All Systems Go:
Power Monitoring at the Kennedy Space Center

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Presentation Outline

- KSC/Shuttle Overview-Facilities, Electrical Consumption/Demand, Utility Billing
- Kennedy Complex Control System (KCCS) Overview
- Energy and Facility Mgmt Functions Overview
- Case Study Examples
- Lessons Learned
- Summary and Closing
- Questions/Comments/Suggestions

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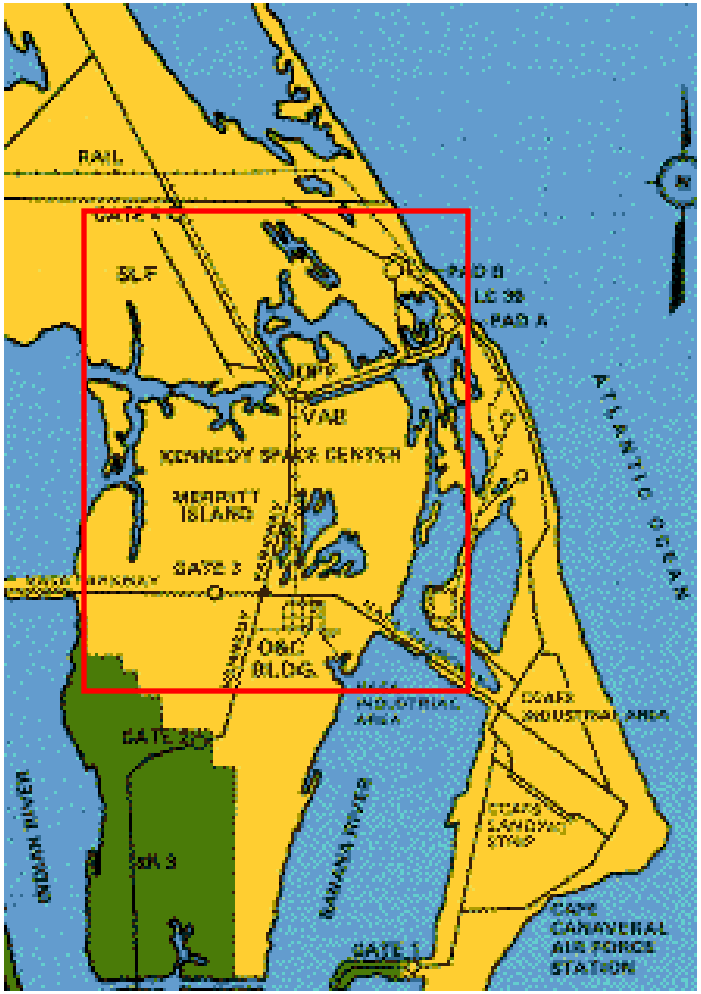
KSC/Shuttle Overview



- KSC situated within wildlife refuge
- 140,000 acres with 6000 acres dedicated to launch operations
- More than 200 facilities of varying sizes and missions many with extensive power distribution systems
- 8 million sq.ft. with 55% dedicated to Shuttle ops
- ~2000 Total NASA Civil Servants
- ~11,000 On/Near-Site Contractors
- Facilities subdivided by user program which drives need for allocation of energy costs/consumption metrics
- Large campus requires metering system have the ability to collect data from geographically disperse facilities

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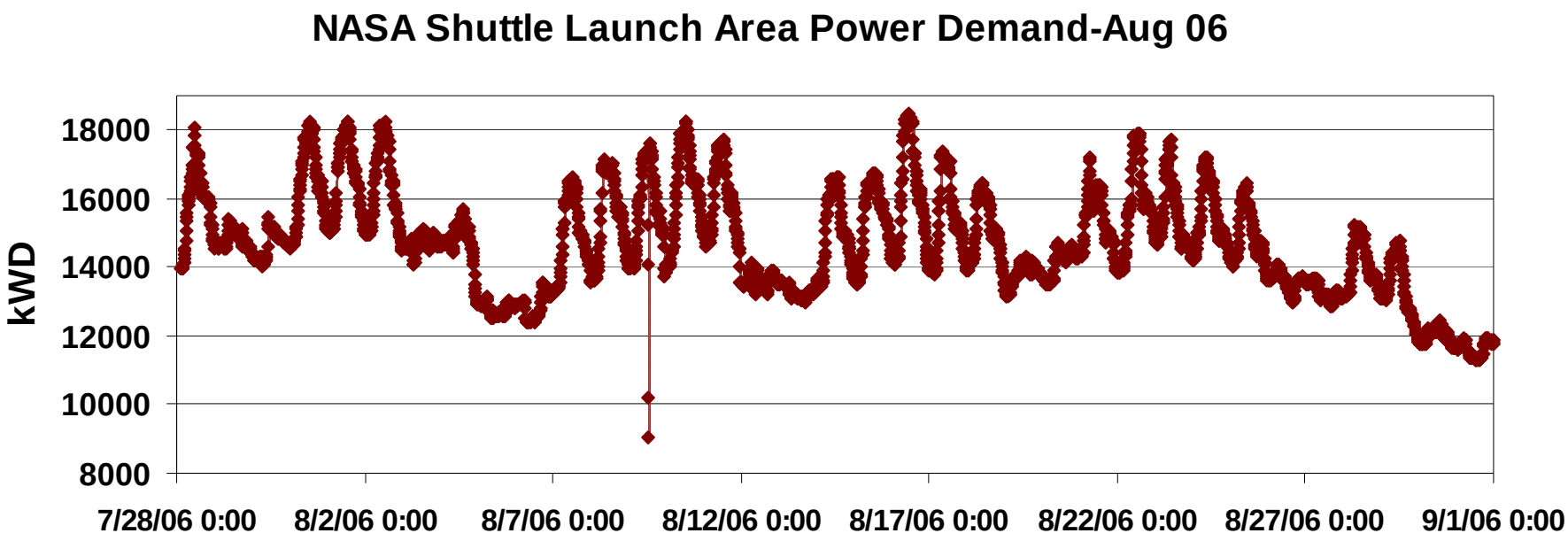
Utility Billing Structure and Load Profile



- Mostly 24 hour operation with some peaking during 1st shift
- Annual Consumption - Total NASA: 250,000 MWh Total Shuttle:155,000 MWh
- Utility billing structure contains a time of use and a demand component
- Total Shuttle Electricity Charge: $13 million annually w/ 12% demand
- Prior to metering, electricity not costed by accountable programs
- After meter installation and subsequent direct program billing, utility expenditures became regular presentation at program budget review

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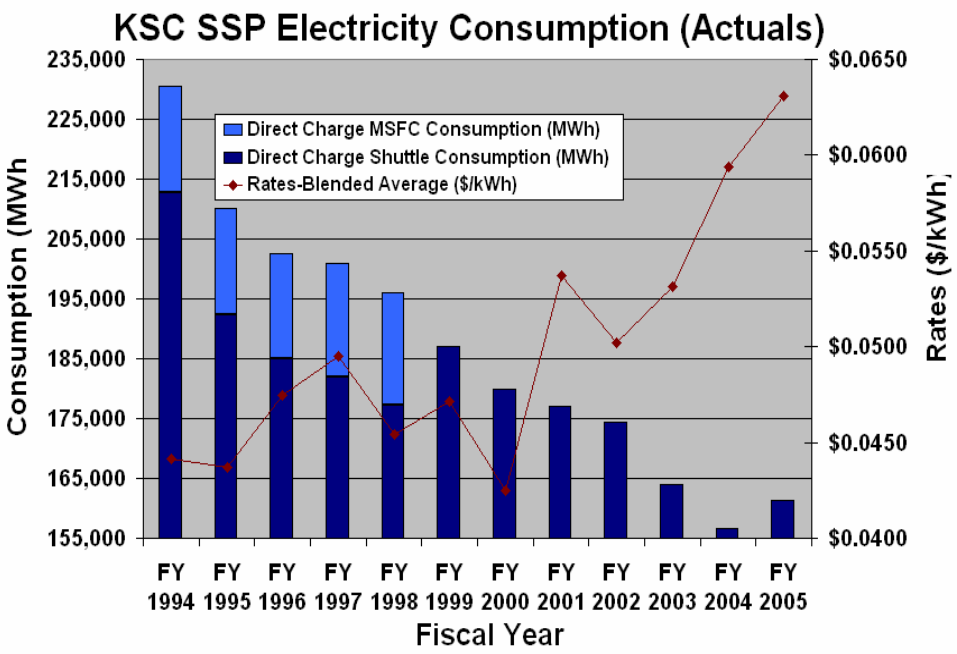
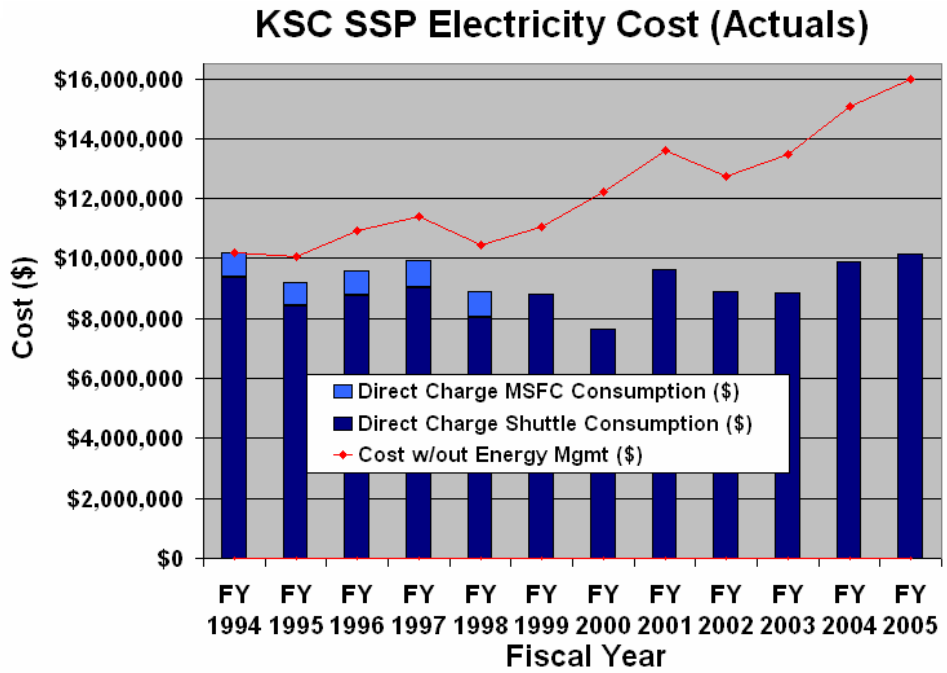
KSC Shuttle Electricity Budget Presentation





- Metering data revealed energy conservation measures had significant effect on utility expenditures
- Data provided was catalyst to obtain authorization for more than $10,000,000 dollars in additional energy saving initiatives (In house ECMs, UESC, hardware upgrades) from FY98 to the present.

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Metering System: Progression

- **Original System 1995-1997**
  - Original intent of metering system to: (1.) Allow for direct charge of electricity to accountable programs and (2.) track progress toward federally mandated energy reduction goals both on a per facility basis by program
  - System consisted of 60 Meters communicating over long modbus serial chains to an SMS server.
  - Original system was revenue billing only.
  - Numerous out of service meters
- **System Upgrades 1997-2000**
  - Upgraded to Ethernet connectivity
  - Deployed remote wokstations
  - System begins to get use for power system operations (backups sized based on power data, xformers replaced un actual load, etc.)
  - Failure rate reduced with Fiber, still had a high number of out of service meters
- **Merged with newly developed KSC SCADA system KCCS 2000-present**
  - Power meters replace other discrete field relays and functions
  - Control element introduced- via Modbus/TCP vs. contact closure
  - System functions greatly expand
  - Power system refurbishment installs hundreds of networkable items
  - System nearly always at greater than 95% devices reporting

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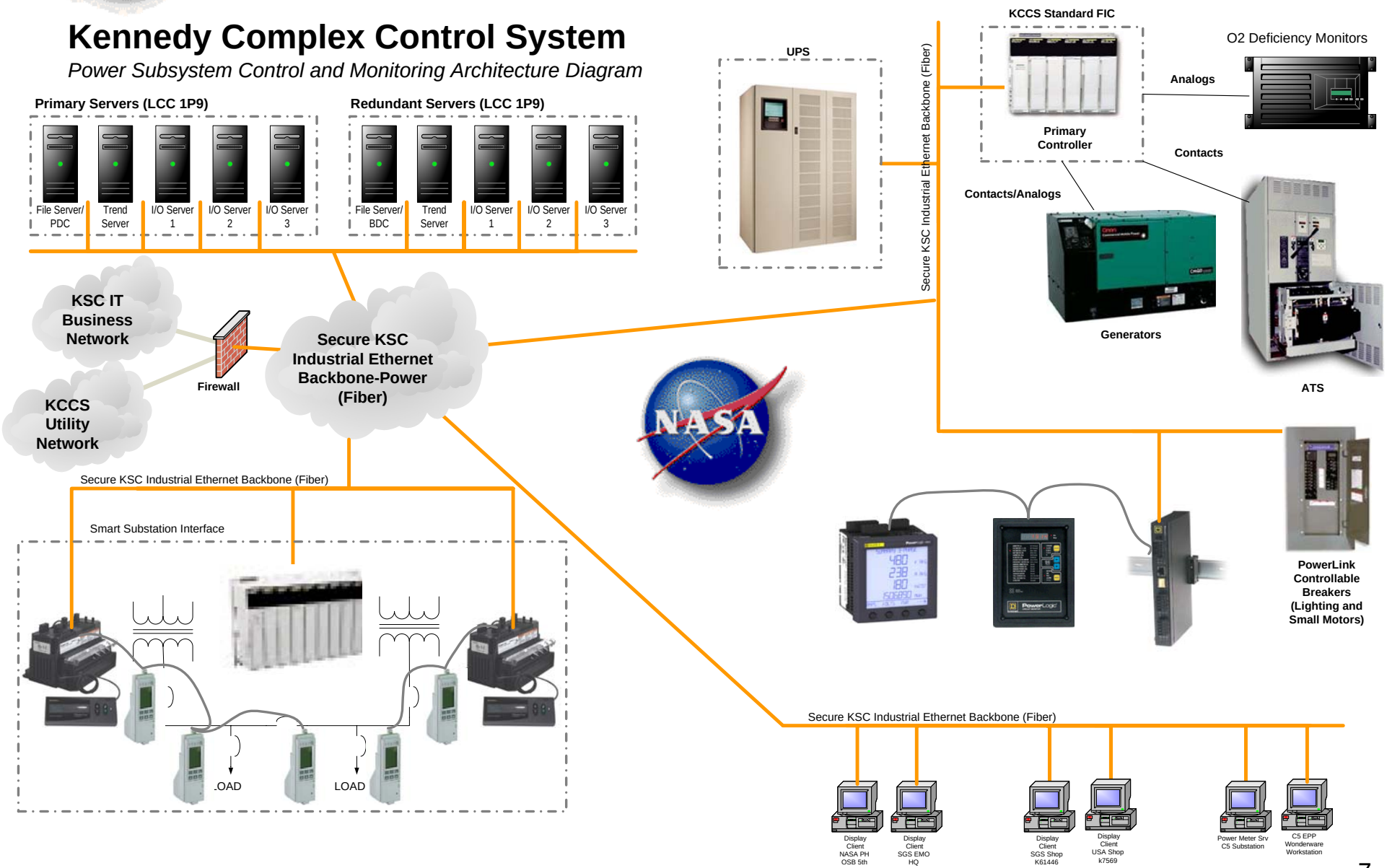
Kennedy Complex Control System

Power Subsystem Control and Monitoring Architecture Diagram



KCCS System: System Size

- KCCS uses CitectSCADA front end to monitor and control KSC facilities operations including Power, Water, HVAC, Pneumatics
- The Power component of KCCS:
  - 3 redundant I/O Server Sets (Citect on win pc)
  - 1 redundant Trend Server Set (Citect on win pc)
  - Display nodes at multiple KSC locations (mgmt keys)
  - ~1200 communicatable devices including PLC (mostly Modicon Quantum), Power Meters (CM4000/2000,PM820), Trip Units (Digitrip and Micrologic), UPS (Powerware 9315), and small subset of other manufacturer hardware (Multilin, GE Fanuc, ABB SLC, etc.)
  - ~300 concurrent TCP-IP connections
  - >75,000 datapoints
  - Trended Tags at frequencies from 1/sec
  - Alarm Scan rates as low as 100ms
  - System Manager also maintained as engineering tool

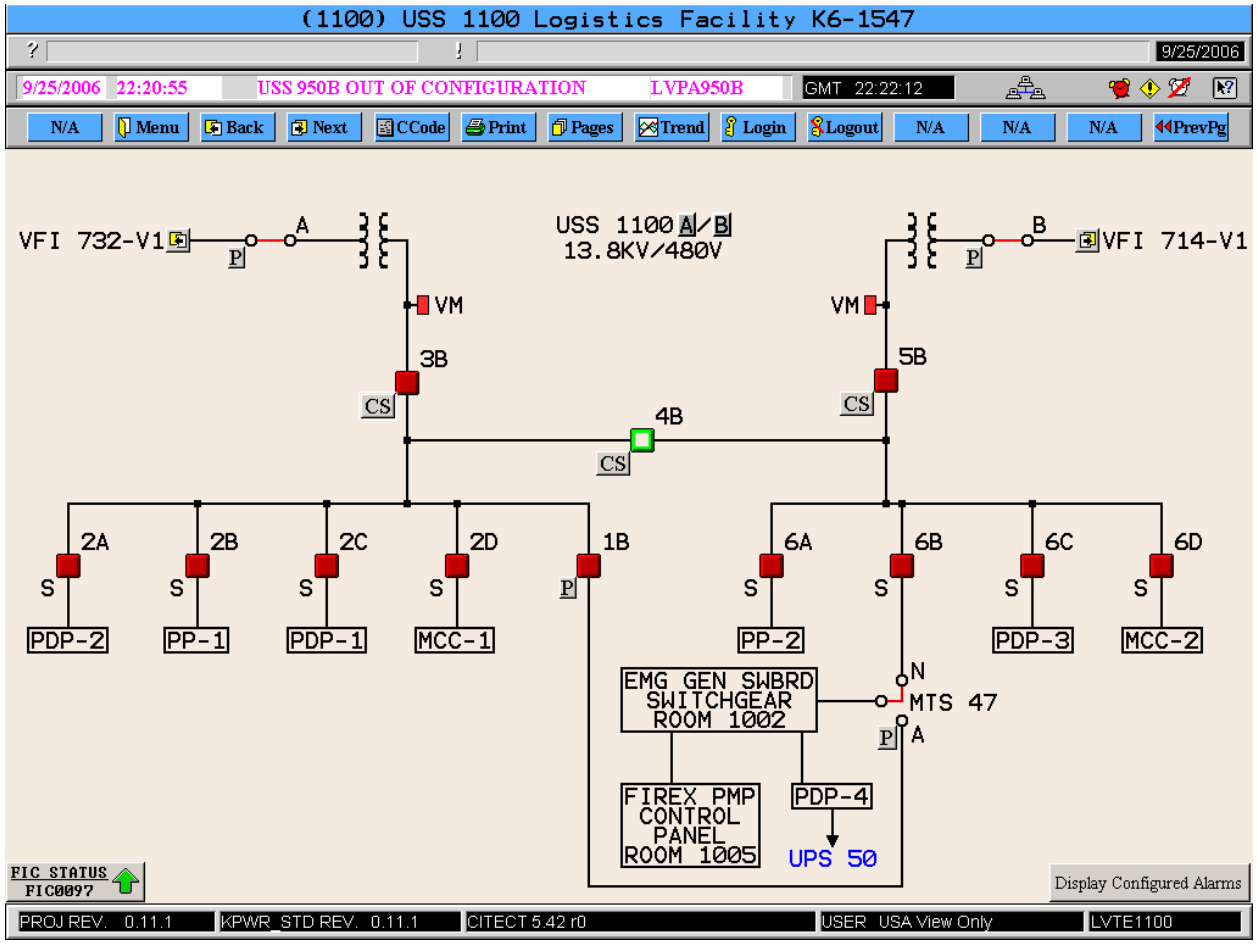
Metering System: Fundamental Usage/Benefits

- "You can't manage what you can't measure"
  - Data collected used to focus energy management efforts and identify trends
- Energy consumption trends, either + or -, can be used to justify funding for energy conservation measures
- Metering provides KSC the capability to do reimbursable account billing to reclaim tenant energy costs (tourist attractions and other commercial activities on center)
- Metering provides KSC management traceable energy metrics for on-site performance based contractors

Metering System: Ancillary Usage/Benefits

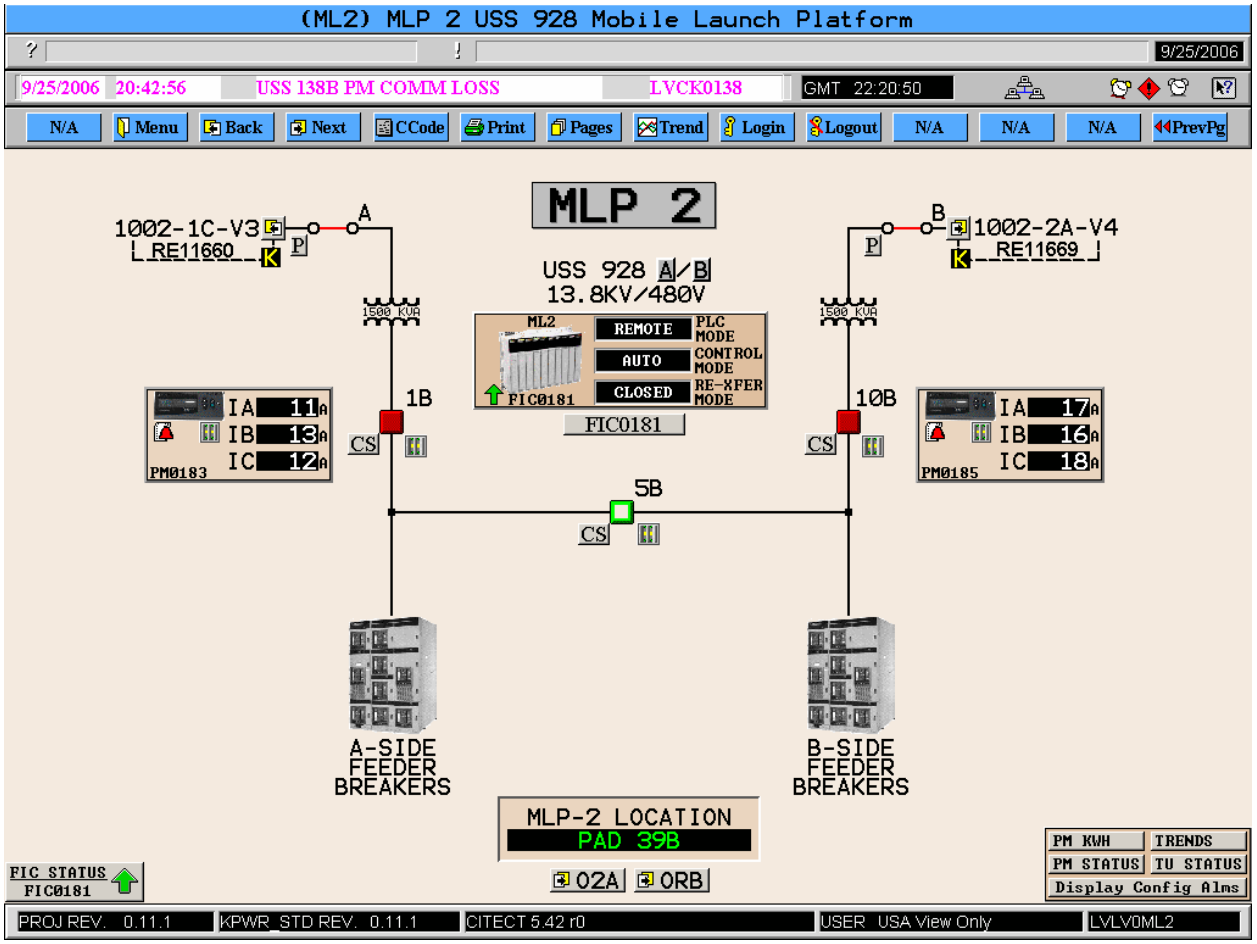
- Data used for many purposes unrelated to energy management
  - Significant savings from power distribution system downsizing made possible by long-term, load trend data from metering system
  - Used to size backup power requirements when facility maintenance requires utility system outage
  - The metering system has served as key tool to diagnose and mitigate high profile power system problems
  - Data collected can be used to schedule preventative maintenance of power switchgear in lieu of schedules
  - Load/Resource Management

Older Vintage Substation



- Shuttle Logistics Facility
- Discrete Indications
- Read into remote PLC
- VM is Timemark Voltage Monitor with Contact Closure
- Some locations would report kW, A, or V

Modern Vintage Substation



- Smart Networked Devices
  - CM4000 Meters
  - Quantum PLC
  - Micrologic 5.0P Bkr TU
  - 3 Ethernet Connections w/ 2 Modbus Serial chains for TU within Switchgear
- Citect “Genies” expand into detailed analysis screens

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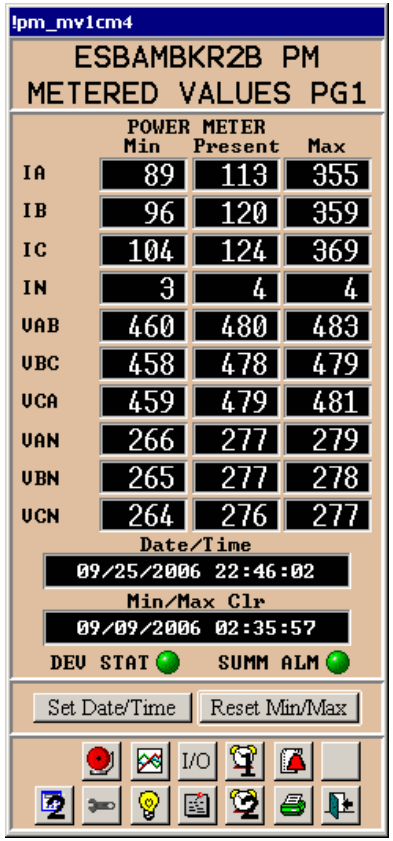
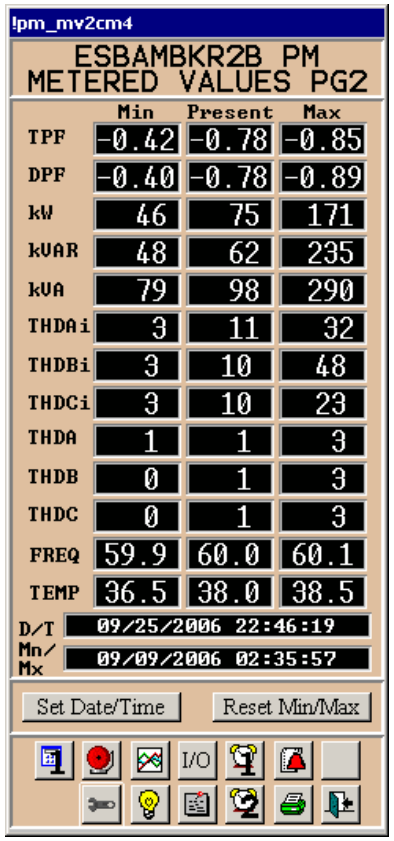
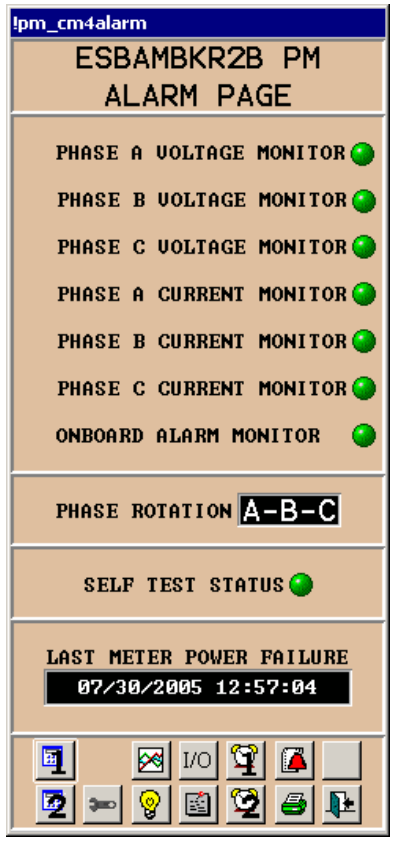
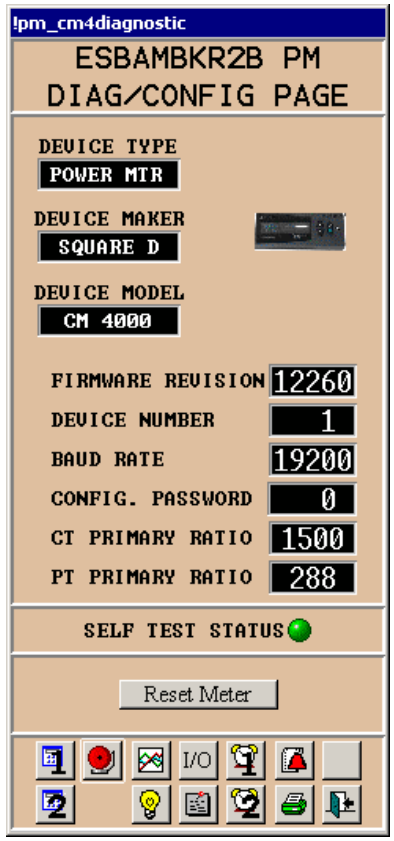
CM4000 Power Meter in KCCS (Citect)









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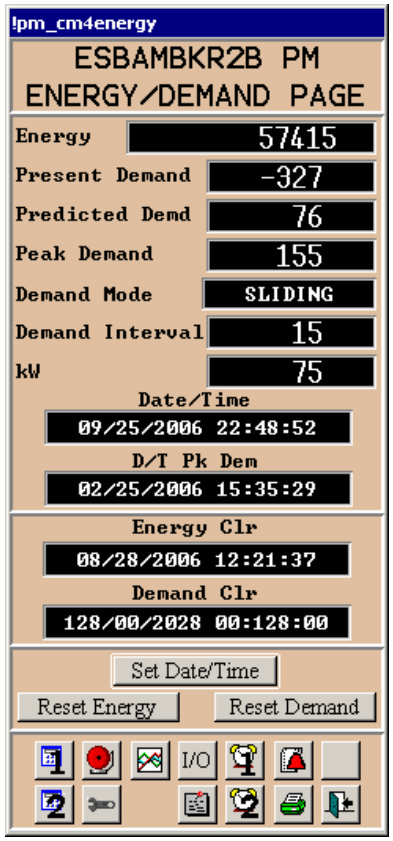
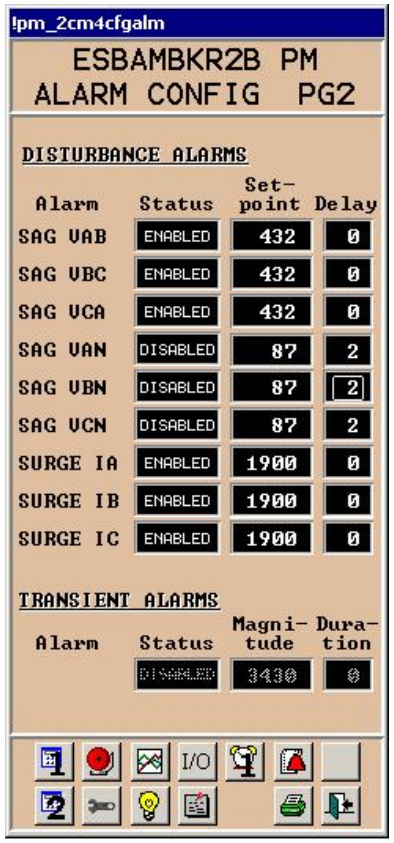
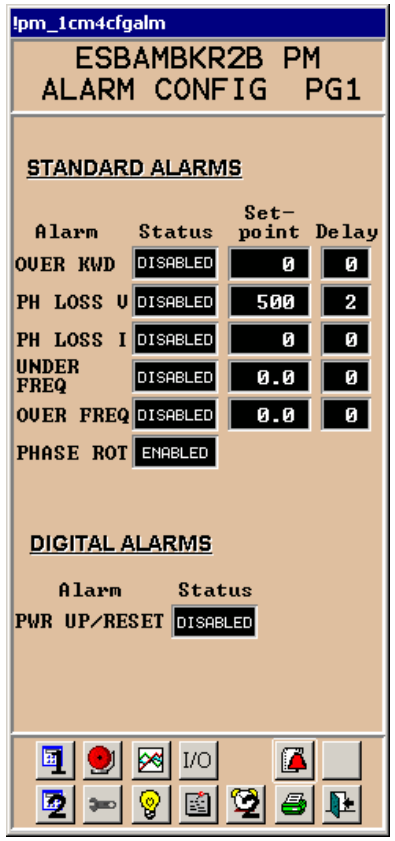
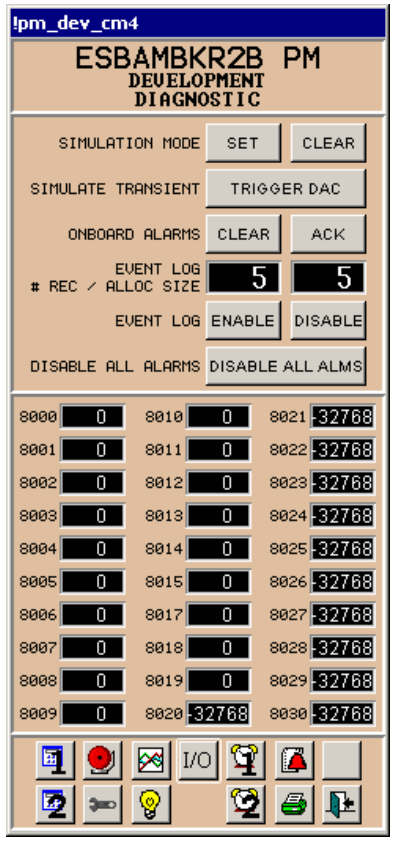
CM4000 Power Meter in KCCS (Citect)

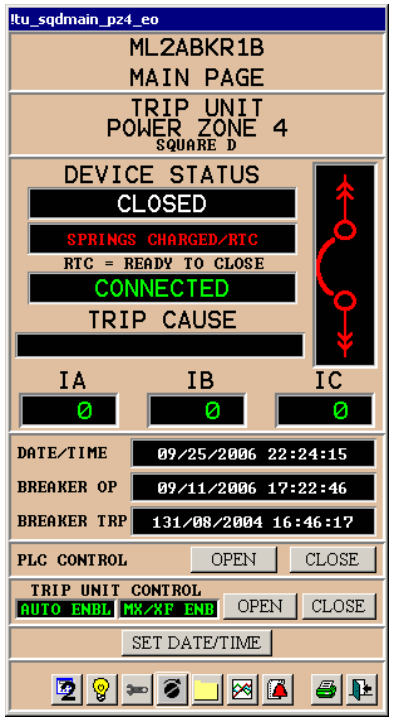


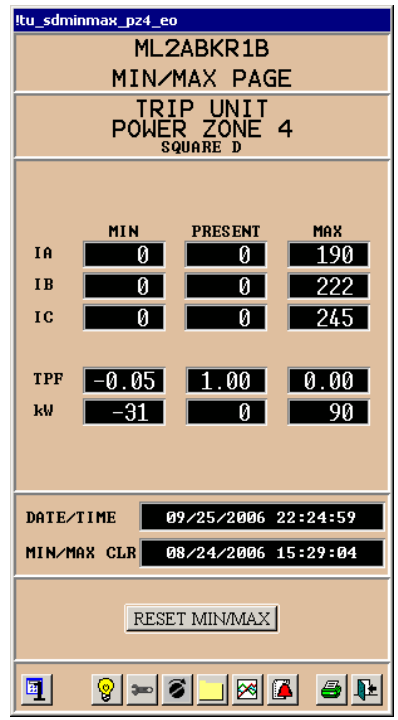


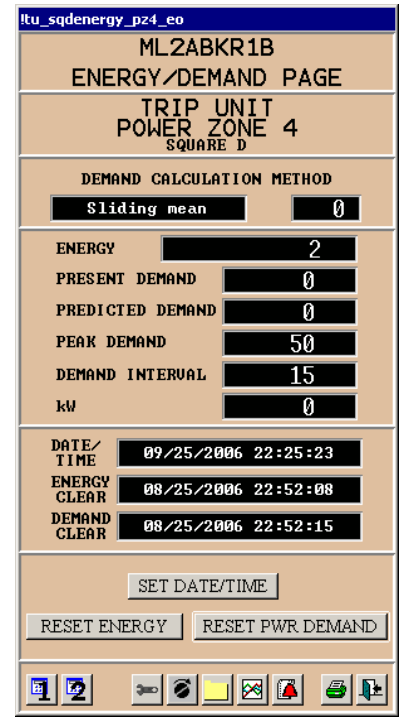




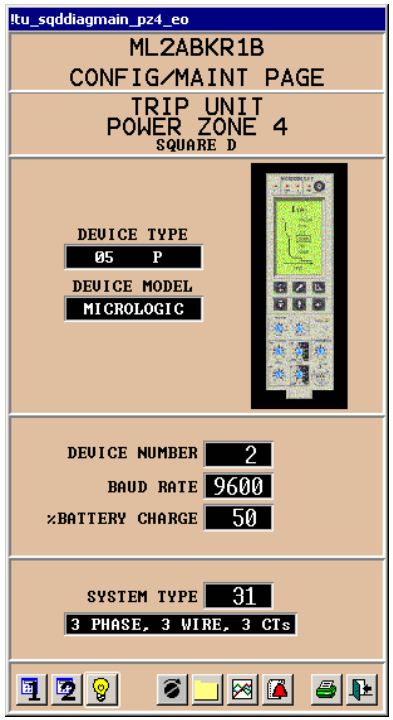
MicroLogic 5P Trip Unit in KCCS (Citect)

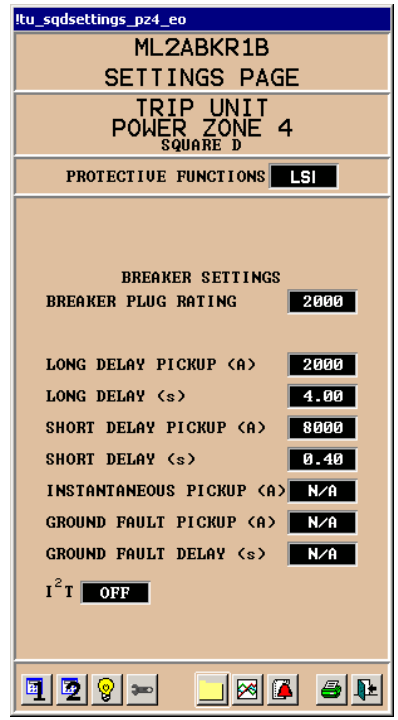


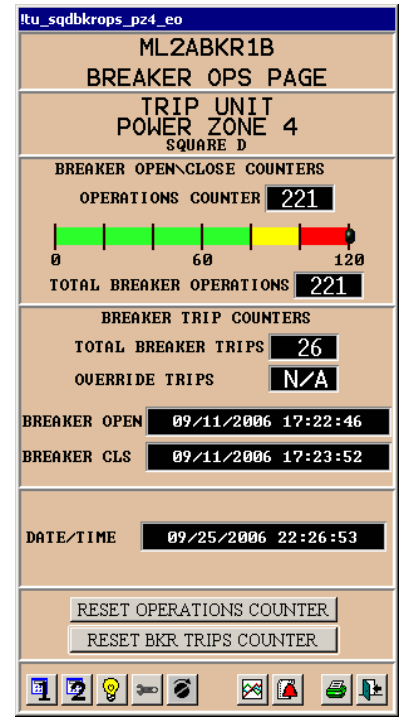




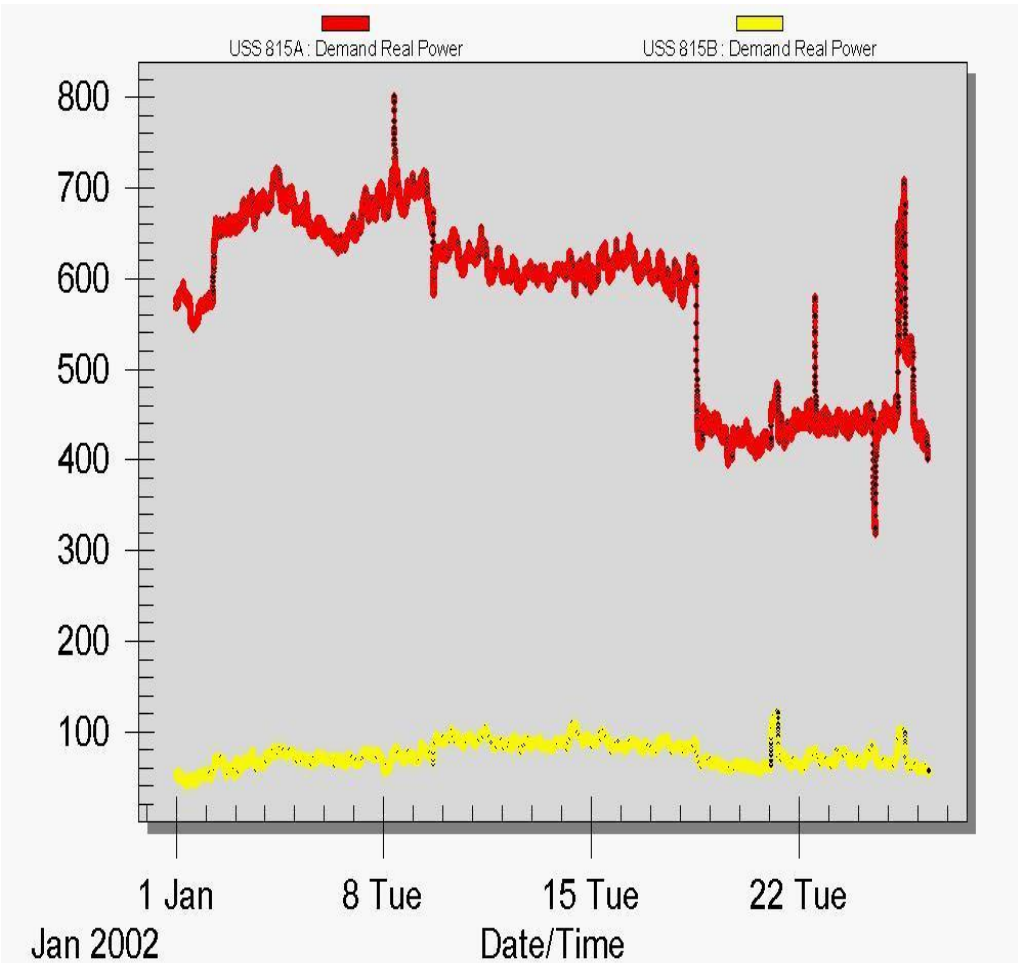
MicroLogic 5P Trip Unit in KCCS (Citect)







Case Study Example: Orbiter Processing Bays



- Metering system identifies utility costs associated with orbiter processing
- Operation management decisions- stop processing at OPF 3 (orbiter in/out)
- Redesign downsized double ended substation based on trend data from metering system
  - CofF Revitalization effort to replace all facility switchgear
  - (4) 2MVA to (4) 1MVA (design)
  - Significant savings (>$100K)
- Similar situations in all KSC power system redesigns with savings in excess of metering system cost.
- Generator sizing during outage saves additional funds

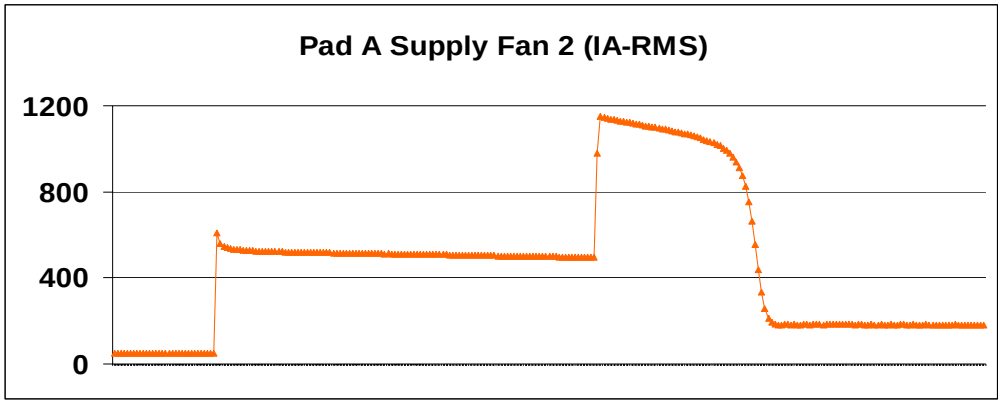
Case Study Example: Pad A Supply Fan Coordination

100ms RMS Event Capture File
Device: **s920**
Current Date: **5/7/2002 10:41 M**

	Date/Time	IA	IB	IC	kWTtl	kVARTtl	kVATtl
510	5/7/2002 10:40:18 AM 1	49	49A	51A	33kW	24kVAR	41kVA
511	5/7/2002 10:40:18 AM 101	50	50A	51A	33kW	25kVAR	41kVA
512	5/7/2002 10:40:18 AM 202	608	620A	538A	127kW	447kVAR	465kVA
513	5/7/2002 10:40:18 AM 314	561	587A	535A	130kW	425kVAR	444kVA

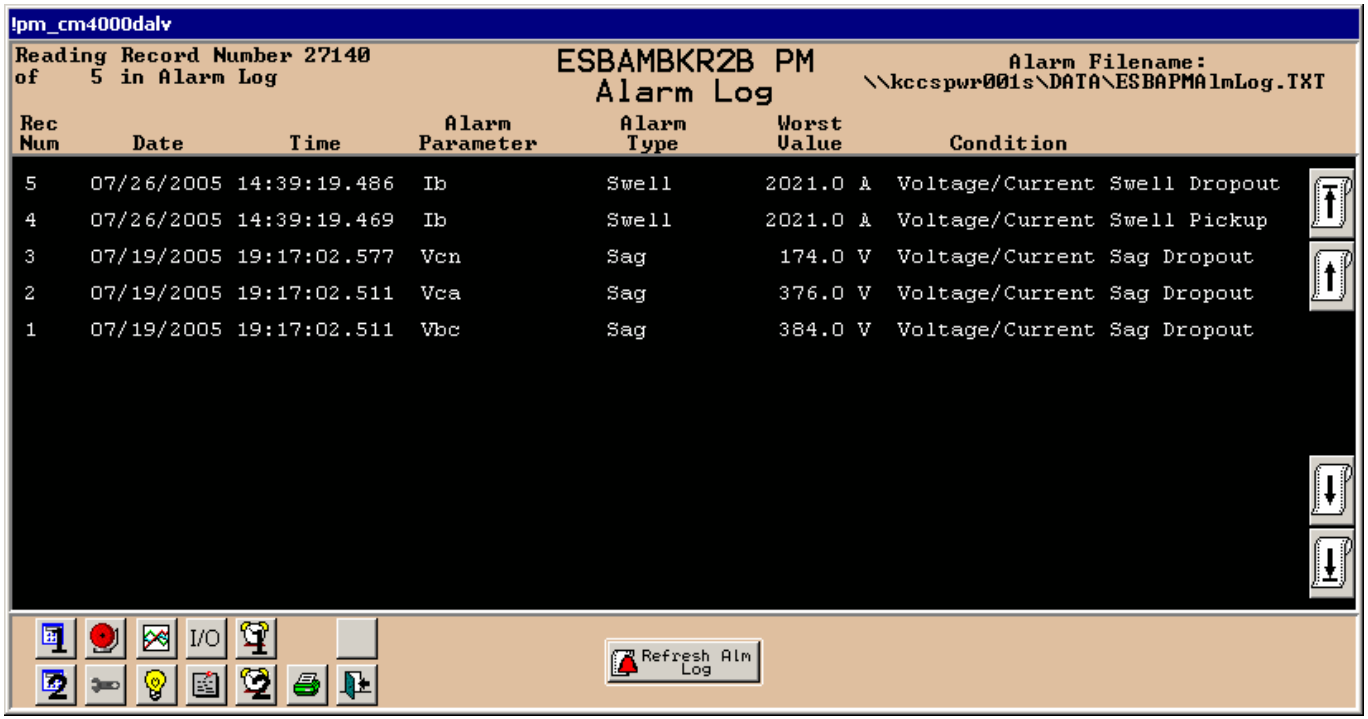
100ms RMS Event Capture File
Device: **s920**
Current Date: **5/7/2002 10:41 M**

	Date/Time	IA	IB	IC	kWTtl	kVARTtl	kVATtl
629	5/7/2002 10:40:29 AM 901	495	524A	494A	132kW	379kVAR	401kVA
630	5/7/2002 10:40:30 AM 1	978	1063A	1017A	268kW	731kVAR	779kVA
631	5/7/2002 10:40:30 AM 101	1151	1161A	1166A	283kW	832kVAR	879kVA
632	5/7/2002 10:40:30 AM 201	1147	1159A	1160A	277kW	831kVAR	876kVA



- SF at Pads provide positive purge on MLP and rooms under pad surface to stop collection of noxious and explosive gases
- Fans passed preliminary tests
- Later, sporadic power system shutdowns occurred
- Advanced meters installed as a part of power system mods identified problem
  - Breaker trip settings same as previous system but trip curves less forgiving
  - On board, high speed event recorders captured trip and allowed engineers to revise breaker coordination

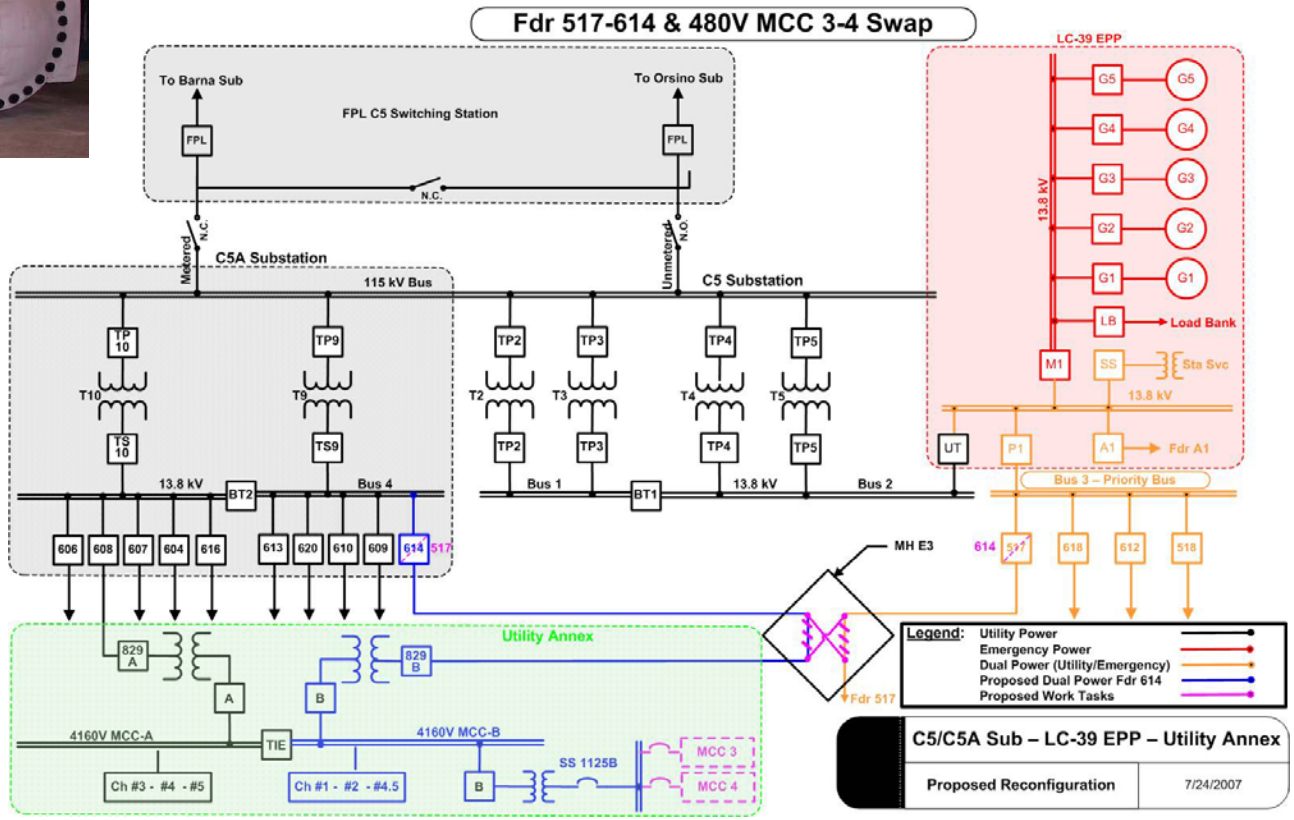
Case Study Example: Breaker Trip (Pad B STS-114 Launch)



- CM4000 Event Log Page in Citect Genie
- Downstream molded case breaker opens during launch
- Meter stores info about event including waveform (retrieved by SMS)
- Problem diagnosed before engineering is allow access to Pad
- Invaluable when Pad is inaccessible

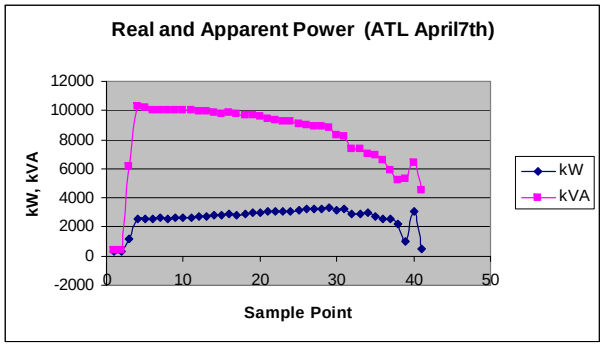
Case Study Example: 2000Hp Chiller Soft Start Testing

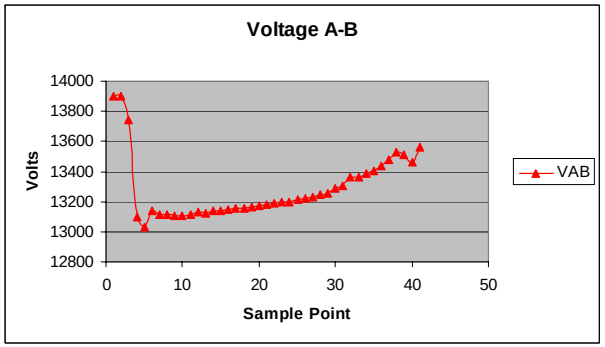
- CM4000 Event Log Page in Citect Genie
- Downstream molded case breaker opens during launch

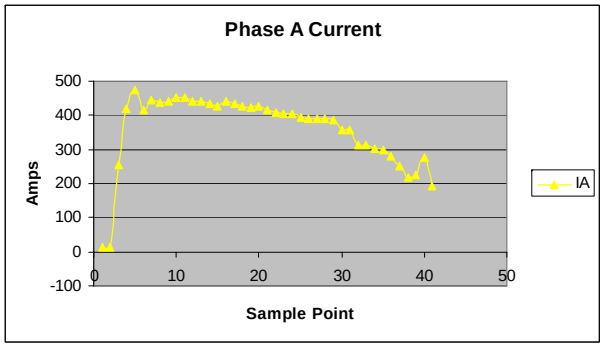


Case Study Example: 2000Hp Chiller Soft Start Testing

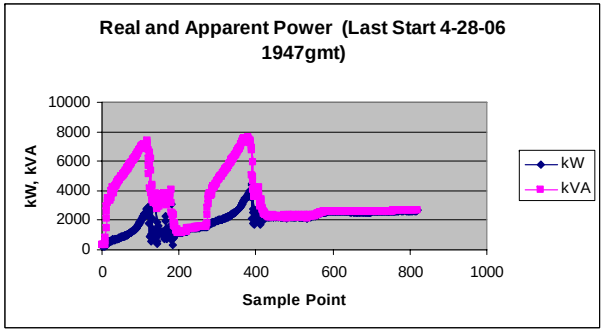
Across the Line Start (1st Chiller Only)

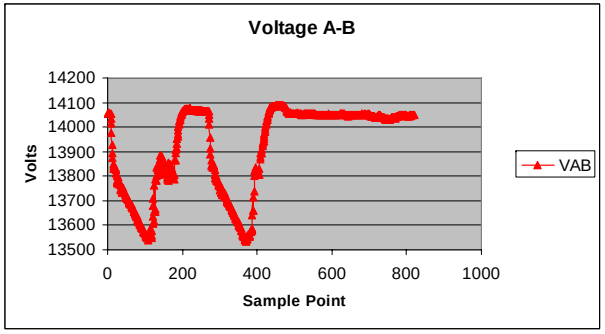


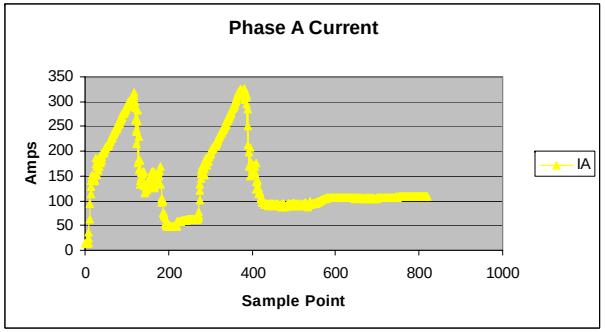




Soft Start (Both Chillers Sequentially)







- Uncertain whether soft starts could facilitate start of 2000Hp Synch Motors by LC39 Area Emergency Generator Plant
- Test performed while Soft Starts fed from Utility Power
- Data Collect from Upstream CM4000 (100ms Log)
- Result: Soft Start current ramp and peak must be reconfigured to lower Surge MVA but soft start on generators is possible based on data.

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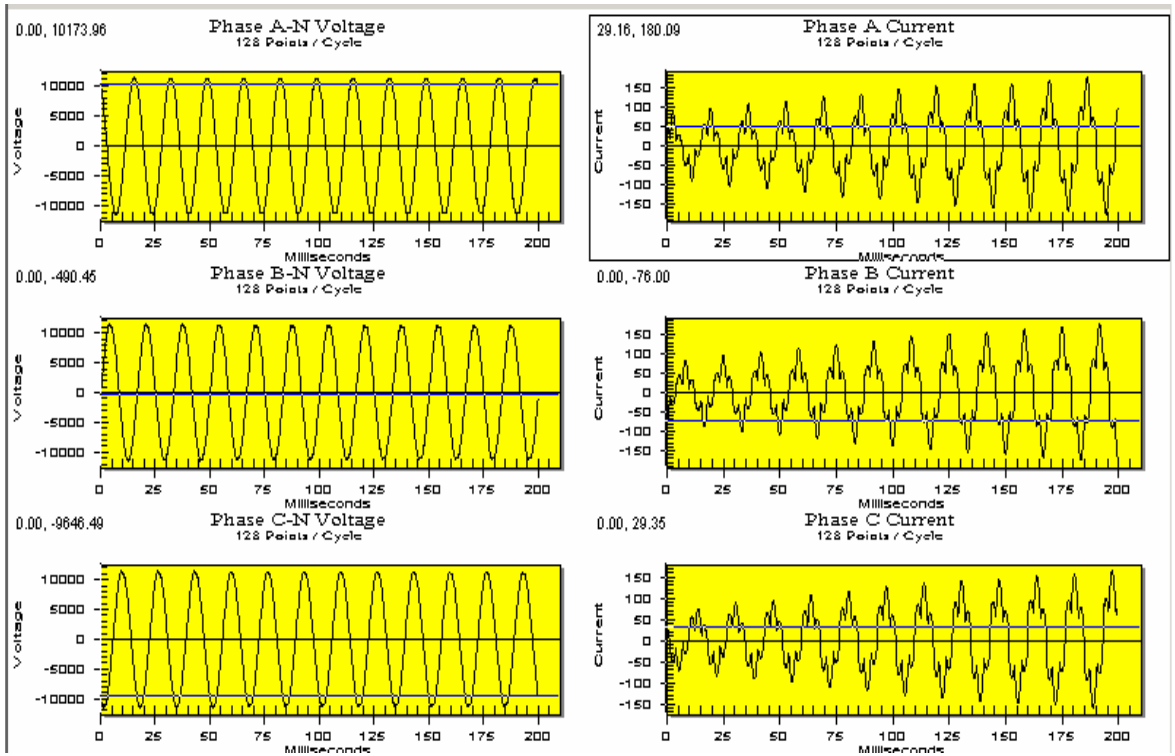
Case Study Example: 2000Hp Chiller Soft Start Testing



- SCR-based Phase Controlled Chopper-
- Significant Concern w/ Several KSC Eng.Groups on Harmonic Content
- Data Collect from Upstream CM4000 (Waveform Capture w/ Swell current trigger)
- Data shows classic distortion profile of Current waveform during ramp up
- At same time, voltage has less than 2% THD
- Data disproves claims Harmonic content will damage equipment or cause nuisance trips

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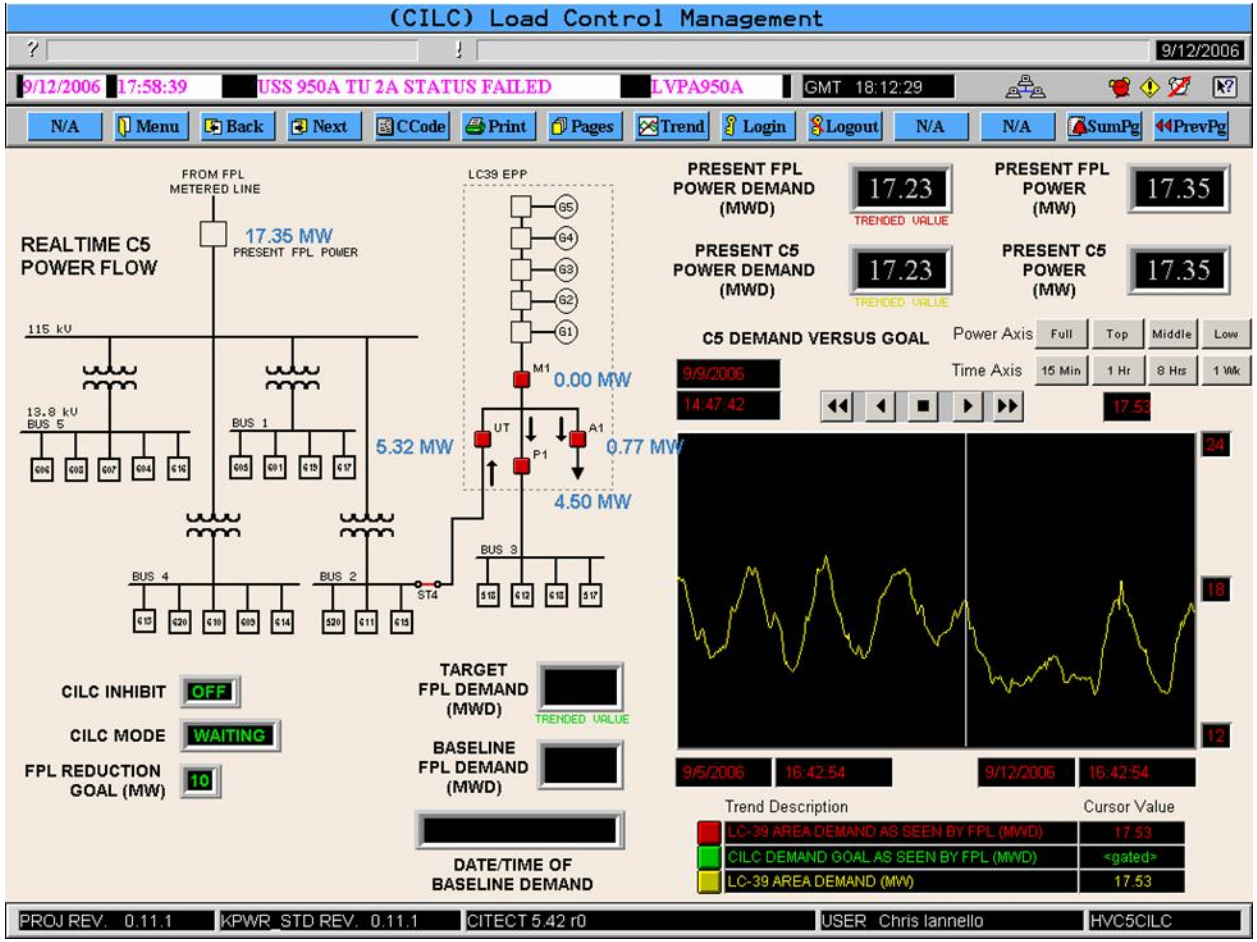
Case Study Example: Emergency Load Control



- LC39 Area Demand 18-20MWd
- LC39 Area Emg. Gens 10MW
- During extended duration utility outage need to secure least important 10MW
- KSC had Emergency Load Control Procedure Implemented with KCCS
- Algorithm secures loads in Phases in reverse priority order.
- KCCS will progressively advance load shed phases until load reduction goal is met.
- Algorithm activated by FPL or Manually to Load Shed non-essential loads
- FPL CILC Program agreement will subsidize this effort
- Networked Power Meters provide data to establish if additional load reduction is required to meet goal

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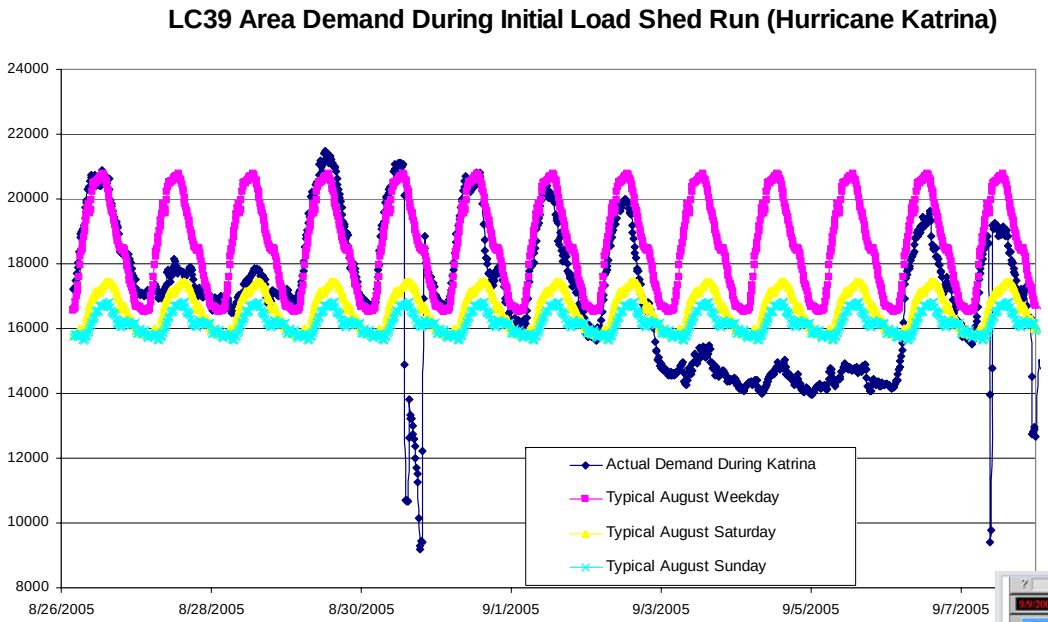
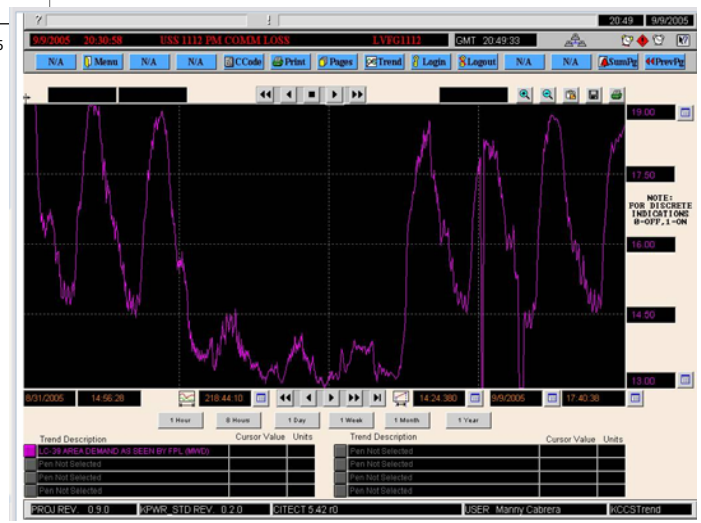
Case Study Example: Emergency Load Control

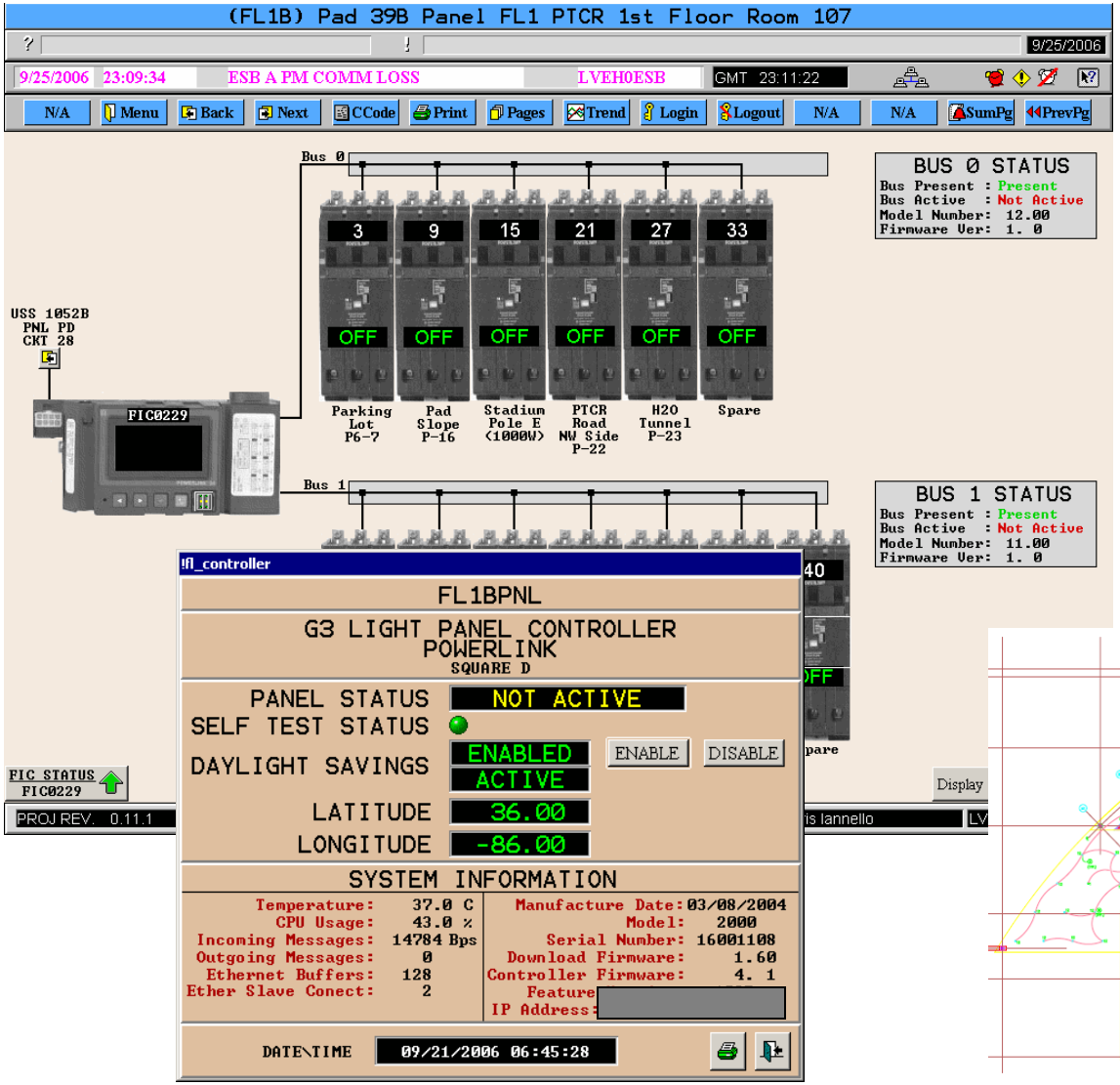


- Initial run of the load shed activity for hurricane Katrina
- Only 1st 2 phases plus some manual load shed
- 2 MW reduction
- Plans to get on CILC tariff for 1MW KCCS automated
- Will pay ~approximate $60K annually and improve operational readiness

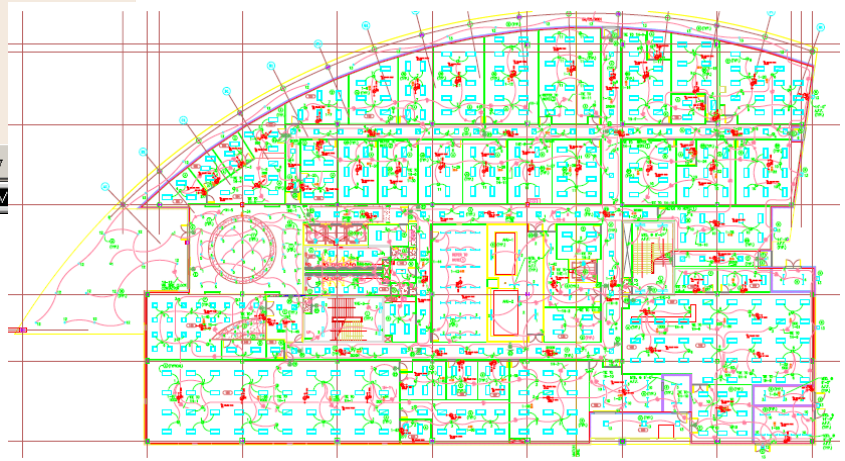
- KCCS Trends from sum of NASA Power Meters show the demand profile closely matched substation metering
- Load reduction mostly obtained by securing/rolling AHUs in nonessential areas
- Starting to look at other nonessential load types



Case Study Example: Emergency Load Control



POWERLINK© G3 Panelboard



Lessons Learned: Costs

- Install Costs
  - Advertised Typical Power Monitoring System 2-5% of Annual Bill
  - Our initial deployment was more than this at $850,000 (~10%)
  - Most cost was involved in labor (~75% $5k hardware, $15K labor)
    - retrofit application, involved complex auto transfer control schemes, and facility outages, fiber solution best option but at premium
- Maintenance Costs
  - Annual cost to maintain less than ~$10K-materials, labor
- Expansion/Upgrade Costs
  - Modify Boilerplate specs for all facility projects to call for meter type, location, network, etc.
  - Make every protective relay, circuit breaker controller, or other networkable device an extension of your metering system

Lessons Learned: Hardware

- Most important consideration is communication protocol and interoperability (next slide)
- Might already have high end meter waiting for networking
- Cheaper meter doesn't always make for cheaper total solution
- Waveform Capture for transient analysis, sag/swell event capture, and power quality valuable to energy management and the facility O&M communities
  - Appealing to facility O&M staff who maintain
- On Board Logging comes in handy
  - Reduce polling load
  - Trends when network down
- Hardware using embedded web server for configuration, installation and health monitoring are invaluable to the O&M since No software required in field

Lessons Learned: Integration with KCCS

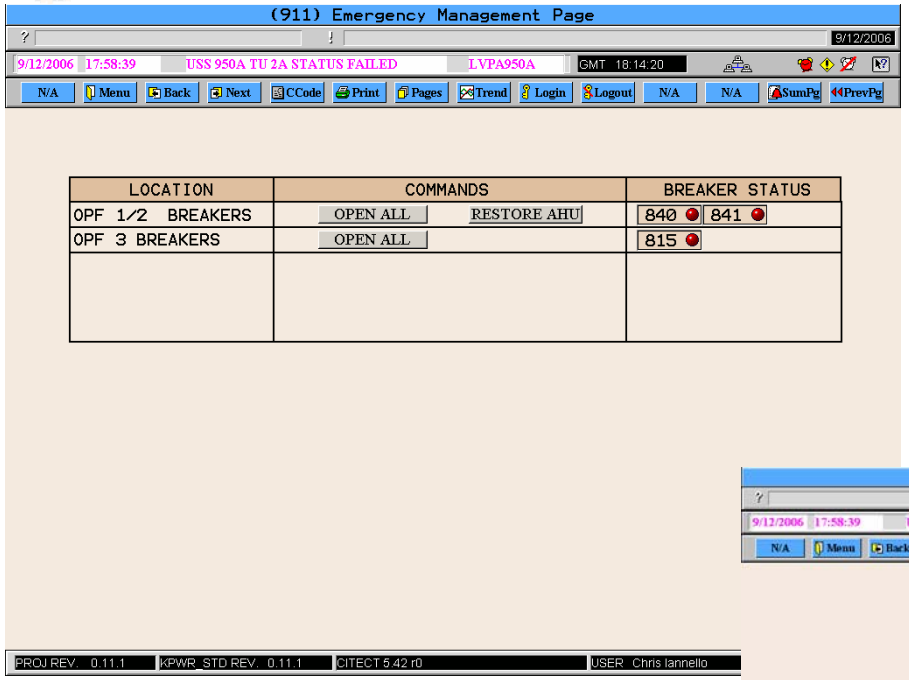
- Merging of monitoring and control networks with energy monitoring was a good move for KSC
  - Better maintenance of metering system since its now power monitoring system too and better maintenance of power system because data allows maintenance as needed versus schedule.
  - Synergy (power meters replace traditional analog and relay based status measurements and provide self health info)
  - Puts information necessary for automatic load control with the control systems that have the ability to do something with it (automatic)
  - Smart meters with bus based communication networks reduce cable plant needs significantly
  - SCADA screens currently in work encompass all energy types
  - Available information greatly increased
  - Long term data trending/storage capability

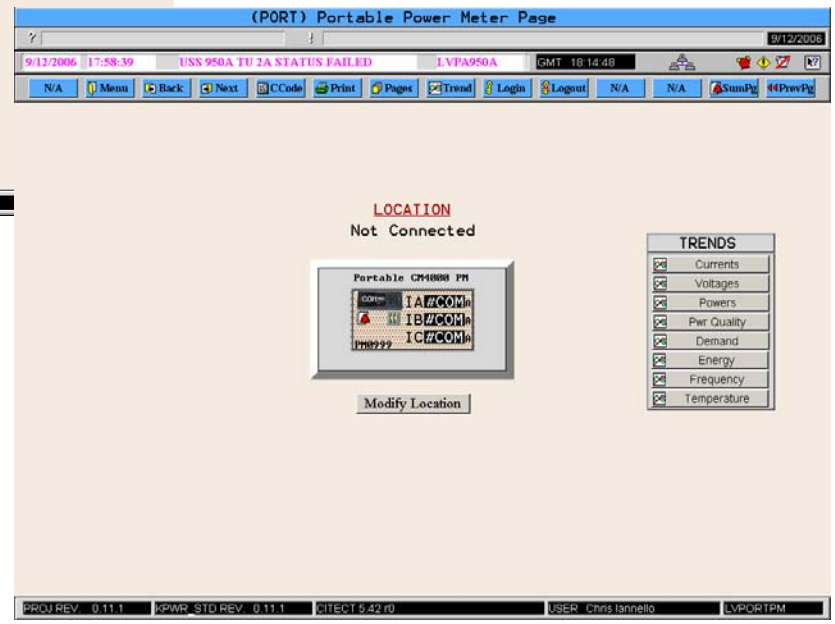
Summary of Lessons Learned

- Synergy with monitoring and control systems, O&M houses to maximize usefulness
- Standardize hardware set using specification boilerplates for meter functionality and communications protocol.
- Open Ethernet based, protocol highly desirable
- Metering installations, in a retrofit setting, can be labor intensive and prone to wiring error
- Costs often greater than advertised
- Cheaper meter isn't always cheaper total cost
- Although SCADA best overall option, expect to maintain some component of the meter vendor software indefinitely

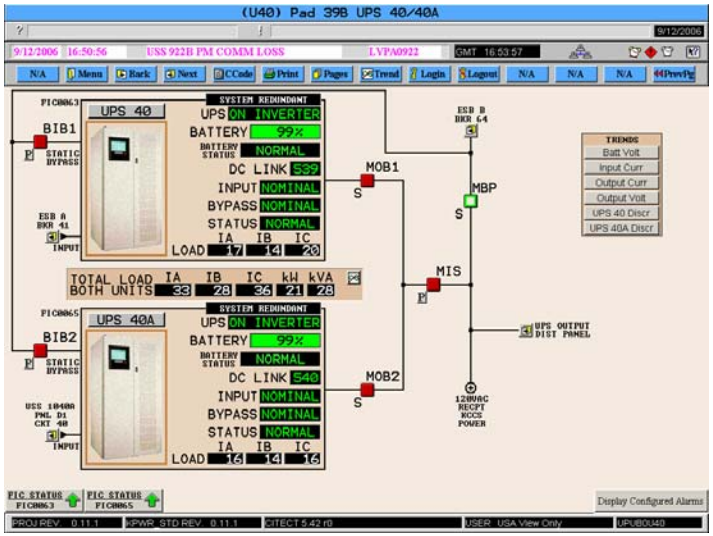
Backup Slides

KENNEDY SPACE CENTER
LAUNCHING A VISION





9/12/2006 16:50:56
USS 922B PM COMM LOSS
LVPA0922
GMT 16:53:32
Trend Description
Cursor Value
Units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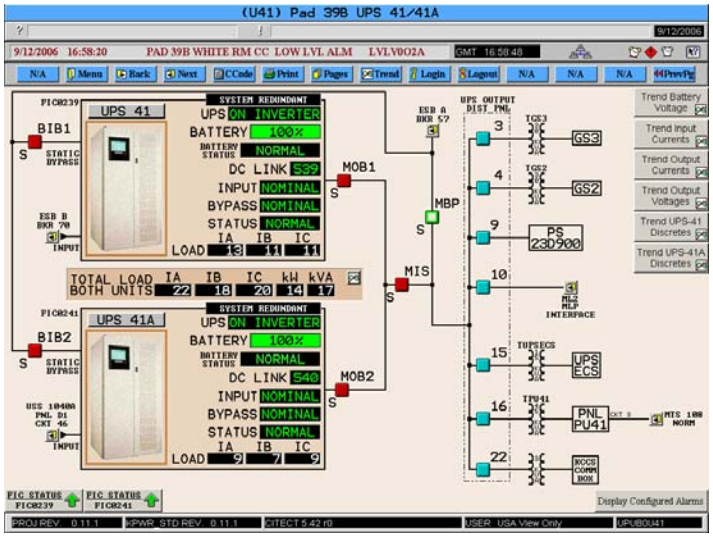
USS 922B PM COMM LOSS
LVPA0922
GMT 16:53:57
UPS 40
UPS 40A
SYSTEM REDUNDANT
UPS ON INVERTER
BATTERY 99%
BATTERY STATUS NORMAL
DC LINK 539
DC LINK 540
INPUT NOMINAL
BYPASS NOMINAL
STATUS NORMAL
LOAD 17 14 20
LOAD 16 14 14
TOTAL LOAD BOTH UNITS IA IB IC kW kVA
33 28 36 21 28
BIB1
BIB2
MOB1
MOB2
MBP
MIS
TRENDS
Batt Volt
Input Curr
Output Curr
Output Volt
UPS 40 Discr
UPS 40A Discr
Display Configured Alarms


(U41) Pad 39B UPS 41/41A
9/12/2006 16:58:20
PAD 39B WHITE RM CC LOW LVL ALM
LVLV002A
GMT 16:58:48
UPS 41
UPS 41A
SYSTEM REDUNDANT
UPS ON INVERTER
BATTERY 100%
BATTERY STATUS NORMAL
DC LINK 539
DC LINK 540
INPUT NOMINAL
BYPASS NOMINAL
STATUS NORMAL
LOAD 13 11 11
LOAD 9 7 9
TOTAL LOAD BOTH UNITS IA IB IC kW kVA
22 18 20 14 17
BIB1
BIB2
MOB1
MOB2
MBP
MIS
GS3
GS2
PS 23D900
UPS ECS
PNL PU41
Trend Battery Voltage
Trend Input Currents
Trend Output Currents
Trend Output Voltages
Trend UPS-41 Discretes
Trend UPS-41A Discretes
Display Configured Alarms

9/12/2006 16:58:20
PAD 39B WHITE RM CC LOW LVL ALM
LVLV002A
GMT 17:00:19
Trend Description
Cursor Value
Units