# Analysis of the NAS Battery and Multi-Technology Demonstration at AEP

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# Partners

- DOE / Sandia National Laboratories
- AEP EmTech, LLC.
- Tokyo Electric Power Co.
- NGK Insulators Ltd.
- ABB Inc.
- EPRI



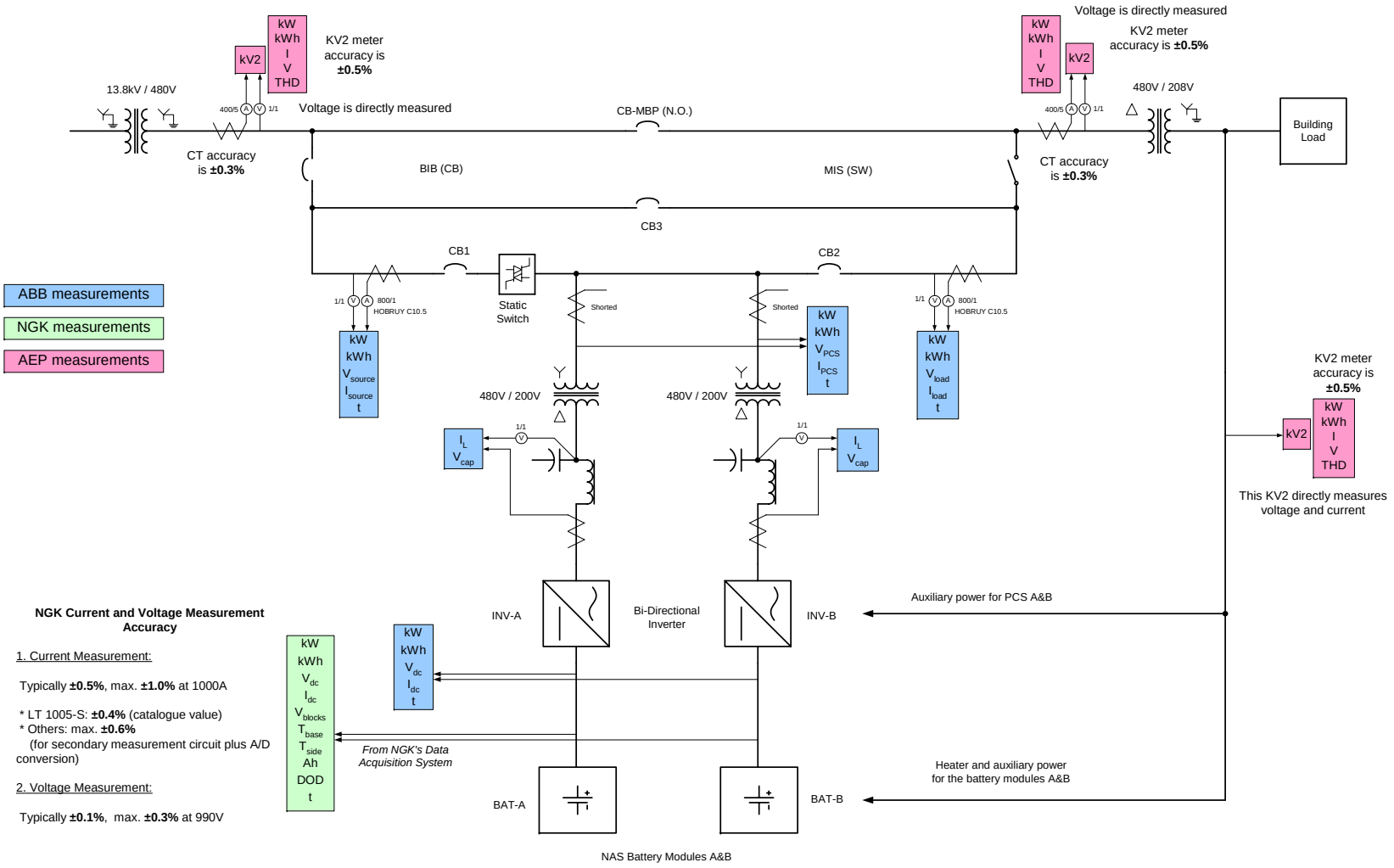




# Project Scope

- Performance assessment of NAS demonstration system
- Economic analysis of NAS
- Multi-technology comparison

# Instrumentation

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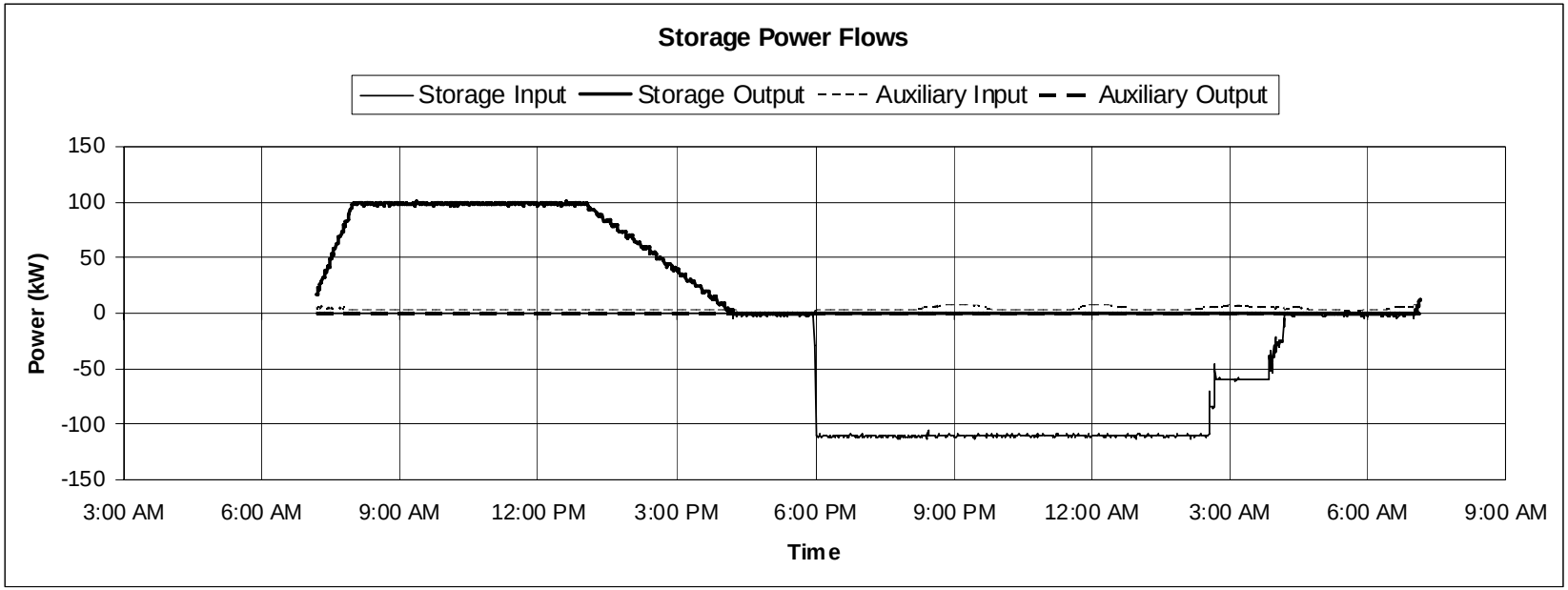
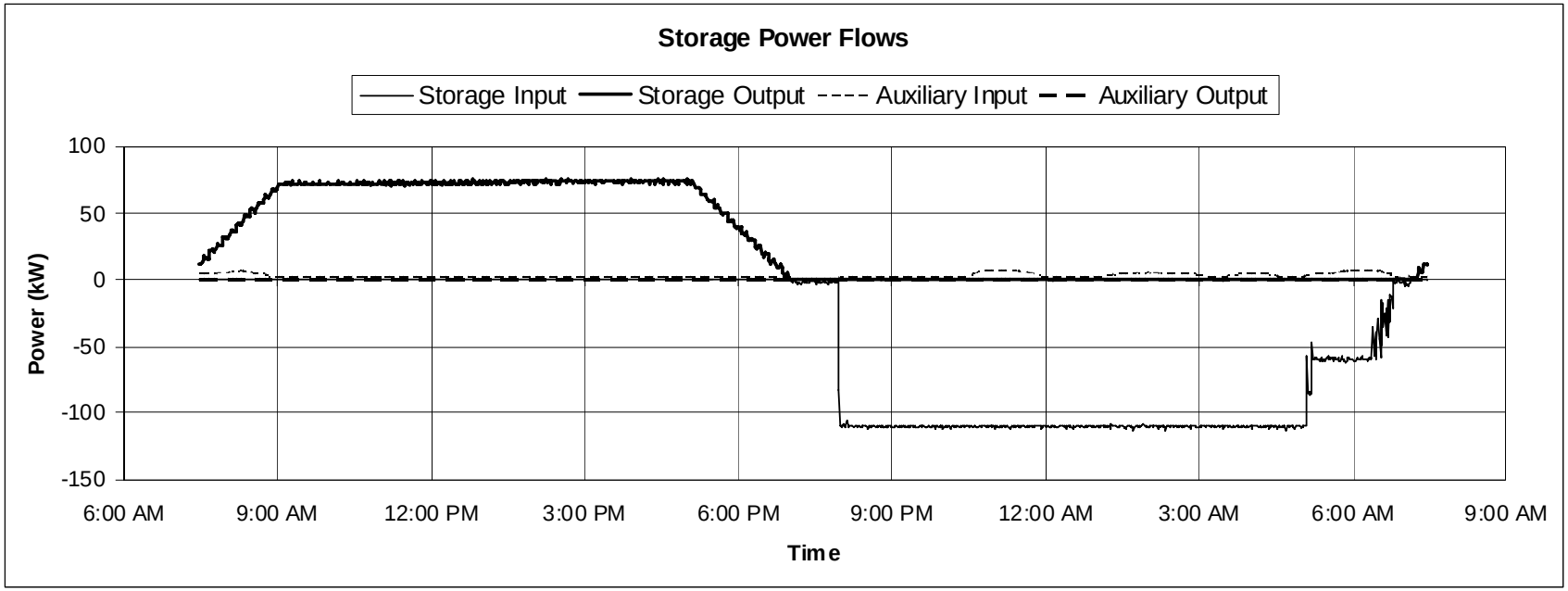
# Regime 6 Profile (2/5/2004)



# Regime 7 Profile (5/19/2004)



# Sample Cycle Storage Energy

| Regime | Storage Charge | Storage Discharge | Auxiliary Load | Charging Cost | Total Cost | Aux. Portion |
|---|---|---|---|---|---|---|
| 6 | 1050 kWh | 699 kWh | 66 kWh | 351 kWh | 417 kWh | 16% |
| 7 | 1100 kWh | 726 kWh | 68 kWh | 373 kWh | 441 kWh | 15% |

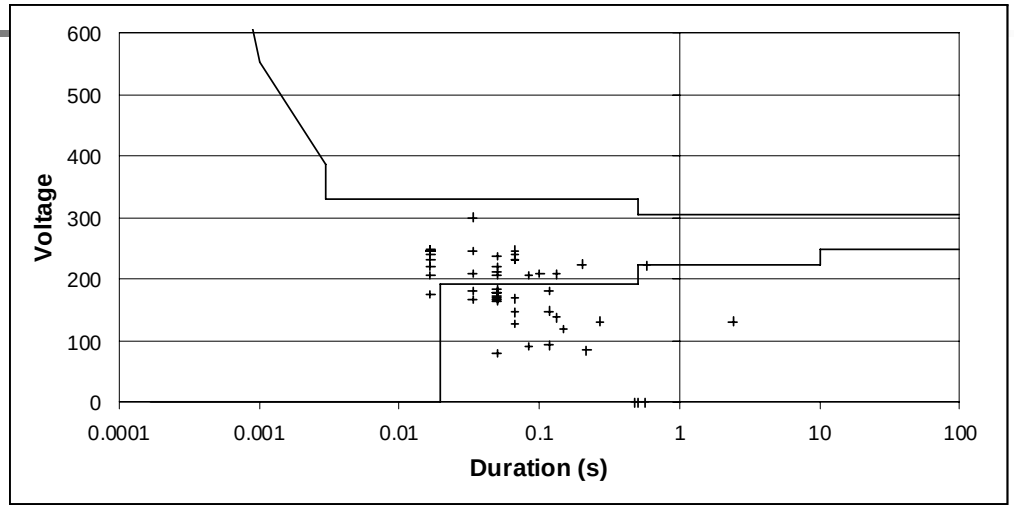
# System Performance

| Regime | Charging Efficiency | System Efficiency |
|---|---|---|
| 6 | 64-68% | 57-63% |
| 7 | 65-69% | 57-63% |

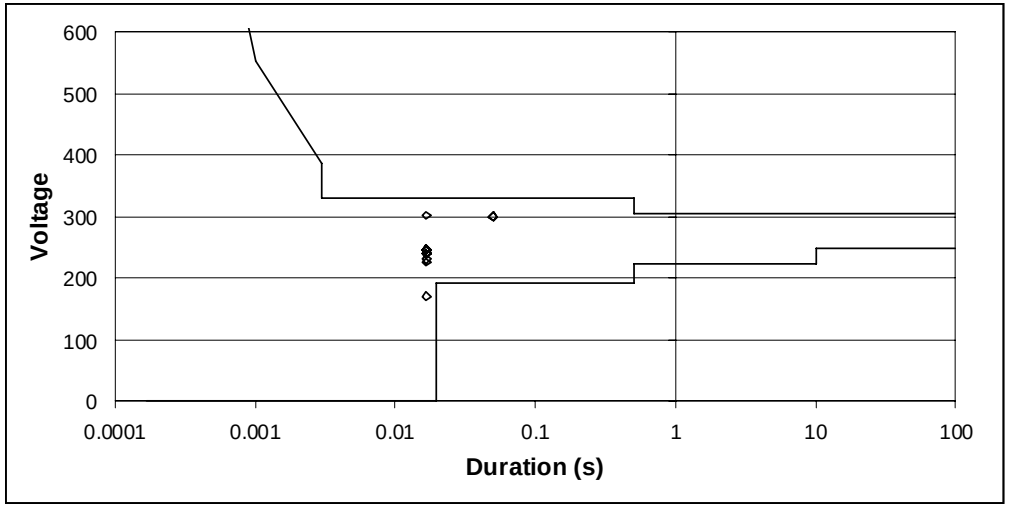
- Charging efficiency includes PCS, static switch, and battery
- System efficiency includes PCS, battery, and auxiliaries
- Auxiliary load includes: battery heaters; PCS cabinet heaters (x2); control cabinet heater; PCS fans (x2); microcontrollers; instrumentation.

# Power Quality Impacts

Grid




Load

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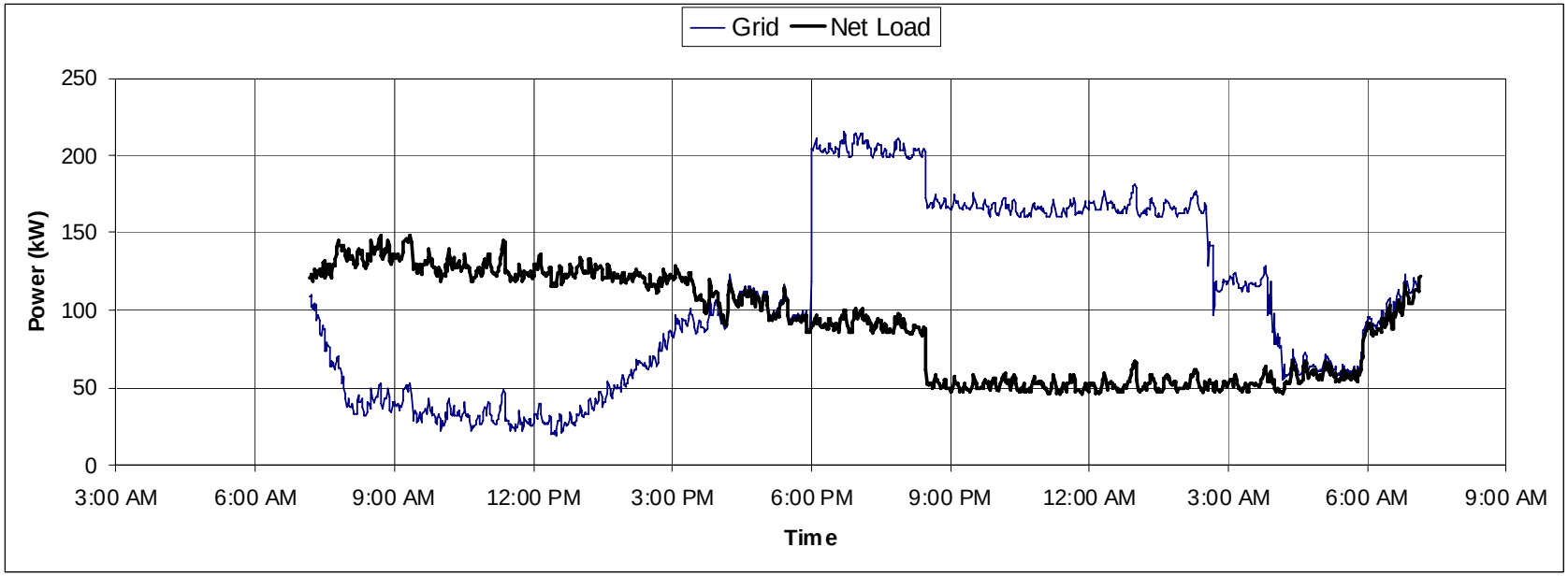
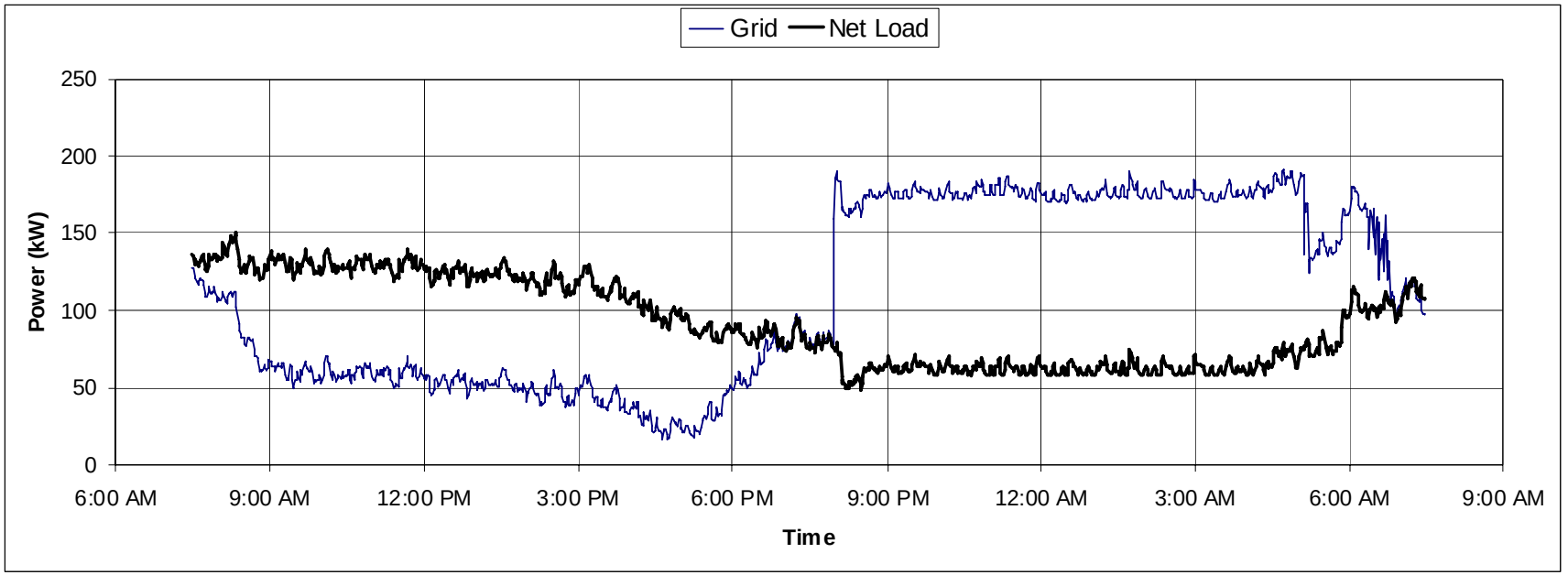
# Regime 6 Peak Shaving



# Regime 7 Peak Shaving



# Lessons Learned

- Battery system overall efficiency needs to be addressed in the specification
- For PQ+PS systems, efficiency should be pegged at the nominal PS power level
- Performance monitoring and measurement sensitivities need to be addressed in the specification
- Control system should optimize peak loads

# Multi-technology Comparison

PureWave

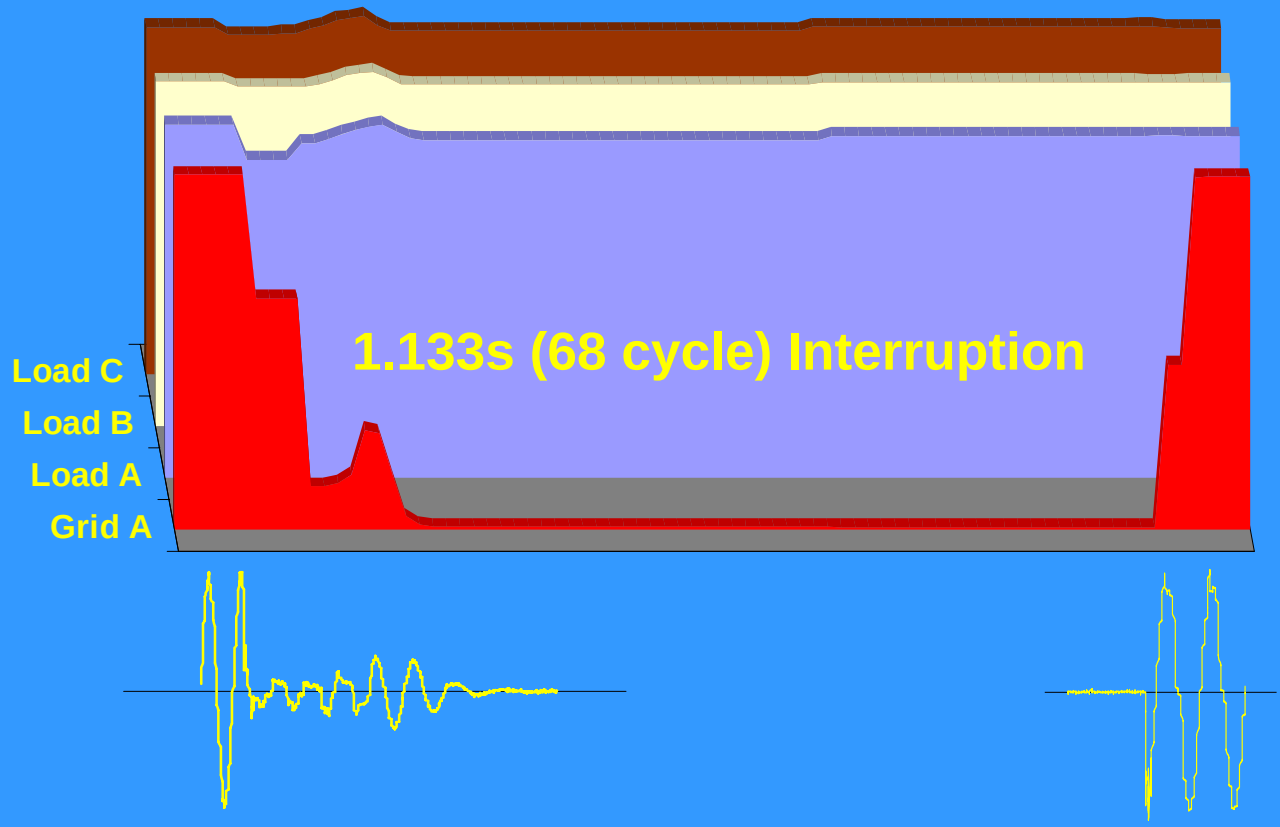
MGE UPS / ActivePower


NAS

# 2 Recorded Concurrent Events

- 6 months data collected (Oct'03 – Apr'04)
- 14 extended periods of concurrent data collection
- 2 events propagate through all three systems during concurrent data collection:
  - 68-cycle interruption
  - Voltage sag sequence (8 sags)

# Interruption Protection

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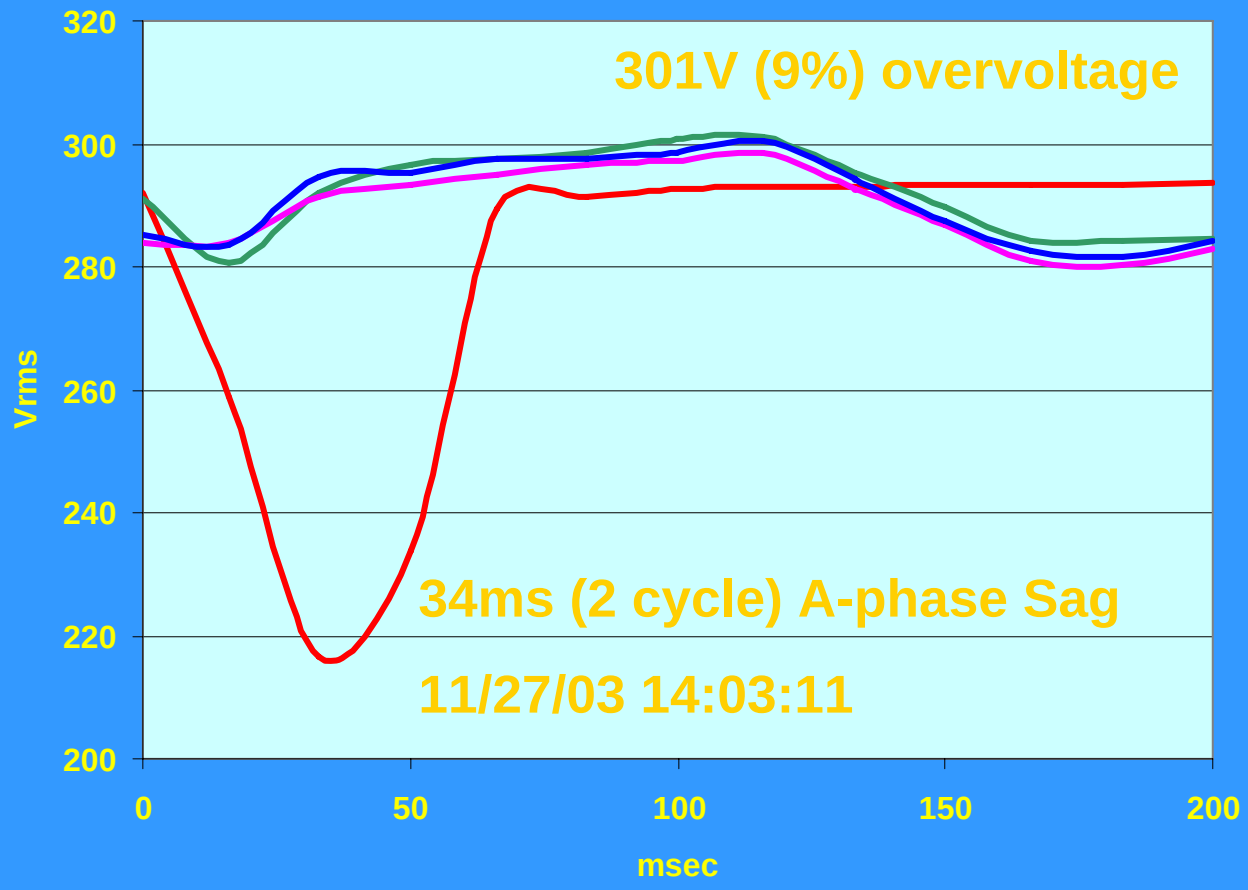
# Sag Protection

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# Conclusions - 3 Technologies

- Interruption
  - Two systems fully protected loads
  - One system protected load against outage, but introduced a voltage sag on one phase
- Voltage Sag
  - All three systems fully protected load

# NAS Economic Analysis

- Customer combined PQ/PS application
- National tariff review
- Cost / performance data based upon commercial products and existing manufacturing capacity

# System Specifications

| | Module | System (5 Modules) |
|---|---|---|
| PS/PQ Power Rating | 50 kW / 150 kW | 250 kW / 750 kW |
| PQ duration | 30 seconds | 30 seconds |
| PS Energy | 360 kWh | 1800 kWh |
| Price | $75k (module price) | $605,000 (installed) |

- Installed cost (TI/NGK) includes modules, PCS ($202/kW), BOP ($100/kW), land, and installation.
- PQ rating - pulse factor of 3.
- Based on mature price projections.

# Technical Assumptions

| | |
|---|---|
| PS Discharge Duration | 7.2 hours |
| Recharge Duration | 8.64 hours |
| Calendar Life | 15 years |
| Cycle Life | 2500 cycles |
| | |
| O&M | $26/kW-yr |
| AC/AC Roundtrip Efficiency | 77% |

- O&M includes maintenance, standby heat losses, property taxes, and insurance.
- Efficiency includes DC/DC battery efficiency and power conversion efficiency (double pass).

# Other Assumptions

| | |
|---|---|
| Tariff Data | |
| On Peak Demand Charge ($/kW-mo) | 10 |
| Facilities Charge ($/mo) | 25 |
| On Peak Energy Charge ($/kWh) | 0.08 |
| Off Peak Energy Charge ($/kWh) | 0.06 |
| Customer Billing Data - Without NAS | |
| Peak (operating) Days in Billing Cycle | 20 |
| On Peak Consumption (kWh) | 400000 |
| Off Peak Consumption (kWh) | 100000 |
| Peak Demand (kW) | 1000 |
| Financial | |
| Escalation Rate | 2.50% |
| Discount Rate | 7% |
| State Marginal Tax Rate | 5% |
| Federal Marginal Tax Rate | 35% |
| Study Period (yr) | 15 |
| Reduced losses from PQ protection | |
| Value ($/kW-event) | 5 |
| Events per year | 20 |

# Bill Comparison

| | Original | New | Benefit |
|---|---|---|---|
| | | | |
| On Peak Consumption (kWh) | 400,000 | 364,000 | |
| Off Peak Consumption (kWh) | 100,000 | 146,753 | |
| On Peak Demand (kW) | 1,000 | 750 | |
| Power factor | 1 | 1 | |
| Billed On-Peak Demand (kW) | 1,000 | 750 | |
| Total consumption (kWh) | 500,000 | 510,753 | |
| Load factor | 0.694 | 0.946 | |
| | | | |
| Utility Bill ($) | | | |
| On-peak Demand Charge | 10,000 | 7,500 | 2,500 |
| Facilities Charge | 25 | 25 | 0 |
| On-peak Energy Charge | 32,000 | 29,120 | 2,880 |
| Off-Peak Energy Charge | 6,000 | 8,805 | -2,805 |
| Total Bill ($/mo) | 48,025 | 45,450 | 2,575 |
| | | | |
| PS Operating months/yr | | | 8 |
| Annual Utility Bill Savings ($/yr) | | | 20,598 |

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# Proforma (15 yr)

| | | | YEAR | YEAR | YEAR | YEAR | |
|---|---|---|---|---|---|---|---|
| | **NPV** | | **0** | **1** | **2** | **3** | **…** |
| **NAS Ownership** | | | | | | | |
| NAS Capital Cost | **-604,500** | | -604,500 | | | | |
| NAS Depreciation | | | | -30,225 | -57,428 | -51,685 | |
| NAS O&M | **-68,621** | | | -6,500 | -6,663 | -6,829 | |
| | | | | | | | |
| **Power Quality** | | | | | | | |
| PQ Loss Savings | **791,783** | | | 75,000 | 76,875 | 78,797 | |
| | | | | | | | |
| **Peak Shaving** | | | | | | | |
| Utility Bill Savings | **217,460** | | | 20,598 | 21,113 | 21,641 | |
| Net Profit/(Loss) Before Tax | | | | 58,873 | 33,898 | 41,924 | |
| LESS: Tax | **-219,787** | | | -22,519 | -12,966 | -16,036 | |
| Net Profit/(Loss) After Tax | | | | 36,354 | 20,932 | 25,888 | |
| ADDBACK: Depreciation | | | | 30,225 | 57,428 | 51,685 | |
| **Net Present Value (NPV)** | **116,335** | | -604,500 | 66,579 | 78,360 | 77,573 | |
| | | | | | | | |
| **Internal Rate of Return (IRR)** | **9.801%** | | | | | | |
| | | | | | | | |
| | | | | | | | |
| MACRS Depr Rate (15 year) | | | | 5.000% | 9.500% | 8.550% | |

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# Conclusions - NAS Economic Analysis

- Reasonable IRR (9.8%) for typical PS/PQ combined application
- Benefits dominated by PQ loss savings, rather than utility bill savings
- Customer-specific analysis should include impact of tariff switching (penalties for increased demand charge, BESS oversizing)

# Project Wrap Up

- Economic analysis report
- Multi-technology comparison report