

However, Intended Only for Intermittent Use

- Best maintained fail to run for 24 hours 15% of the time
- Long-duration event beyond the ability of most to cope



Reliability of Emergency Diesel Generators
Source: *Emergency Diesel Engine Generator Power System Reliability 1987-1993*
Grant, G.M., et. al., Idaho National Engineering Laboratory INEL-95/0035, February 1996

2003 Energy *Distributed Generation (DG)*

Power Generation at the Point of Use

- Eliminates reliance on vulnerable utility grid
- Ensures public service during sabotage or accidents

Variety of DG Technologies (and fuels) Available

- Reciprocating engines (natural gas, diesel, biofuels)
- Turbines (natural gas, steam, wind)
- Fuel Cells (natural gas, digester gas, hydrogen)
- Photovoltaics

Combined Heat & Power (CHP)

- Increases energy efficiency / reduces energy usage
- Reduces greenhouse gas emissions

2003 Energy Centralized vs. Distributed Energy

Central Utility Grid

- Large components far from uses
- Vulnerable to widespread failure
 - Miles of unprotected transmission lines
 - Dependence on just a few critical links and nodes

Distributed Energy Resources

- Redundant sources located at the point-of-use
- Short, protected connections to the load
- Can be designed to be extremely fault tolerant
 - Multiple paths for electricity to reach the consumer
 - No single component or link could cause disruption
- Multiple, small systems less attractive for saboteurs

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2003 Energy Obstacles to Implementation

Grid Interconnection

- AC interconnection is an issue with many utilities

Economics

- Gas vs. Electric "spark spread" operating cost
- Prime mover capital costs and standby backup charges

Reliability

- The best DG units are still only 96% available
- Synchronization and interdependence issues

Adaptability

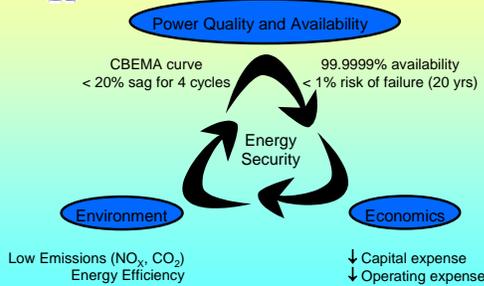
- Modularity and scalability
- Not core competency of facility managers

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2003 Energy Critical Facility Requirements



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2003 Energy Myth of the "Nines"

(Number of hours in a year) X (unavailability) = downtime

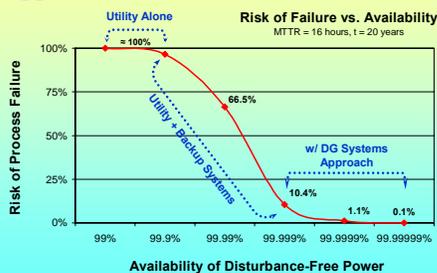
Nines	Availability	Unavailability	Downtime
"one nine"	90%	10%	876 hours
"two nines"	99%	1%	87.6 hours
"three nines"	99.9%	1.0.E-3	8.76 minutes
"four nines"	99.99%	1.0.E-4	53 minutes
"five nines"	99.999%	1.0.E-5	5.3 minutes
"six nines"	99.9999%	1.0.E-6	32 seconds

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2003 Energy Risk of Failure Comparison



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2003 Energy So Where Does DG Make Sense?

Sure Power's Thesis

DG makes sense where:

- 1) Serious consequences occur when a critical system experiences a one-second power deviation; and
- 2) The cost of a traditional grid + backup system, normally purchased to protect the critical system, would pay for a high availability DG system

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Systems Approach Required

Probabilistic Risk Assessment (PRA)

- Components can be modeled in a complex system
- Formal, defensible, reviewable design process

Allow service without power disruption to load

- Repair, maintenance, failure, growth, reduction, etc.

Eliminate cascade and single points of failure

Address real world common-cause limits

- Become dominant when unavailability reaches 10^{-6}
- Simple is better than complex

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Benefits of Systems Approach

- Increased availability, lower chance of failure
 - compared to conventional systems (1% vs. 67%)
- Economic value
 - both capital costs and operating costs
 - lower losses, greater efficiency, spark gap opportunities
- Environmental leadership
 - reducing greenhouse gas emissions
- Modularity
 - allows customers to better match expense to real load
- Space savings
 - compared to conventional approaches

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You can download a white paper with more detailed information on power quality, reliability, availability and the risk of failure:

“Power Impacts on the Cost of Risk – Tools for Championing Power Quality and Reliability Initiatives from a Risk Management Perspective”
http://www.surepowersystem.com/pdf/power_impacts_on_cost_of_risk.pdf

*Thank you.
Questions?*

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*Whit Allen:
Question on reliability versus risk
(probability) of failure.*



Consequences of Power Event

Damage function models have changed

- Industrial Age
 - time of power outage = business downtime
i.e. (5-minute) power outage = (5-minute) business downtime
- Internet Age
 - short power fluctuation = long business downtime
i.e. (4-cycle) voltage sag = (32-hour) business downtime

INDUSTRY EXAMPLE	ELECTRICITY TOLERANCE	MTTR ² OPERATIONS
Data Center	.008 seconds / CBEMA curve	16 hours ³
Semiconductor Manufacturing	20% voltage sag for (4) cycles	32 hours

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Reliability as Measurement Tool

The probability that a system or component will operate for a given time

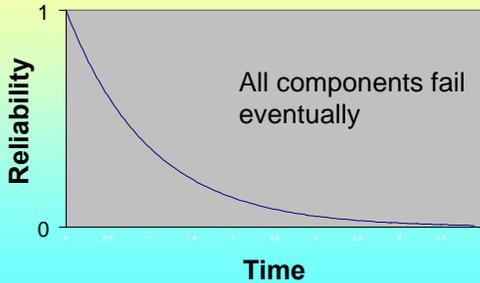
- can be function of time, events, environment
- Reliability tends towards 0 (all things fail)
- $R = 1 - P_f$ (Probability of Failure)
- most useful for analysis of missions during which equipment may not be repaired
- mission length must be known
- Failure rate λ expressed in failures/hour (simplified concept for calculations; most items wear and do not have constant failure rates)
- Mean time to failure $MTTF = 1/\lambda$
- $R = e^{-\lambda t}$, $P_f = 1 - e^{-\lambda t}$

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2003 Energy Reliability w/ Constant Failure Rate



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2003 Energy Availability as Measurement Tool

Probability that a system will function at a future instant in time

- most useful in analysis of repairable systems
- does not require defined mission length
- described in "9s" i.e. 0.999 or 99.9% = three "9s"
- constant rate of repair is assumed (easy to calculate)
- rate of repair μ expressed in repairs per hour
- Mean Time to Repair MTTR = $1/\mu$
- $A = \text{MTTF} / (\text{MTTF} + \text{MTTR})$, $A = \mu / (\lambda + \mu)$
- $U = 1 - A$, $U = \lambda / (\mu + \lambda)$ [U is more useful when $A \approx 1$]
- $\text{MTTF} + \text{MTTR} = \text{MTBF} = \text{Mean Time Between Failure}$

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2003 Energy Calculating Power Risk

For a given availability, find probability of failure:

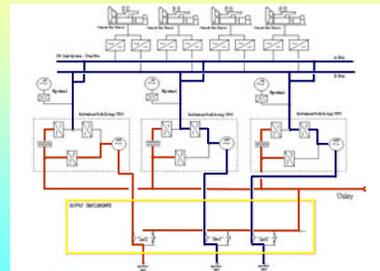
- $U = 1 - A$, $U = \lambda / (\mu + \lambda)$, solve for λ
- $P_f = 1 - e^{-\lambda t}$, where t = mission length

Data center backup power system (2N) example:

- 99.99% availability, $A = .9999$, $U = .0001$
- 20-year mission, $t = 20 * 8,760$ hours
- MTTR = 16 hours, $\mu = 0.0625$ per hour
- $P_f = 66.5\%$

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2003 Energy One System Example



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