Maximizing Uptime in Mission Critical Facilities
Electricity as the Fuel for the Digital Economy

- Since 1980 >85% of growth in US Energy has been met by electricity
- 60% of US GDP comes from industries run by electricity
  - 1950 this only 20% of industry was run by electricity
- 60% of new capital spending is on IT equipment
- IT and telecom continue as fastest growing market segments
- Energy consumption is measured in Quads (Quadrillions of BTUs)
- US consumption of raw energy has risen 10 fold in the 20th century, electricity has risen 30 fold.
U.S Energy and Electricity Consumption

* Energy consumed to produce electricity
Improvements in efficiency = less energy consumption?

- In 1946 the Electrical Numerical Integrator And Calculator (ENIAC) was introduced as first computer contained 17,468 vacuum tubes, 70,000 resistors, 10,000 capacitors, 1,500 relays, 6,000 manual switches, weighed 30 tons, consumed 174,000 Watts of Electrical Power, and could brownout parts of Philadelphia whenever it was started up.

- ENIAC required 10 watts/tube

- ENIAC compared to PlayStation would suggest reduced demand
  - PlayStation has 10,000 times the processing power
  - Consider (1) 70 watt PlayStation per teen age household

- “The more efficient our technology, the more energy we consume”
Improvements in efficiency = less energy consumption?

- Pentium 1/1,000,000 of a watt/transistor

- Energy required to process a single logic instruction is cut in half every 14 months

- Number of gates/chip rises as fast as gates themselves shrink
  - Chip area grows larger
  - Total power required/chip rises even faster
  - Cooling microprocessors to keep them from melting is already a challenge

- Intel engineer projection if trends were to continue
  Current Chip → Nuclear Reactor → Rocket Nozzle → Sun's Surface
Microprocessor Peak Power

![Graph showing the increase in peak power per CPU for various Intel microprocessors over time. The x-axis represents years from 1970 to 2000, and the y-axis represents peak power in watts. Notable processors include the 8008, 8080, 8086, 286, 386, 486, Pentium, Pentium Pro, Pentium III, and Pentium IV. The graph shows a steady increase in peak power over time.]
Computing and the Internet: Aggregate U.S. Electricity Consumption

![Graph showing the increase in electricity consumption due to computing and the Internet from 1980 to 2000.](image-url)
Transistors for Logic and Power

- Transistor Radio
- IBM 7000 Series
- 4004
- 8080
- 8086
- 386
- Pentium

Power Logic

Maximum Power/Gate

- Bipolar
- MOSFET
- IGBT

1945 1960 1975 1990
Technology Improves Efficiency, Reduces Footprint

100 KVA UPS Today
7.5 SqFt
900 lbs

100 KVA UPS 1980
29 SqFt
7,460 lbs
Energy Production and Distribution

- Environmental zoning regulations make it increasingly difficult to locate smoke stacks, cooling towers, substation and distribution lines where we live.

- Electricity is relatively easy to transmit

- Power plants are located further from point of use with elaborate transmission

- Power generation plants have not and are now being built

- Minimal investments are being made in upgrades of transmission grid
U.S. Electricity Transmission

Transmission Grid Investment ($ Billion)

Total Electricity Use (Trillion kWh)

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Power consumption will continue to increase with minimal investment in power generation or grid upgrades. US corporations will need to monitor internal MISSION CRITICAL power needs.

Excerpts from The Bottomless Well by Peter Huber and Mark Mills
Data Center Challenges

- The load is unpredictable
- Reduced impact of Harmonics
- Energy efficiency is becoming important again
- Continuous deterioration of the power grid reliability
- Increased government regulation (Sarbanes-Oxley) for maintaining the viability of business operation and information
- Managing single and dual cord loads
- Increases in power density
Factors Affecting Data Center Performance

- Location
- Overall system design
- Construction Quality
- Equipment Quality
- Thoroughness of Initial Commissioning
- Age
- Maintainability
- Operations and Maintenance Program
- Personnel Training
Tier 1-IV Data Center Design

- Benchmarking done over several years with large DC input
- Initial concept started with United Parcel (the other UPS) Windward DC
- Worked with IBM and other hardware companies towards dual-powered hardware
- Top 10% of sites used for benchmark meaning only 10% performed at reliability levels
- Goal was to achieve 5 nines in reliability, 99.999%
Tier 1-IV Data Center Design

Tier I-Basic

- No redundancy in components, Single Power Path
- Support space to raised floor ratio, 20%
- Initial Watts/Ft², 20-30 with ultimate of 20-30
- Raised floor height, 12”
- $/Ft², $450
- IT downtime due to site, 28.8 hours
- Availability, 99.671%
Tier 1-IV Data Center Design

Tier II-Redundant Components

- N+1 redundancy in components, Single Power Path
- Support space to raised floor ratio, 30%
- Initial Watts/Ft², 40-50 with ultimate of 40-50
- Raised floor height, 18”
- $/Ft², $600
- IT downtime due to site, 22 hours
- Availability, 99.749%
Tier 1-IV Data Center Design

Tier III-Concurrently Maintainable

- N+1 redundancy in components, 1 Active and 1 Passive Power Path
- Support space to raised floor ratio, 80-90%
- Initial Watts/Ft², 40-60 with ultimate of 100-150
- Raised floor height, 30-36”
- $/Ft², $900
- IT downtime due to site, 1.6 hours
- Availability, 99.982%
Tier 1-IV Data Center Design

Tier IV-Fault Tolerant

- Must be able to sustain 1 unplanned worst case infrastructure failure
- Must be concurrently maintainable
- 2(N+1) or S+S redundancy in components, 2 Active Power Paths
- Support space to raised floor ratio, 100%
- Initial Watts/Ft², 50-80 with ultimate of 150+
- Raised floor height, 30-36”
- $/Ft², $1,100+
- IT downtime due to site, .4 hours
- Availability, 99.995% (Could not reach 5 Nines)
Power System Fundamentals

Tier I and II
Single Module and Parallel Redundant
Single Module UPS

Rectifier, Converts AC to DC Power

Battery, Provides Emergency Back-up

Static Bypass Provides Alternate Power Path

Inverter, Converts DC to AC Power
40-160 KVA

40 and 80 kVA
- 31.6 in
- 18.9 in
- 73.7 in

120 and 160 kVA
- 31.6 in
- 35.6 in
- 73.7 in
225 – 500 KVA

225-300 KVA
Dimensions: 64” W, 32” D, 73” H
Weight: 3,900 – 4,300 lbs.

400-500 KVA
Dimensions: 74” W, 32” D, 73” H
Weight: 6,200 lbs.
625-750 KVA

Dimensions: 149” W, 32” D, 73” H
Three Shipping Splits
Weight: 13,400 lbs.
225kVA to 1.1MVA Scalable

Up to 4 x275 KVA Power Modules
Paralleled for Capacity or Redundancy

Dimensions: 60 to 108” W, 32” D, 73” H
1 Shipping Split
Weight: 3,000 lbs. (@550 kVA)
Single Module with Maintenance Bypass (MBP)

- Tier I design
- MBP allows for manual transfer for maintenance
- Can be internally upgradeable
Normal Power Flow

- Total Power conditioning by double conversion
Power Flow Loss of Utility Power

- No Interruption of power to critical load
- No switching required
- May or may not be genset
- If no genset, AC is lost
Static Bypass Power Flow

• No interruption to load
• Transfer is automatic during failure can also transfer manually from UPS control panel
• Should have alarm at site for notification of key personnel
Maintenance Bypass Power Flow

- Manual function, no interruption
- Allows full maintainability of UPS
- Relatively low cost
- Should include interlock!
Tier I Designs

- Single path for power and cooling (no redundancy)
- Provides 99.671% availability
Tier I Applications

160kVA UPS with IDC 480/208V with 84 poles distribution
Two Module Parallel Redundant

- Tier II design
- Any one module can fail
- Capacity may be achieved by internal upgrade only
- Lowest cost means of achieving redundancy
Two Module Parallel Redundant

UPS Module

Parallel Tie Cabinet

UPS Module
Parallel for Increased Capacity

- Still only Tier II
- Used when load exceeds capacity of one module
- System bypass must be sized for full load
- Redundant module is always recommended
System Parallel Cabinet
Parallel and Scalable

• Recent design capability in low end systems
• Simple and cost effective
• Provides redundancy and scalability
• MBP must be sized for ultimate capacity
Tier II Designs

- Single path for power and cooling with redundant components. Provides 99.741% availability
Tier II Applications

80kVA Two module redundant system using IAC-ST
Power System Fundamentals

Tier III and IV
1 Active and 1 Passive Power Path
2 Active Power Paths
Static Switch

- Redundancy is a dual source power path to the load
- The closer the redundant element is to the load the better the system redundancy
1 Active and 1 Passive Power Path, Tier III

Each UPS can be N or N+1

- UPS A
- Power Sync
- UPS B
- PDU A
- PDU B
- STS
  - Single Cord Loads
  - Dual Cord Loads
Tier III Designs

- Multiple path for power and cooling with only one path active. Redundant components, concurrently maintained. Provides 99.982% availability.
Tier III Applications

Two independent 80kVA UPS systems using IAC-SB maintenance bypasses.

Static transfer switch

Distribution cabinet
Two Active Power Paths, Tier IV, 2N

Each UPS can be N or N+1
Tier IV Designs

- Multiple active power and cooling distribution paths, with redundant components, and designed-in fault tolerance. Provides 99.995% availability

AC Source 1

AC Source 2

All dual cord loads, redundant power supplies
Tier IV Applications

Two independent 80kVA UPS systems using IAC-SB maintenance bypasses.

Distribution cabinets
Tier IV + Designs

- Multiple active power and cooling distribution paths, with redundant components, and designed-in fault tolerance. Provides 99.995% availability.

AC Source 1

All dual cord loads, redundant power supplies

AC Source 2
Tier IV + Applications

Two independent 80kVA N+1 UPS systems using IAC-ST HotSync parallel tie cabinets, and redundant battery strings on each module.
Battery Systems

- Valve Regulated (VRLA) or wet-cell
- 15 – 30 minute back-up is typical
- Constructed of jar, lead plates and electrolyte (acid)
- Temperature impacts time and life if outside 77º F.
  - 15º over cuts life in half
  - Cooler temperature decreases runtime
- Shelf life before needing freshening charge is 6 months
Battery Systems-Valve Regulated (VRLA)

- Installed in Cabinet or Rack, Typically Cabinet
- 5-year design life
- Sealed via a pressure relief valve
- Do not require spill containment, eye wash or special ventilation
- Smaller footprint
- Less weight
- Initial cost is less
- Temperature impacts time and life if outside 77º F.
  - 15º over cuts life in half
  - Cooler temperature decreases runtime
Battery Systems-Valve Regulated (VRLA)

• Can weigh up to 4,800 lbs.
• Annual maintenance is required
• Location should maintain 77°
Battery Systems-Wet Cell-Vented

- Installed on open racks
- Most are 20-year design life
- During charge cycle hydrogen gas is released
- Require spill containment, eye wash and ventilation to outside air
- Recommend separate battery room
- Significant floor loading
- Should be installed by experienced contractor
- Temperature impacts time and life if outside 77º F.
  - 15º over cuts life in half
  - Cooler temperature decreases runtime
Battery Systems-Wet Cell-Vented
Operational Procedures and Monitoring

- Most failures occur due to change of state events
- Training, training, training
- Clear and concise test and operational procedures
- Observe and understand and document all changes to the DC infrastructure
- Some type of alarming/monitoring; Alarm panel, SNMP, Web or facility monitoring
Service and Support

- Know the service organization and how to reach them
- Know response time
- On site spares; storage and inventory
- Focus on adequate and proper maintenance
- Keep accurate records
- More maintenance does not mean higher reliability
Summary

- Electrical reliability will become increasingly important due to lack of utility infrastructure investment
- Corporate DC designs will evolve to allow 7x24x365 operation
- Design the DC to meet Corporate objectives: Tier I – Tier IV
- Adhere to Quality Construction
- Assure adequate and thorough commissioning
- Train your internal staff
- Develop and maintain accurate operational procedures
- Document any changes
- Assure proper maintenance
- Monitor critical systems