



CALIFORNIA ISO
California Independent System Operator

Using PI-ACE to Calculate Regulation Performance Metrics

Prepared by

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**Presentation to
2003 OSIsoft T&D Users Conference**

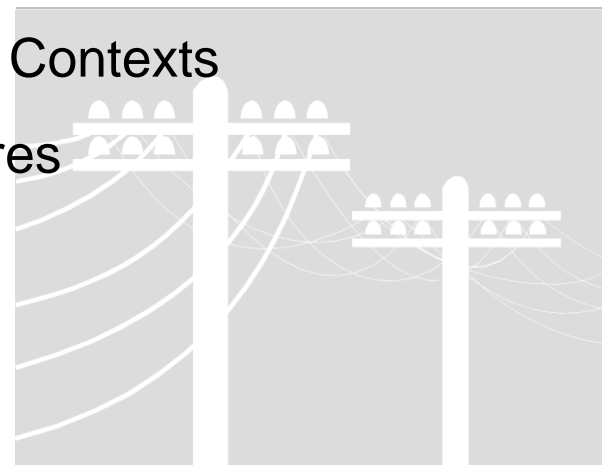
Agenda

Don Covering

- Description of Regulation
- Regulation Performance Metrics
- ProcessBook Display Examples

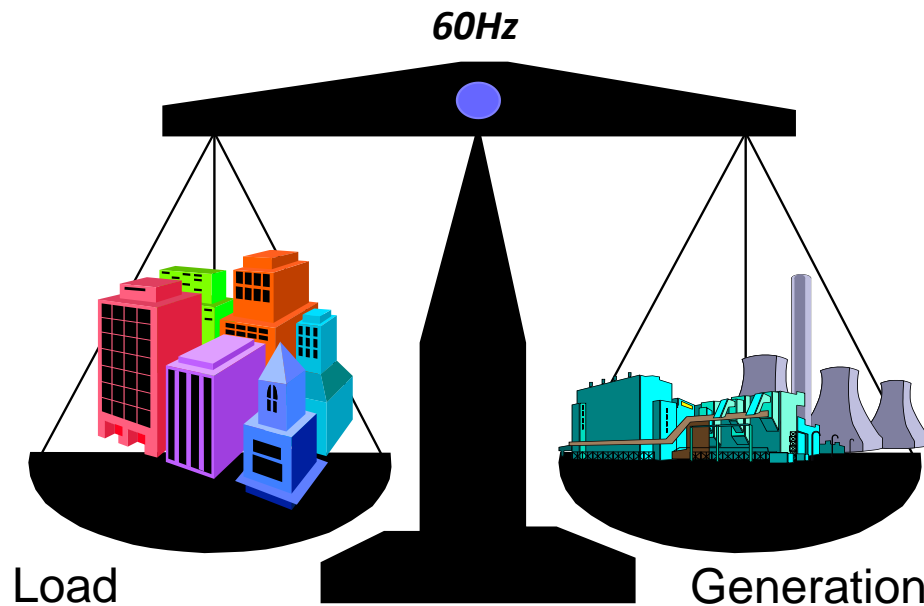
Craig Covering

- California ISO Server Structure
- PI-ACE Tip: Adding Multiple Similar Contexts
- Our last year: Successes and Failures
- Future PI-ACE Plans



What is Regulation?

Regulation – Generators equipped with Automatic Generation Control (AGC) that can change output quickly to accommodate the fluctuations in system supply and demand.



What is Regulation?

- Ancillary Service – Expensive
- Reserved Capacity
- Generators Controlled by CAISO EMS
- Telemetry Requirements
 - ▲ Two Way Communication
 - ▲ Verify AGC Status
- Generators Require Certification
- Approximately 100 Units Certified
- Typically 5-20 Units (CAISO system)



Why are Performance Metrics Needed?

- **Improve the Quality of Regulation Service**

- ▲ Rank Regulation Performance
- ▲ Share information with Generator Owners
- ▲ May Eventually Penalize Poor Performers

- **Improve Reliability**

- ▲ Better Response to System Emergencies
- ▲ NERC Control Performance Standards

- **Reduce Costs**

- ▲ Improve Efficiency of Regulation Service



Performance Metric Requirements

■ Operations Requirements

- ▲ Performance During 10 Minute Intervals
- ▲ Indicate a Variety of Regulation Performance Problems
- ▲ System Performance and Individual Unit Performance
- ▲ Alignment with Certification Tests

■ Compliance Requirements

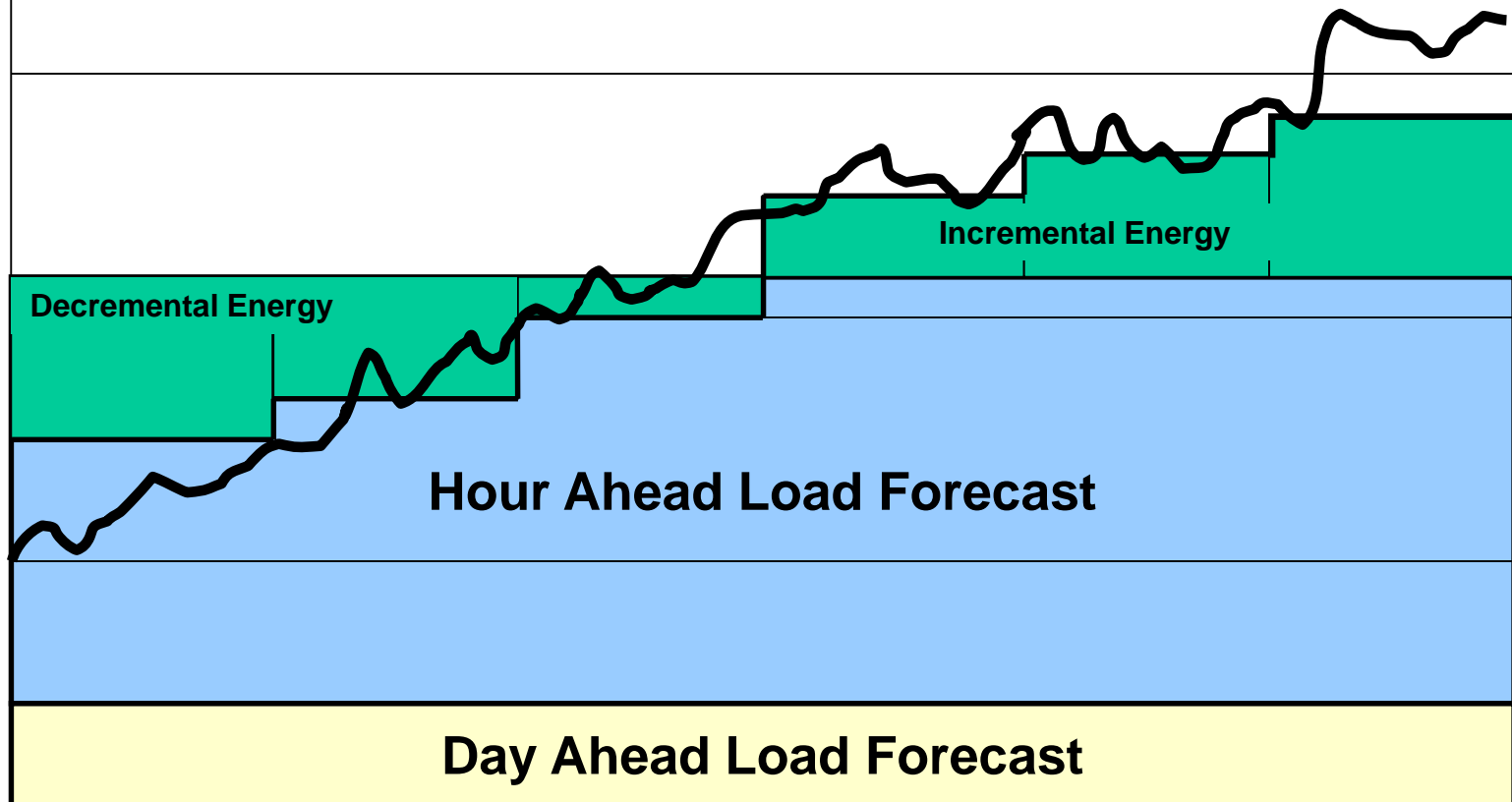
- ▲ Performance During 1 Hour Intervals
- ▲ Provides a Link to Billable Market Quantities
- ▲ Historic Information
- ▲ Alignment with Certification Tests

■ EMS Requirements (All of Above Plus...)

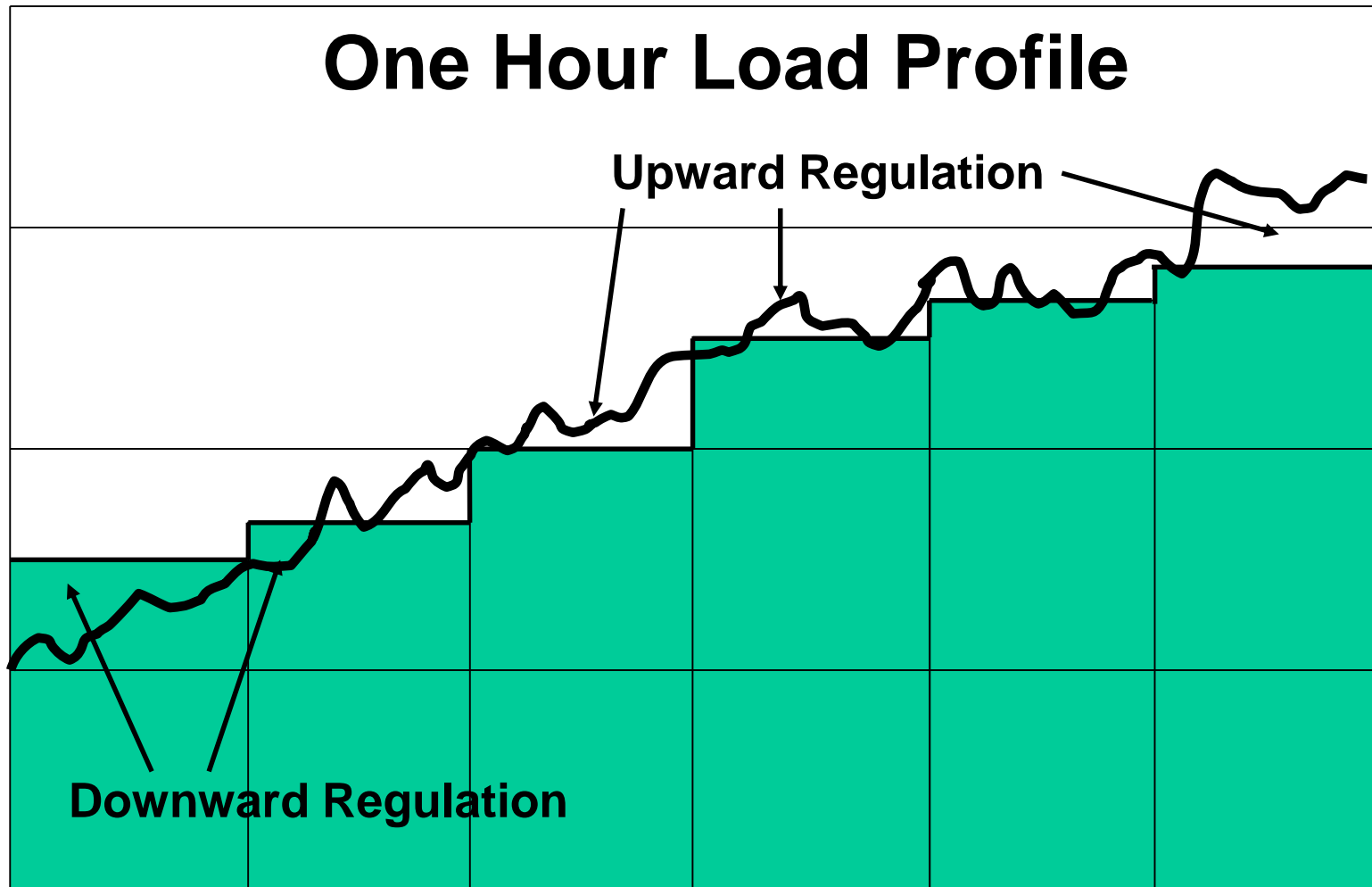
- ▲ Performance Analysis Capabilities
- ▲ Ability to Send Trends to Generator Operators

Regulation – System Perspective

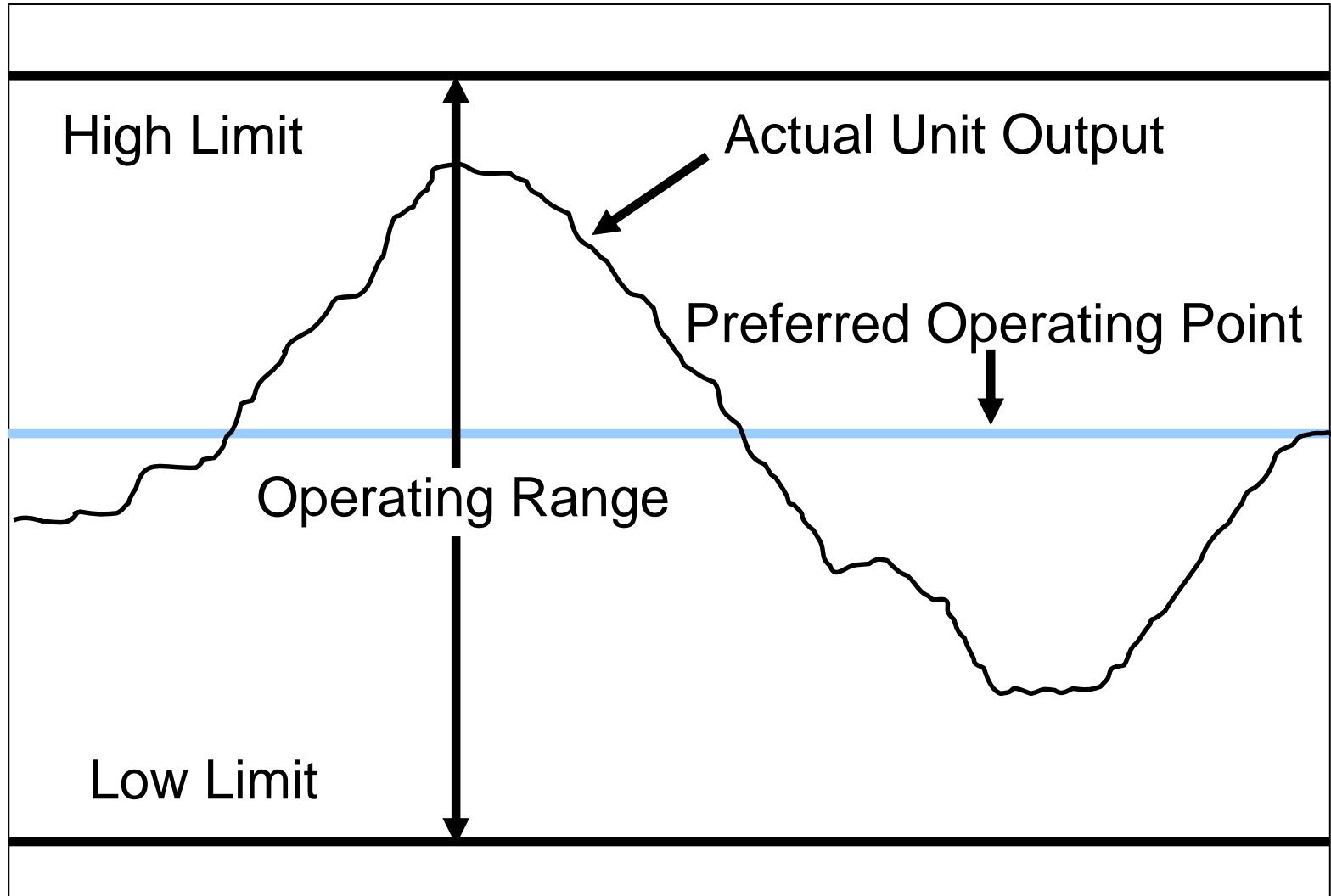
Typical One Hour Load Profile



Regulation – System Perspective

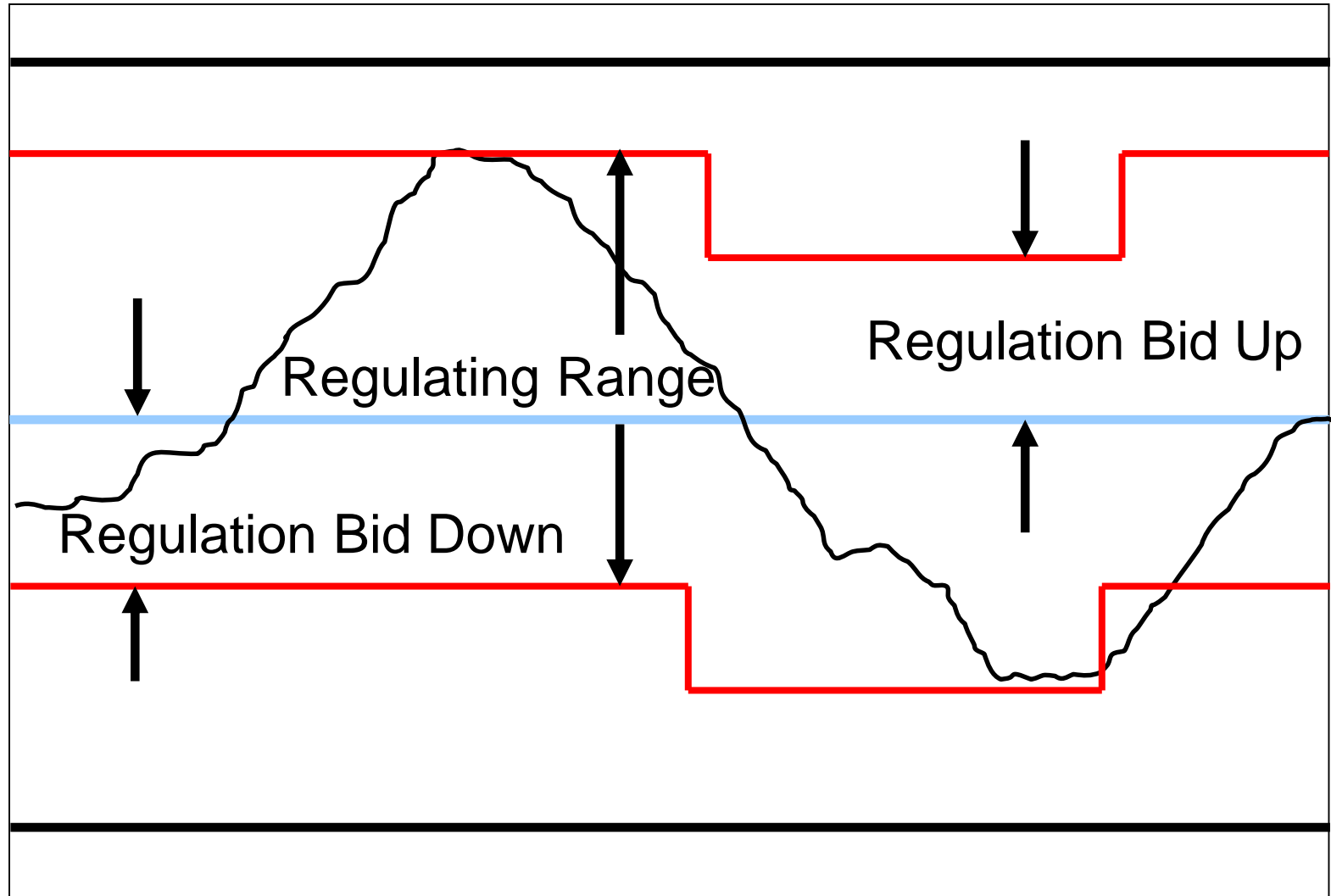


Regulation – Generator Parameters



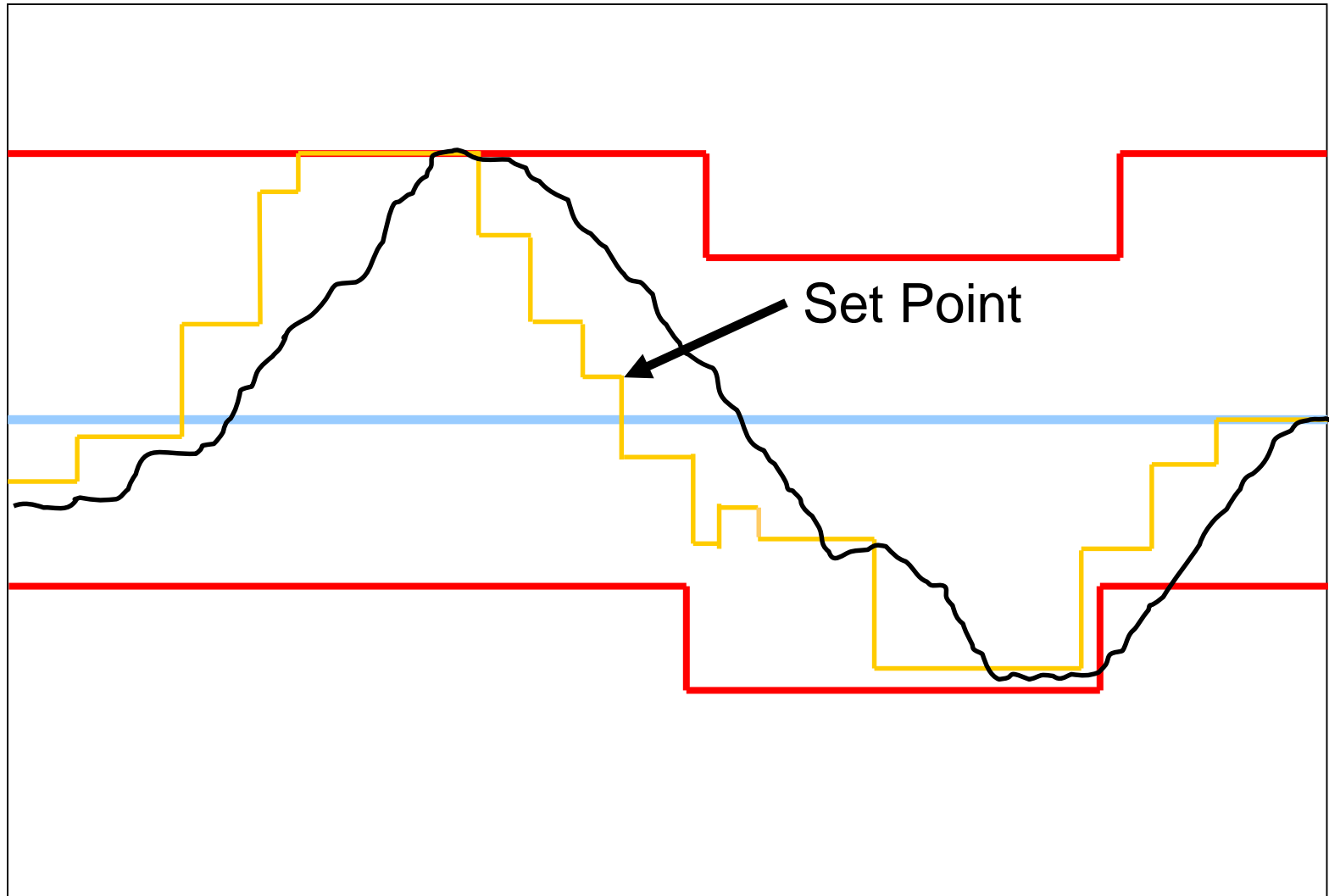


Regulation – Generator Parameters



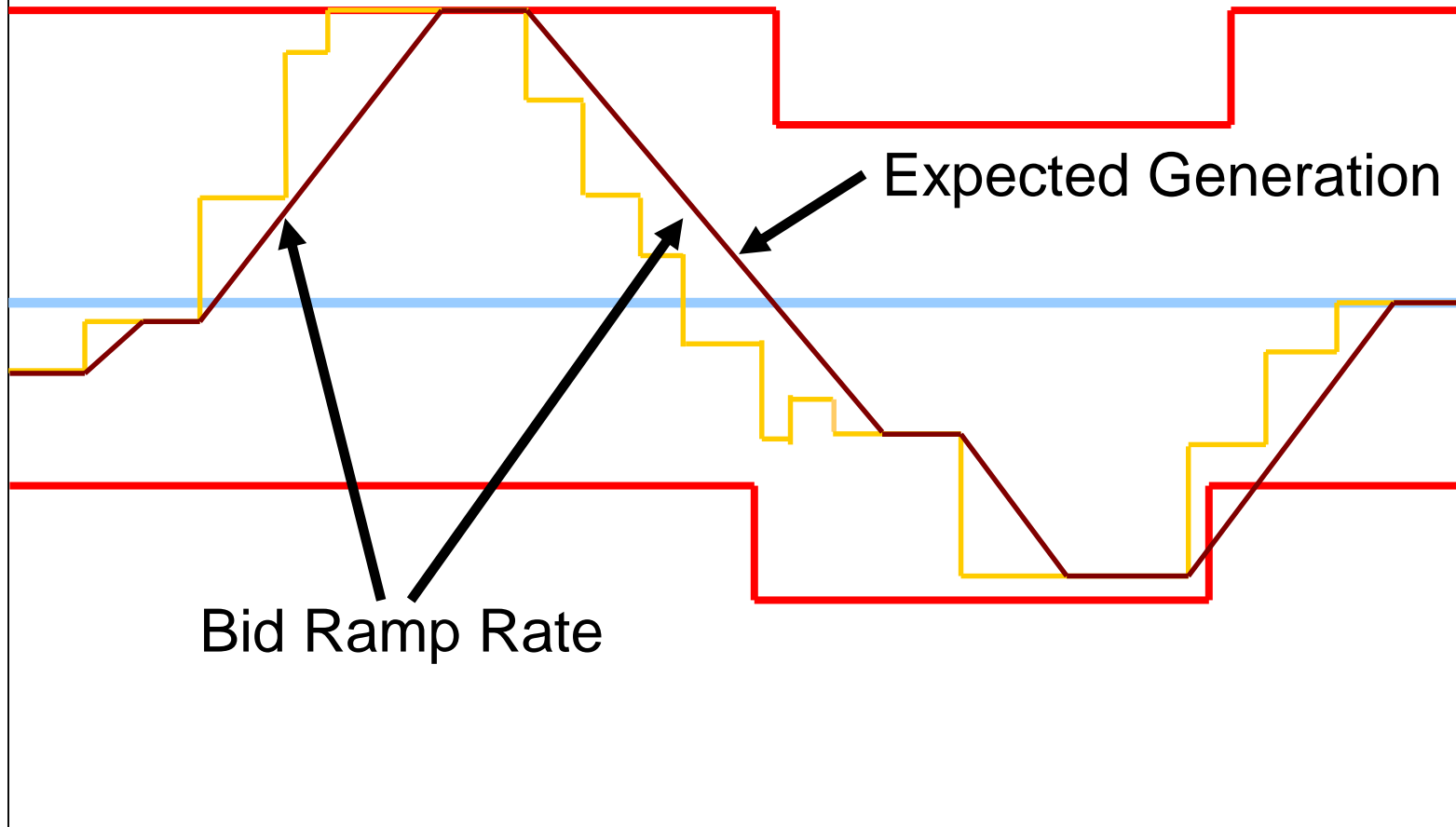


Regulation – Unit Control



Expected Generation Calculation

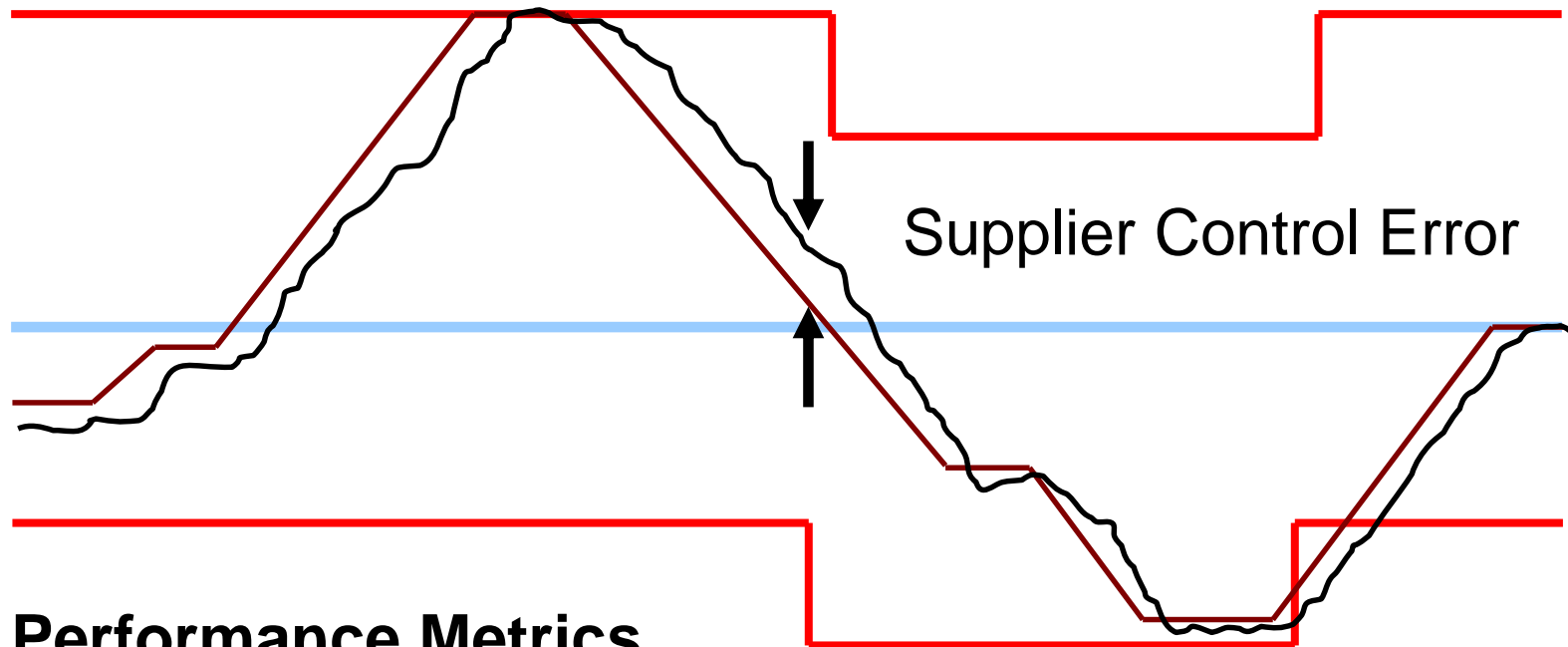
Expected Generation Calculated with PI-ACE





Performance Metric Calculation

Calculated with PI-ACE



Performance Metrics

- 1) Energy Calculations
- 2) Line Statistic Calculations

Calculation Period

- Instantaneous Value
- 10 Min Summation
- 1 Hr Summation



Performance Metric Formulas

Supplier Control Error Energy

$$SCE = \sum_{j=1}^N ABS (Actual_j - Expected_j)$$

$$SCEPerf = \left(1 - \frac{SCE - bias}{Error} \right) * 100$$

Where:

Bias = 1 mwh

Error = 10 mwh (10*bias)

If $SCE > 11 * bias$, $SCEPerf = 0\%$



Performance Metric Formulas

Line Statistics

$$\text{StdDevRatio} = \sigma_{\text{Actual}} / \sigma_{\text{Expected}}$$

$$\text{Correlation} = \frac{\sum_{j=1}^N (\text{Expected}_j - \mu_{\text{Expected}})(\text{Actual}_j - \mu_{\text{Actual}})}{(\sigma_{\text{Actual}} * \sigma_{\text{Expected}})}$$

$$\text{StatPerf} = \text{StdDevRatio} * \text{Correlation}$$

Where StatPerf = 1 if $\sigma_{\text{Expected}} = 0$ or $\frac{\sigma_{\text{Actual}}}{\sigma_{\text{Expected}}} > 2$



Performance Metric Formulas

Performance Metric

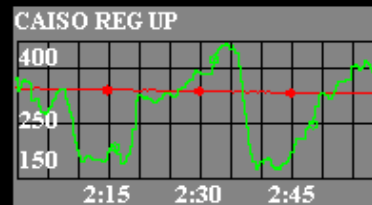
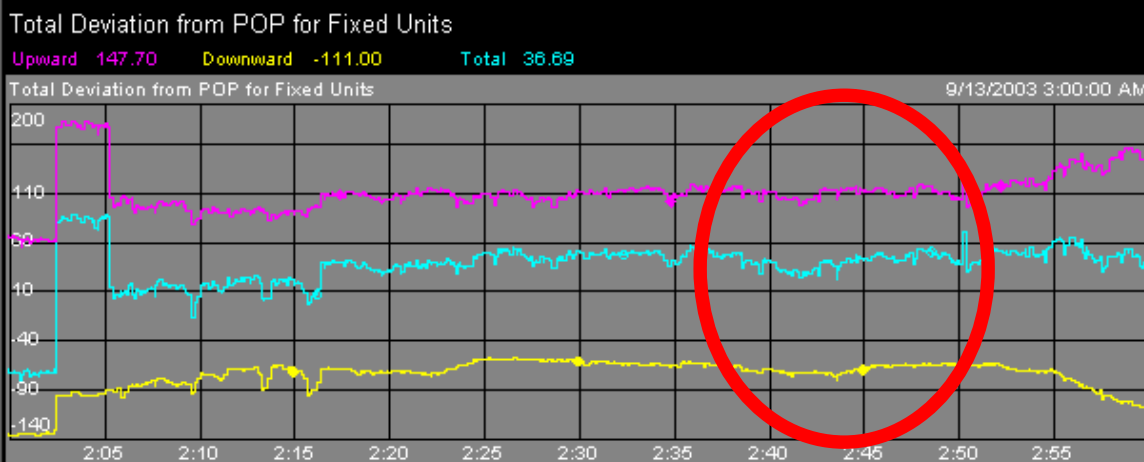
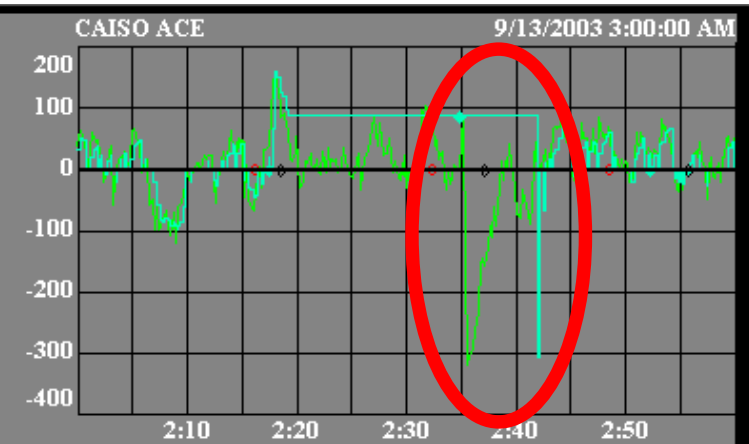
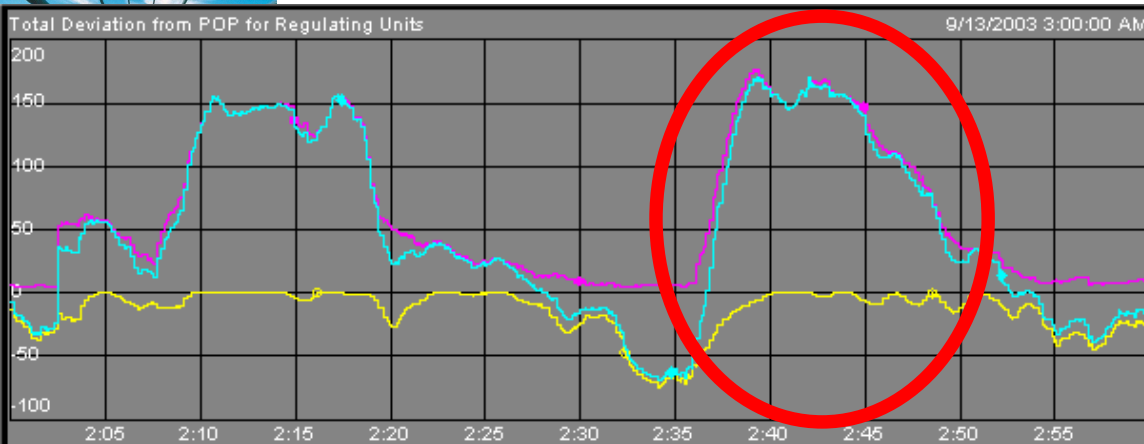
$$PerfMetric = \frac{(SCEPerf + StatPerf)}{N} * 100$$

Where:

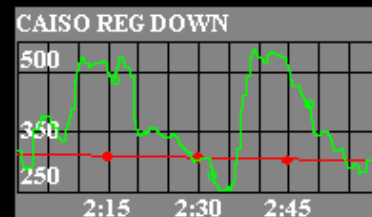
N=1 if StdDevRatio or Correlation fail (StatPerf = 1)

N=2 if StdDevRatio and Correlation are good

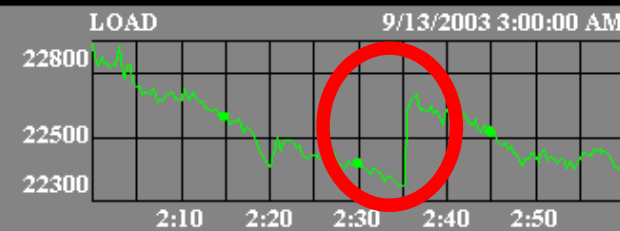
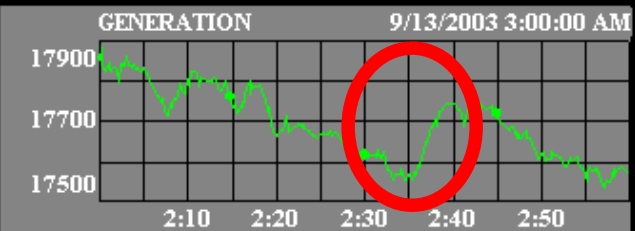
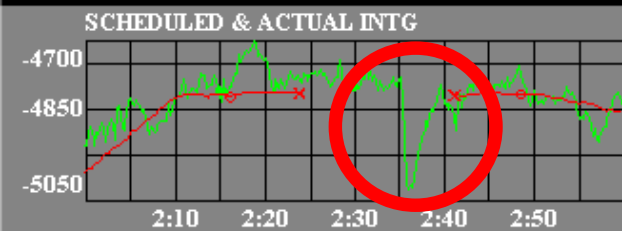
Regulation – System Perspective



UPPER REGULATION		
REQUIRED	ACTUAL	POP DEV.
302	339	8
LOWER REGULATION		
REQUIRED	ACTUAL	POP DEV.
302	304	-26
FIXED		
POP DEV.	TOTAL	POP DEV.
37		-17



SPINNING RESERVE		
REQUIRED	ACTUAL	POP DEV.
640	1035	5.4 %
OPERATING RESERVE		
REQUIRED	ACTUAL	POP DEV.
1280	1696	8.2 %



Regulation – System Perspective

Units on Regulation

Unit	AGC	P	H	A	L	U	D	Unit	AGC	P	H	A	L	U	D	Unit	AGC	P	H	A	L	U	D								
Cogeneration																															
	170	180	168	120	5	5			10	10	10	10	0	0			0	70	-2	17	0	0			0	165	1	10	0	0	
									10	10	10	10	0	0				20	20	21	20	5	5			0	493	4	65	0	0
Hydro																															
	30	29	29	30	2	1			0	0	0	0	0	0				20	20	22	20	4	4			130	130	131	130	5	5
	15	15	23	15	0	0			0	70	20	2	0	0				0	226	0	90	0	0			0	0	-1	0	0	0
	5	45	7	5	7	7			0	0	1	0	0	0				0	250	0	90	0	0			30	30	33	30	6	6
	5	45	7	5	7	7			0	0	1	0	0	0				31	31	36	31	4	4			30	185	33	50	5	5
	20	50	18	5	5	5			226	226	233	226	0	0				228	228	234	228	0	0			0	0	-1	0	0	0
	80	80	74	20	9	9			136	136	141	136	0	0				228	228	234	228	0	0			485	525	480	435	6	6
	0	156	0	25	8	8			0	174	0	40	0	0				0	240	-2	135	0	0								
	0	164	-1	15	8	8			68	320	51	70	7	7				150	471	440	420	15	15								
	4	14	6	4	15	15			0	320	0	70	0	0				0	49	-1	19	0	0								
	10	9	9	9	0	0			0	252	6	70	0	0				0	50	-2	19	0	0								
	121	149	118	93	10	5			0	252	18	69	0	0				0	85	1	36	0	0								
	40	37	37	37	0	0			18	58	18	18	2	2				0	154	1	85	0	0								
	0	0	-1	0	0	0			0	0	0	0	0	0				0	0	0	0	0	0								
	0	400	313	83	37	30			45	45	47	45	10	10				0	0	1	0	0	0								
	0	400	62	83	33	39			0	0	0	0	0	0				52	52	52	52	7	7								
	0	400	2	83	0	0			0	0	0	0	0	0				0	0	-4	0	0	0								
	90	125	91	35	20	5			77	77	78	77	6	6				0	410	0	200	0	0								
	0	145	0	5	13	14			0	125	-3	40	6	2				50	410	50	250	0	0								
	0	0	0	0	0	0			775	805	774	771	12	12				0	140	0	78	0	0								
	0	80	1	5	0	0			0	0	1	0	0	0				0	140	0	78	0	0								
	0	80	1	5	0	0			83	83	72	83	0	0				0	140	-1	78	0	0								
	0	40	-1	5	3	3			0	132	-0	28	0	0				0	140	-1	78	0	0								
	0	40	0	5	3	3			0	117	-0	28	0	0				119	119	96	119	9	9								
	0	56	0	5	5	5			20	114	22	21	3	3				0	46	0	46	0	0								
	0	56	3	5	5	5			63	311	23	65	7	7				0	0	68	0	0	0								
	10	10	9	10	0	0			68	383	71	300	7	7				47	47	45	47	5	5								
	10	10	10	10	0	0			20	20	21	20	0	0				0	179	0	10	0	0								

Good Performance

Poor Performance

CAISO RAW ACE

28.6

UPPER REGULATION

REQUIRED	ACTUAL	POP DEV.
302	339	8

LOWER REGULATION

REQUIRED	ACTUAL	POP DEV.
302	304	-26

FIXED

REG

POP DEV.	TOTAL	POP DEV.
37		-17

Example - Good Performance



SCE 1H Avg = 1.2 mwh

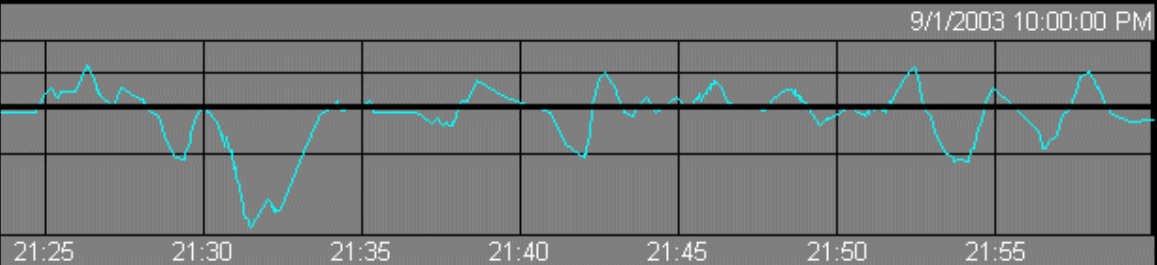
SCEPerf = 98.2%

StdDevRatio = 99.6%

Correlation = 91.4%

Overall Performance

PerfMetric = 94.6%



Supplier Control Error

SCE	-0.82
SCE 10m Avg	0.20
SCE 1hr Avg	1.18

Control Area AGC Data

CAISO RAW ACE	65.1	Total Upward Deviation from POP	0.5
CAISO Filtered ACE	44.0	Total Downward Deviation from POP	-308.6
CAISO Load	30136.6	Total Deviation from POP	-308.1
CAISO Generation	23900.5		
CAISO Interchange	-6234.2		

Example – Border Line Performance



SCE 1H Avg = 3.7 mwh

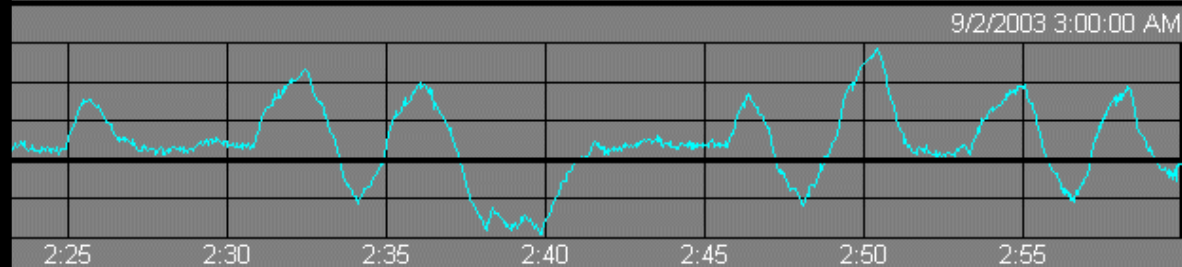
SCEPerf = 73.8%

StdDevRatio = 98.6%

Correlation = 66.1%

Overall Performance

PerfMetric = 69.5%



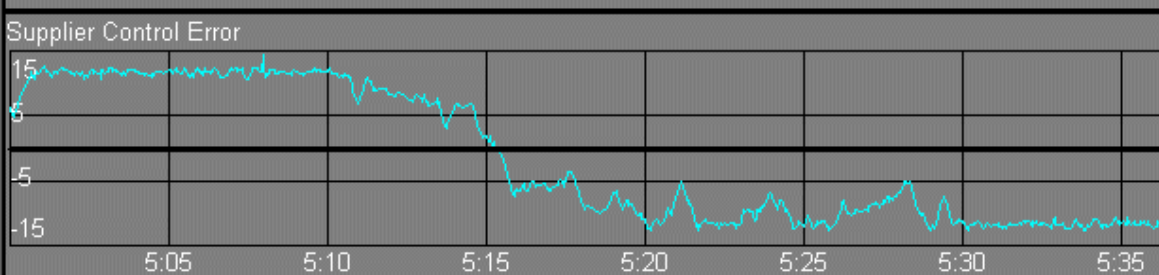
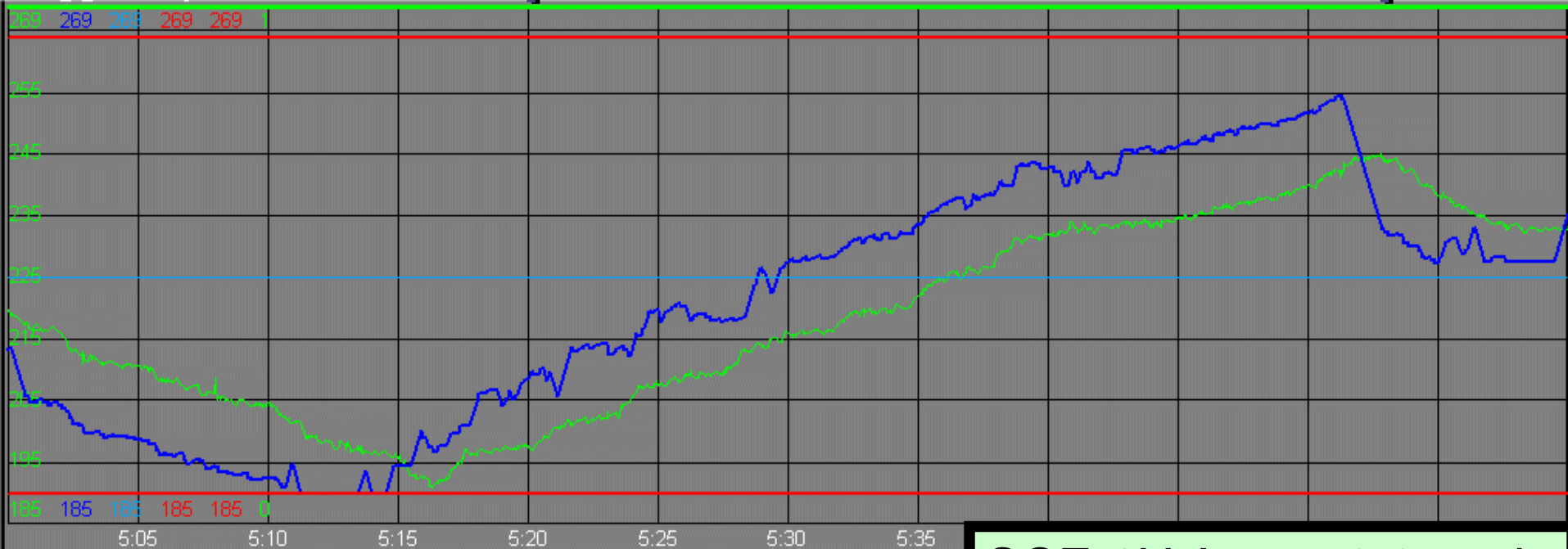
Supplier Control Error

CE	-0.26
CE 10m Avg	0.76
CE 1hr Avg	3.62

Control Area AGC Data

CAISO RAW ACE	-14.6	Total Upward Deviation from POP	42.3
CAISO Filtered ACE	0.0	Total Downward Deviation from POP	-4.4
CAISO Load	22608.8	Total Deviation from POP	37.9
CAISO Generation	18107.0		
CAISO Interchange	-4497.7		

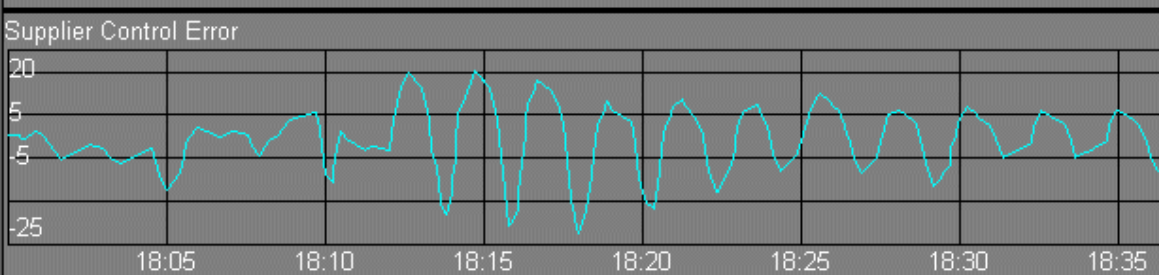
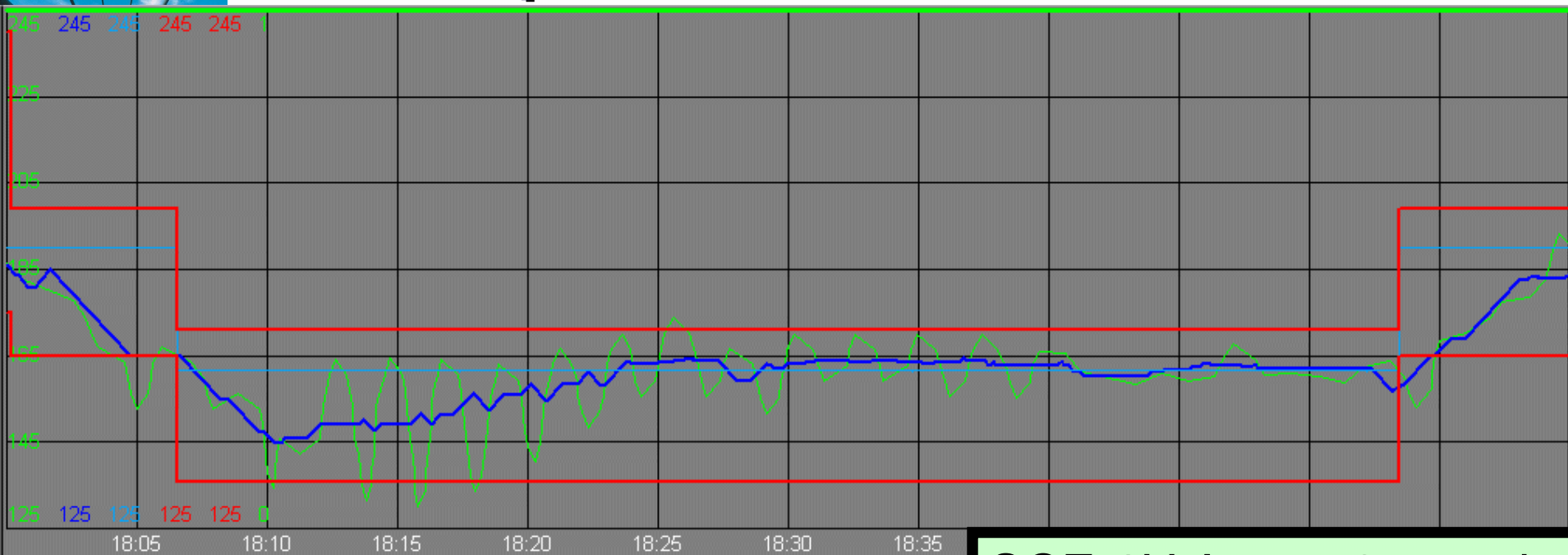
Example - Poor Performance – Response



Individual Unit Data		Supplier Control Error		Control	
AGC Status	Closed	AGC Set Point	244.7	CAISO	
Actual Output	233.0	Bid Up Regulation	39.0	CAISO	
Expected Gen.	235.1	Bid Down Regulation	-35.0	CAISO	
Err. POP	225.0	Bid Up Ramp Rate	14.5	CAISO	
High Reg Limit	264.0	Bid Down Ramp Rate	14.5	CAISO	
Low Reg Limit	190.0			CAISO	

SCE 1H Avg = 9.9 mwh
SCEPerf = 12.4%
StdDevRatio = 87.0%
Correlation = 73.5%
Overall Performance
PerfMetric = 38.1%

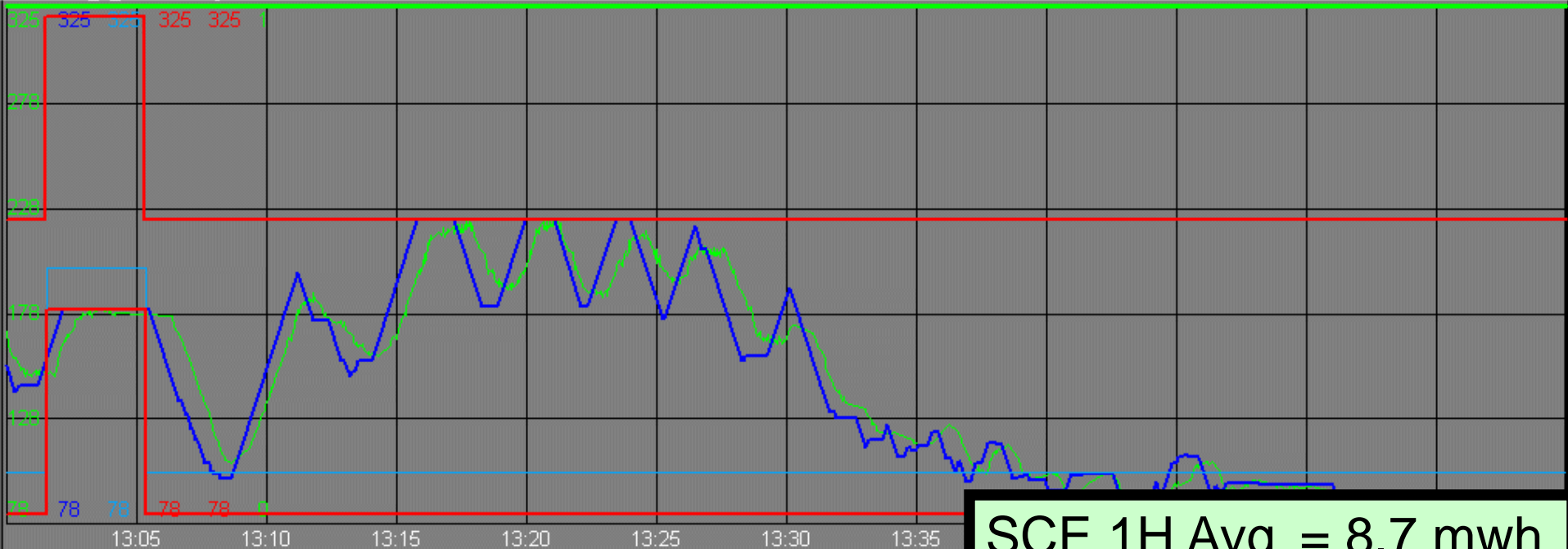
Example - Poor Performance - Oscillation



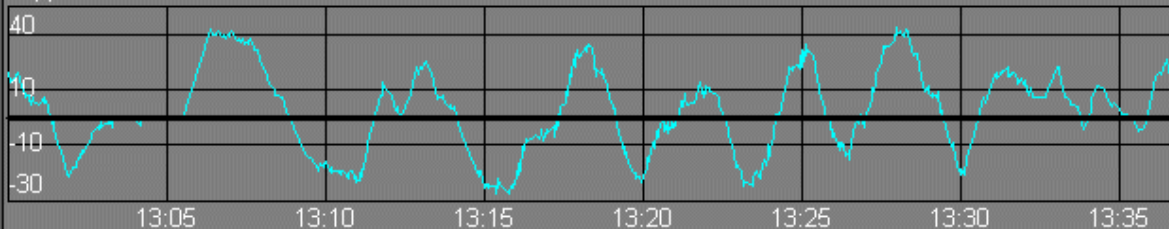
Individual Unit Data		Supplier Control Error		Control Performance	
AGC Status	Closed	AGC Set Point	183.6	CAISO P	
Actual Output	191.0	Bid Up Regulation	10.0	CAISO P	
Expected Gen.	183.6	Bid Down Regulation	-25.1	CAISO L	
Err. PGP	190.0	Bid Up Ramp Rate	6.6	CAISO C	
High Reg Limit	199.0	Bid Down Ramp Rate	6.6	CAISO I	
Low Reg Limit	165.0				

SCE 1H Avg = 6.5 mwh
SCEPerf = 45.0%
StdDevRatio = 43.4%
Correlation = 51.0%
Overall Performance
PerfMetric = 33.6%

Example - Poor Performance – Long Delay



Supplier Control Error



Individual Unit Data

AGC Status	Closed	AGC Set Point	83.0
Actual Output	86.6	Bid Up Regulation	120.0
Expected Gen.	83.0	Bid Down Regulation	-20.0
EL FCP	103.0	Bid Up Ramp Rate	38.3
High Reg Limit	223.0	Bid Down Ramp Rate	39.1
Low Reg Limit	83.0		

Supplier Control Error

SCE	3.00
SCE 10m Avg	0.27
SCE 1hr Avg	8.71

Control

CAISO P	
CAISO P	
CAISO L	
CAISO C	
CAISO I	

SCE 1H Avg = 8.7 mwh

SCEPerf = 23.1%

StdDevRatio = 90.1%

Correlation = 77.3%

Overall Performance

PerfMetric = 46.4%



Performance Metric Implementation

- Test Performance Metrics
- Develop Performance Criteria
- Incorporate Performance into Regulation Certification Tests
- Evaluate and Rank the Performance of Regulating Units
- Share Performance Metrics with Regulation Providers
- May Eventually Penalize Poor Regulation Providers

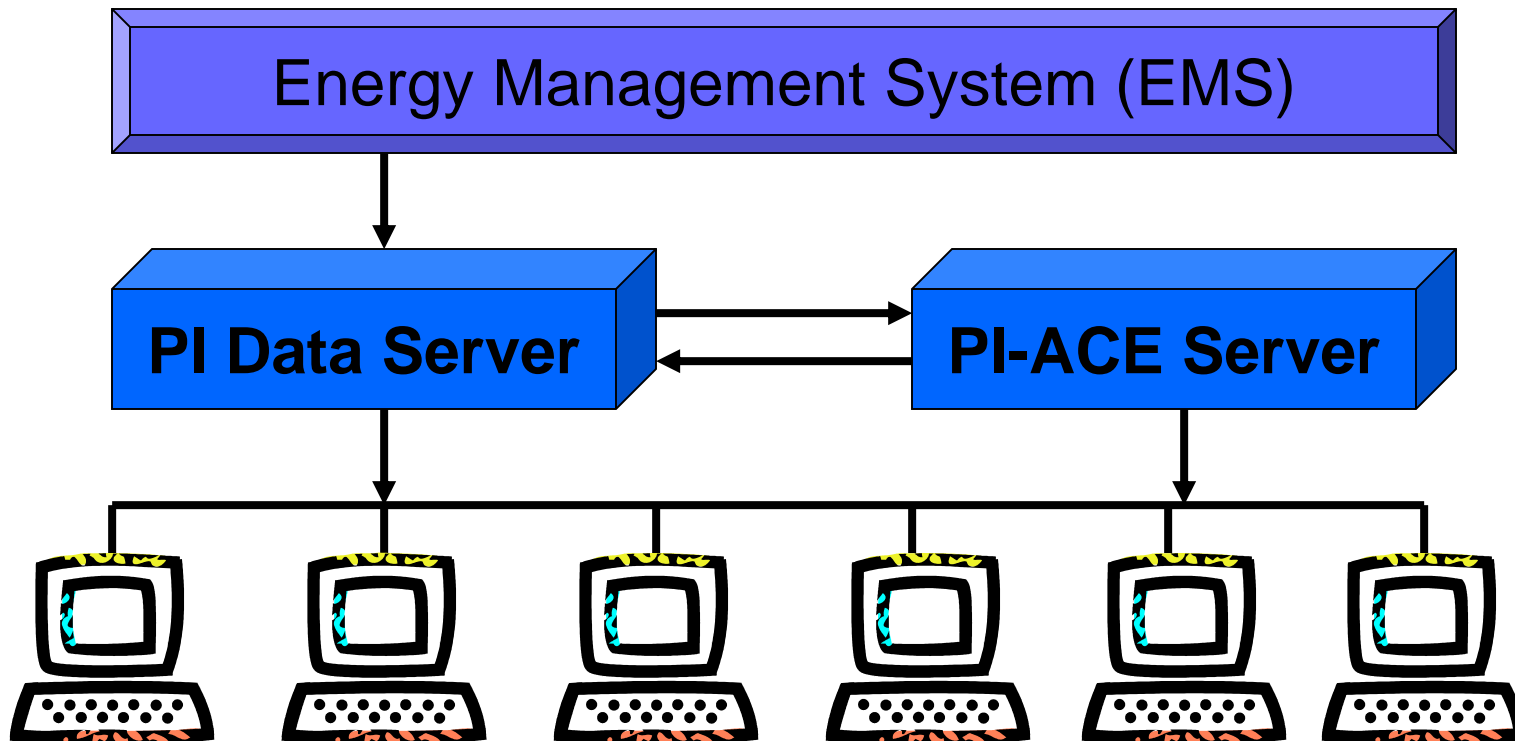


Craig Covering...

- California ISO Server Structure
 - ▲ (Data and Module Database)
- PI-ACE Tip: Adding Multiple Similar Contexts
- Our last year: Successes and Failures
- Future PI-ACE Plans

ISO PI Infrastructure

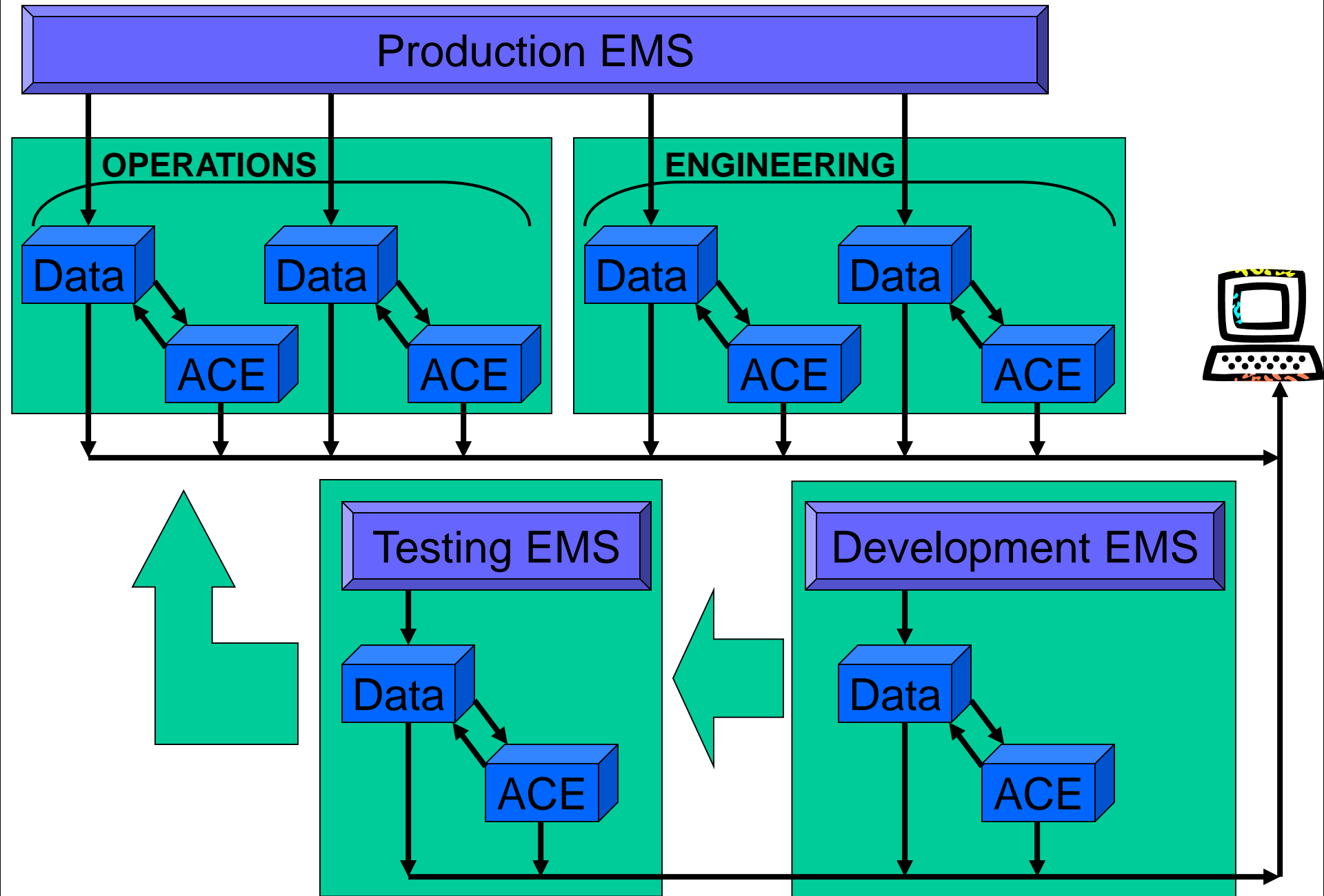
- Paired PI Data servers with PI ACE servers
- Majority of data provided via EMS
- PI-ACE Server also Provides Module Database



Server Specifications

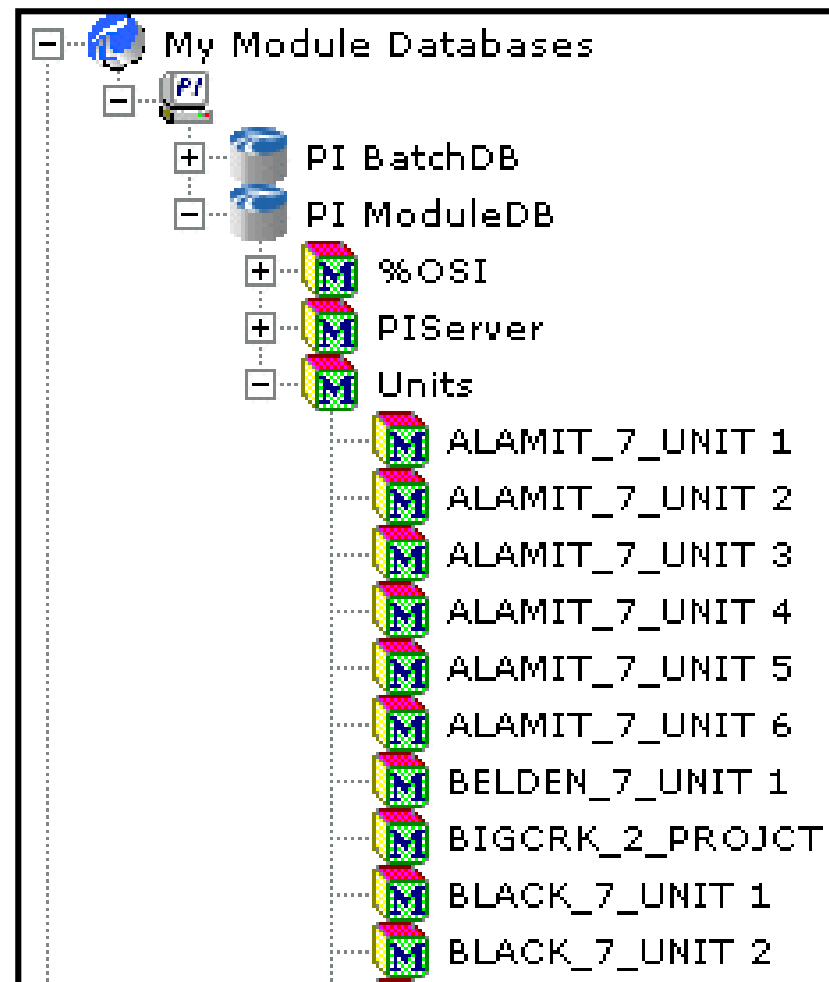
Component	PI Data Servers	PI-ACE Servers
System	HP DL 580	HP DL 380
CPU's	4 x 700Mhz	2 x 2.1 Ghz
Memory	1 Gigabytes	2 Gigabytes
Controller	Built into Mother Board	Built into Mother Board
Outside Network	100 Megabit Full Duplex	100 Megabit Full Duplex
Backup Network	FDDI	N/A
Disk Storage	HP HSG80 Controller Brocade Silkworm 2800 300 Gigabytes	2 x 18 GB Mirrored

ISO PI Infrastructure



















PI-Module Database Structure

- 94 Units on Automatic Generation Control (AGC)
- Each unit modeled in PI-Module Database



PI-Module Database Structure

- Aliases created for key Unit measurements:

Sub-Modules			PI Aliases			PI Properties		
PIAlias Name						Tag Name		
	BSEPT_GEN_MW					Effective POP for BLACK_7_UNIT 2		
	Effective High Reg Limit					Effective High Reg Limit for BLACK_7_UNIT 2		
	Effective Low Reg Limit					Effective Low Reg Limit for BLACK_7_UNIT 2		
	EFFECTIVE_POP					Effective POP for BLACK_7_UNIT 2		
	EXPECTED_GENERATION					Expected Generation for BLACK_7_UNIT 2.CV		
	HGHRG_GEN_MW					Effective High Reg Limit for BLACK_7_UNIT 2		
	LOWRG_GEN_MW					Effective Low Reg Limit for BLACK_7_UNIT 2		
	PROVIDED_REGULATION_10MIN_AVG					Provided Regulation 10min Avg for BLACK_7_UNIT 2.CV		
	PROVIDED_REGULATION_1HR_AVG					Provided Regulation 1hr Avg for BLACK_7_UNIT 2.CV		
	SCE					Supplier Control Error for BLACK_7_UNIT 2.CV		
	SCE_10MIN_AVG					Supplier Control Error 10min Avg for BLACK_7_UNIT 2.CV		
	SCE_1HR_AVG					Supplier Control Error 1hr Avg for BLACK_7_UNIT 2.CV		
	SETPT_GEN_MW					BLACK .UNIT 2 SETPT_GEN_MW7 .AV		
	SETPT_GEN_MW_Q					BLACK .UNIT 2 SETPT_GEN_MW7 .AQ		
	SYSEMSDataUpToCurrentSecond					SYSEMSDataUpToCurrentSecond.CV		
	SYSPIDATAUPTODATE					SYSPIDataUpToCurrentSecond.CV		



PI-Module Database Structure

- Aliases needed for our calculation:

Measurement	Module DB Alias
Generation	- UNMW_GEN_MW
Set Point	- SETPT_GEN_MW
On/Off AGC Control	- UAGC_GEN
Down Ramp Rate	- Unit Reg Ramp Down Rate
Up Ramp Rate	- Unit Reg Ramp Up Rate
Expected Generation	- Expected Generation
Standard Control Error	- SCE
Standard Deviation (10min)	- SCE 10min StdDev
Data Status	- SYSDataUpToCurrentSecond

PI-ACE Tip: Adding Multiple Similar Contexts

```
Dim piUnitMods As PISDK.PIModules
Dim piUnitMod As PISDK.PIModule
Dim piNamedValues As NamedValues
Dim bAddContextStatus As Boolean
```

```
For Each piUnitMod In piUnitMods
    'Set up NamedValues for context
    Set piNamedValues = New NamedValues
    piNamedValues.Add "Type", 0          'Schedule Type
    piNamedValues.Add "Offset", 0       'Offset
    piNamedValues.Add "Period", 60      'Period (seconds)
    piNamedValues.Add "Priority", 3     'Priority
    bAddContextStatus = CreatePIACEModule( _
        "\\server\ACECompliance\GenerationPerformance\" & _
        "\\localhost\Units\" & piUnitMod.Name)
    bAddContextStatus = AddPIACEContextSchedule( _
        "\\server\ACECompliance\GenerationPerformance\" & _
        "\\localhost\Units\" & piUnitMod.Name, piNamedValues)
Next
```

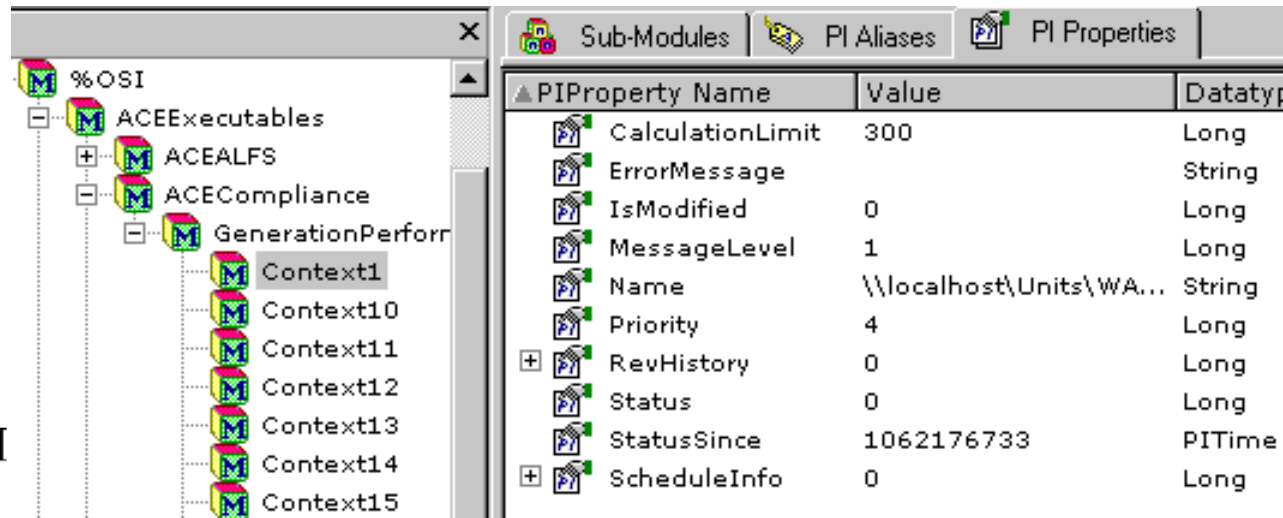


Last Year Successes

- Implemented PI-ACE server infrastructure
- Setup and started 94 calculation to monitor unit quality performance
- Monitored AGC unit performance

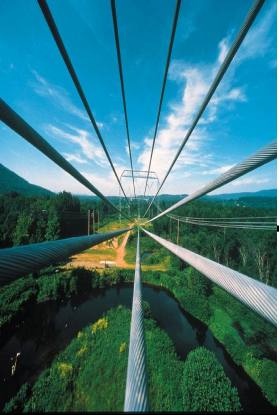
Last Years Failures and Solutions

- Calculation contexts failed and had to be re-started by hand
- Changed 2 configurations stop failures:
 - Modified and improved the ACE code
 - Increased the “CalculationLimit” ACE property from the default (5min) to 60min



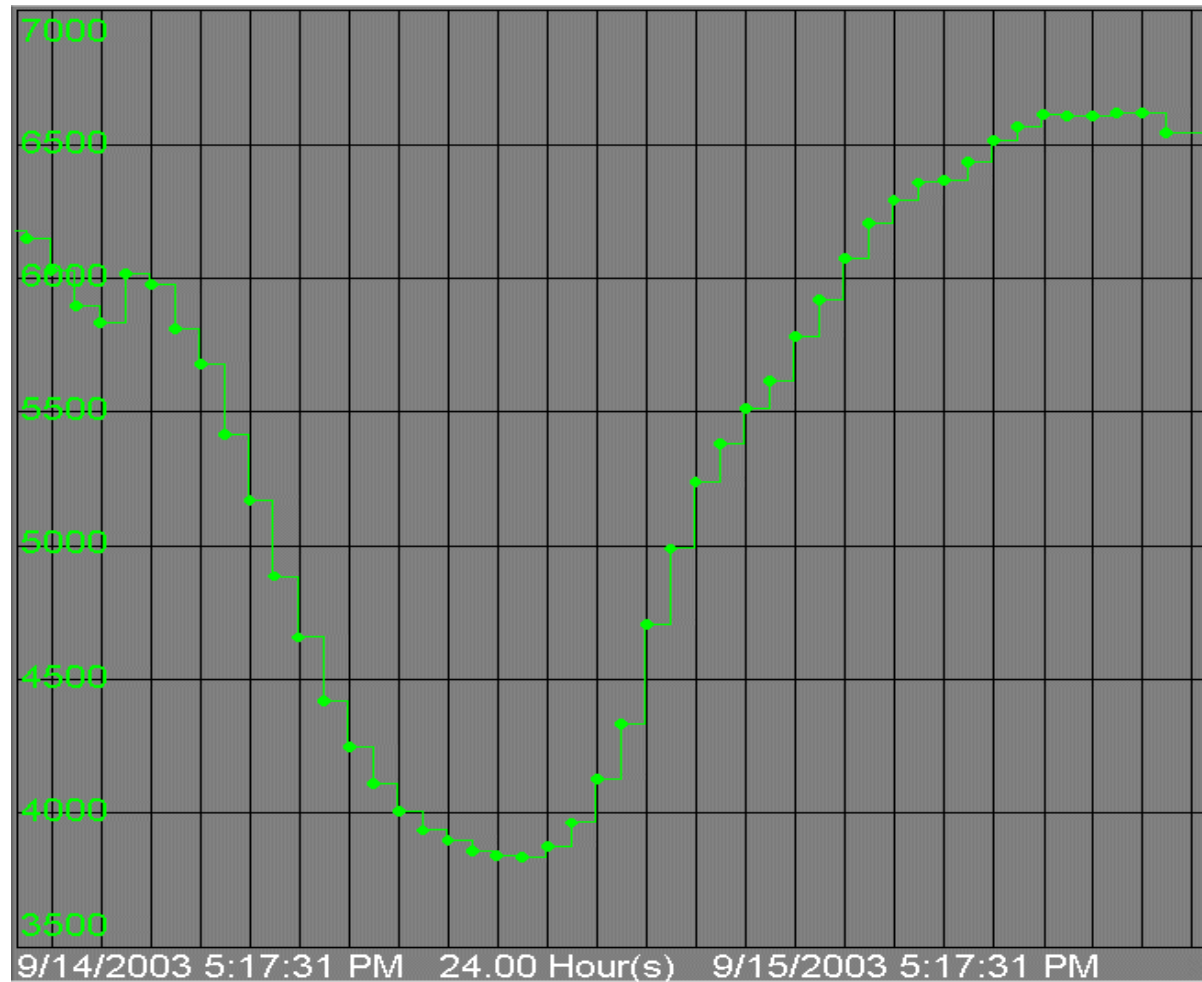
The screenshot shows a software interface with a tree view on the left and a properties table on the right. The tree view is expanded to show 'Context1' under 'GenerationPerform'. The properties table on the right lists various PI properties and their values.

PIProperty Name	Value	Datatype
CalculationLimit	300	Long
ErrorMessage		String
IsModified	0	Long
MessageLevel	1	Long
Name	\\localhost\Units\WA...	String
Priority	4	Long
RevHistory	0	Long
Status	0	Long
StatusSince	1062176733	PITime
ScheduleInfo	0	Long



Future Plans for PI-ACE

- Calculate load curves for our load forecasting
- Post results to web...





Future Plans for PI-ACE

Regulation Performance Metric

- Improve PI-ACE calculation that produces the performance metric result
- Create standard daily/hourly reports detailing AGC unit performance
- Tie the metric results into our AGC market

Discussion

