Low NOx Applications

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Power & Water Solutions

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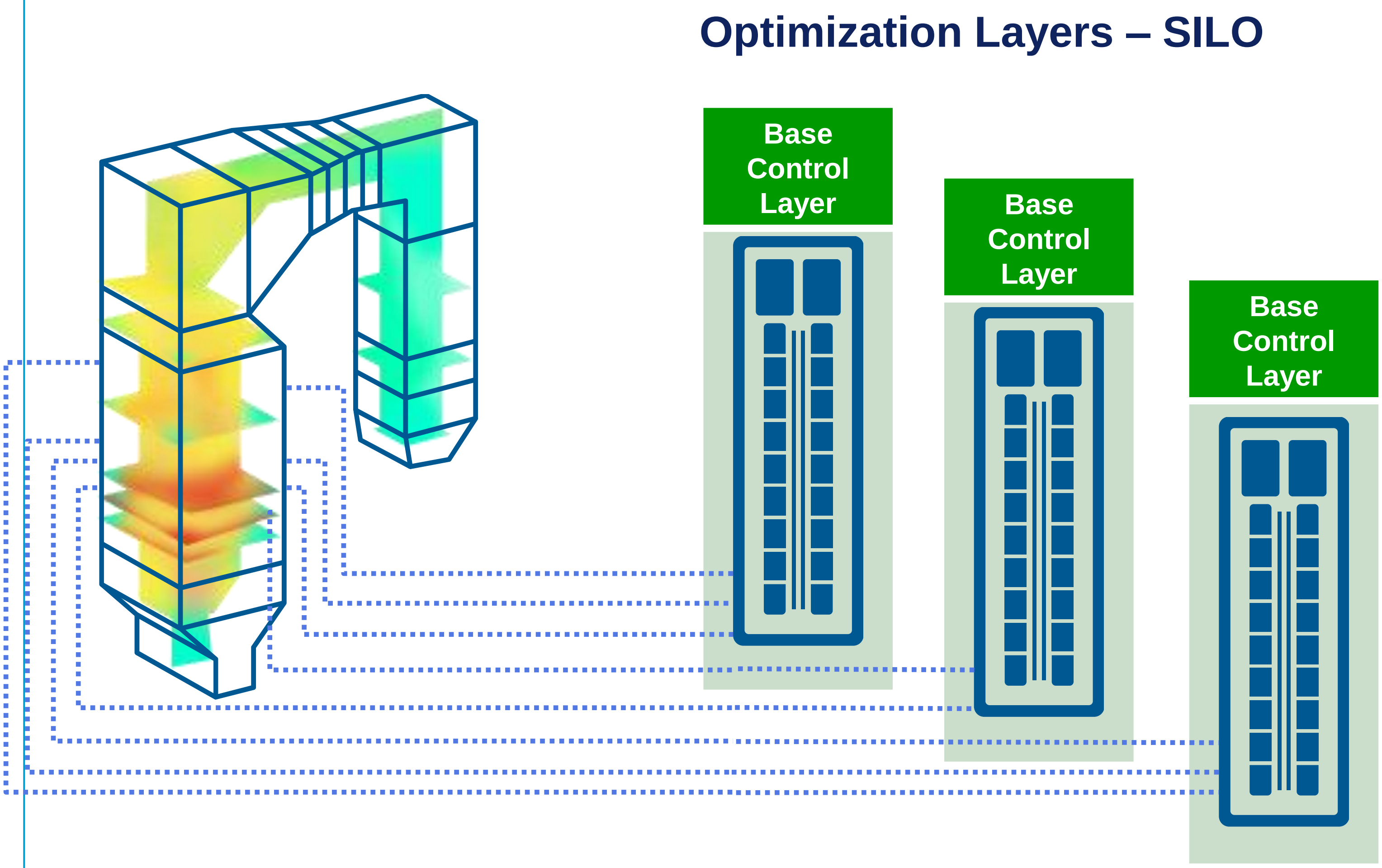
Agenda

- Overview
- SmartProcess Combustion Optimization
- Embedded Model-based Combustion Optimization
- Implementation – Projects, Customer Sites
- Case Study – Results

SILO – Optimization Layers



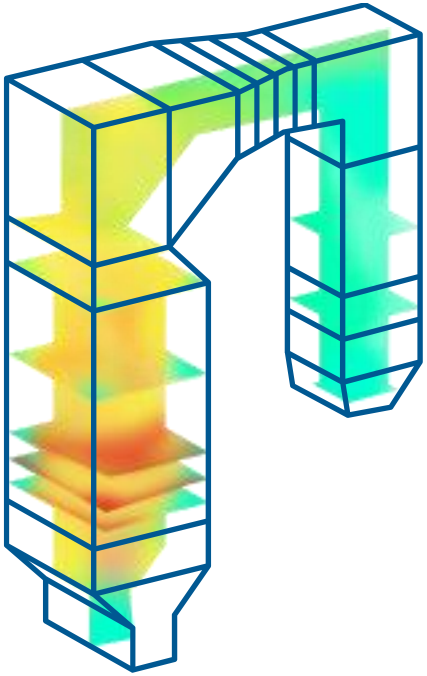
SILO – Optimization Tasks

Measured Disturbances

Boiler Load
Coal Mills
Configuration

Non-Measured Disturbances

Coal Calorific Value
Biomass Co-Firing
Quality of Mills
Grinding



Control Signals

Secondary Air
Dampers
OFA, SOFA, COFA
O_2
Coal Feeders

Control Signals

RH Steam Temperature
SH Steam Temperature
CO, NO_X, O_2 balance

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SILO vs. Other Approaches

MPC – model predictive control

- **Advantages**
  - **Dynamic MIMO model**

- **Disadvantages**
  - **Insufficient adaptation to non-stationary characteristics**
  - **High economic cost related with model creation process**
  - **Modification of production schedule due to identification experiments**
  - **Insufficient approximation of not typical process states (i.e. different fuel parameters, unusual coal mills configuration)**

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SILO vs. Other Approaches

SILO

- Advantages
  - Knowledge gathering in on-line and off-line modes

  - Efficient adaptation mechanism inspired by operation of immune system

  Feature : SILO II is able to adapt to different operating points and it is able to follow changes of the process characteristics. Thus the SILO performance is high in wide range of process operating points.

  - Extended run time of SILO system

  Feature : The customer saves money on re-tuning the optimization software and has more flexibility in plant revisions.

  - No need for model creation process:
  - No identification experiments
  - No inefficient process operation
  - No need to change the production schedule of the plant

  Feature : There are no off dispatch times needed for identification experiments.

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SILO vs. Other Approaches

- **Advantages**
  - **Easy modification of optimization task structure**

Feature : The customer does not have to pay for changing the structure of the optimization and has more flexibility plant revisions

  - **Approximation of static process characteristic is more accurate**

Feature : SILO uses higher number of signals and more narrow ranges of values of these signals to define the process sub-space in which the linear process approximation is automatically performed

  - **Optional utilization of expert knowledge**

Feature : Some expert knowledge about the process can be implemented even if this knowledge is fuzzy and not precise

- **Disadvantages**
  - **MPC controllers can be applied for processes where the process dynamic is crucial. Execution and optimization times are typically in the seconds time vs 5-15 seconds for higher level algorithms**

Summary – Case Study

We Energies Valley

93.7 % system utilization for over 7 years

23.7 % decrease in excess oxygen

12% sustained NOx reduction

10% reduction in desuperheater spray flow

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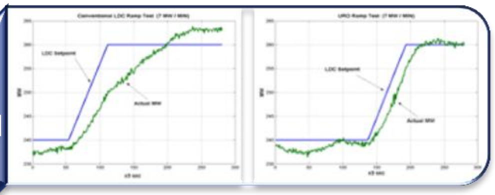
Ovation Model-based Applications

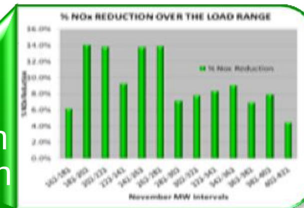
Ovation Model-based Applications

Load Demand Optimization



Market Demand Incremental Revenue Gains of $250,000+

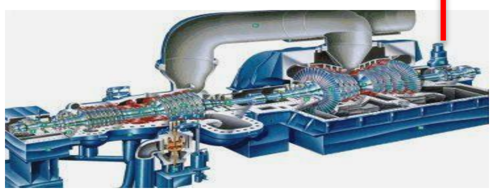
Combustion Optimization

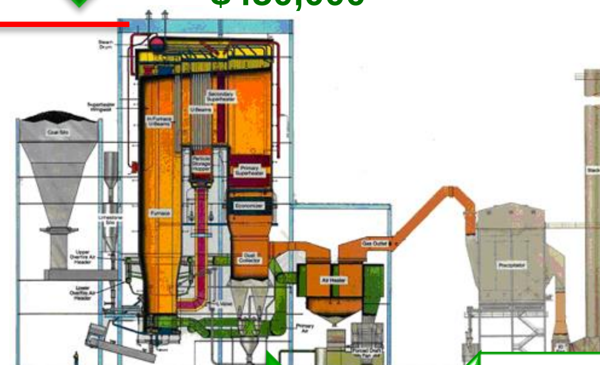


CO2 Reduction of 1-2% or 100,000 tons

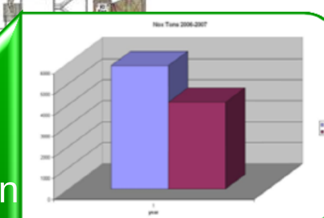
Heat Rate -100 BTU/ kwh

Fuel Savings $450,000



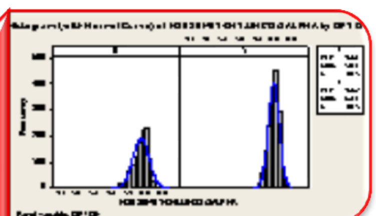


SCR Optimization



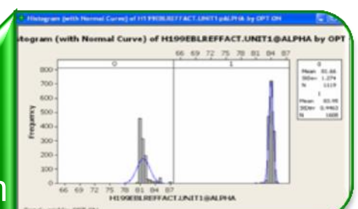
Ammonia reduction $100,000

Steam Temp. Optimization



Reduced Tube Leaks – EFOR reductions $250,000

Sootblower Optimization



Efficiency Gains 1-2% or $600,000

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Old Way - Control Optimization

Old Way (Black Box)

- **Worked with high availability**
- **Box on network (cyber security issue)**
- **Hardware / media converters / disk drives**
- **Multiple programs / OS issues**
- **Documents not perfect**
- **3rd Party parts / software**
- **Support / response can be less than ideal**
- **Updating/ patching a concern in today's cyber secure IT architectures**

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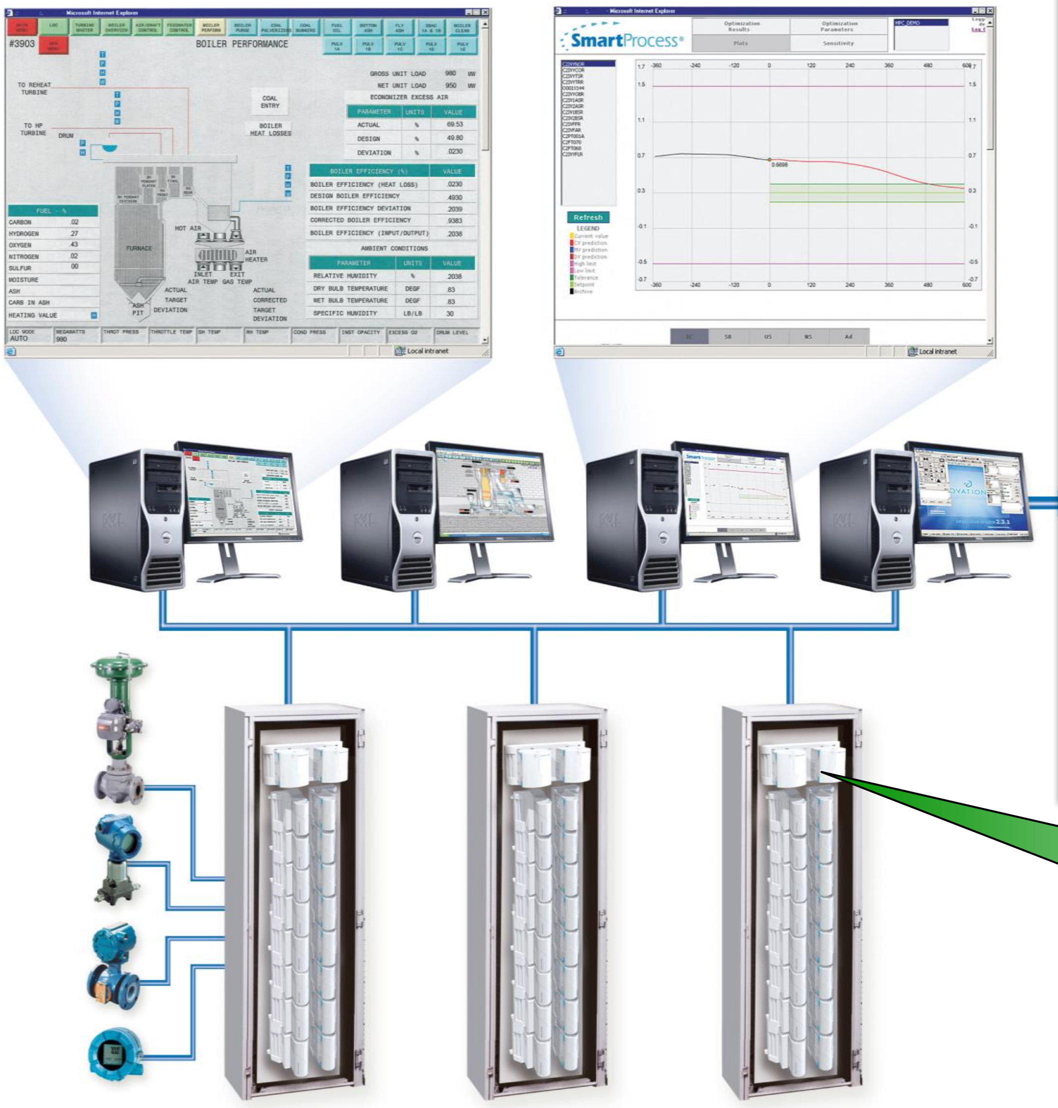
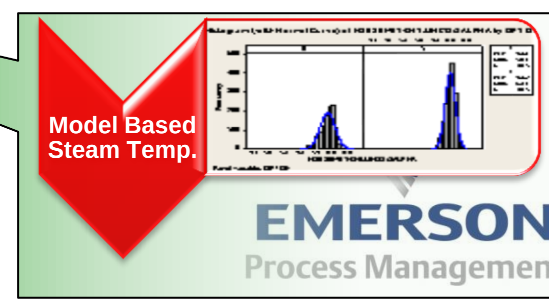
New Way – Embedded Model Based Control



Ovation Model-Based Approach

- ***Integrated-works with highest availability***
  - **Embedded in Ovation Red Controller (Redundant)**
- ***WYSIWYG***
  - **Control Builder advanced edit functions**
- ***Documentation***
  - **Algorithms in APC Manual**
- ***System Documentation***
  - **Easy to track sheets / revisions to logic**
- ***Training flexibility***
- ***Emerson Solution** - by Emerson*
- ***SureService 24/7 –** support by Emerson*



Ovation Model-based Applications – Embedded DMC

- What is DMC?
  - DMC is dynamic matrix control
  - DMC belongs to the MPC (model predictive control) class of algorithms
  - Ovation APC algorithm (Embedded, no 3rd party box)
- How is DMC used?
  - A control model is formulated using Control Variables (CVs), Manipulated Variables (MVs), and Disturbance Variables (DVs).
  - A model is created from step-response testing
  - Based on the model, the CVs prediction is computed using a horizon calculation function

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Ovation Model-based Applications – Embedded DMC

- Advanced Process Control (APC) Toolkit – DMC Algorithm
  - Model Based
  - Output is Step Response
  - NO PIDs
  - Proactive
  - Used for controlling error (PV vs. SP)
  - Disturbance Immunity

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Ovation Embedded Combustion Optimization

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Ovation Model-based Applications – Combustion Optimization (OPT)

- Status –Beta Tests complete
- Lowering NOx while controlling CO
- Balanced O2
- Proper Combustion

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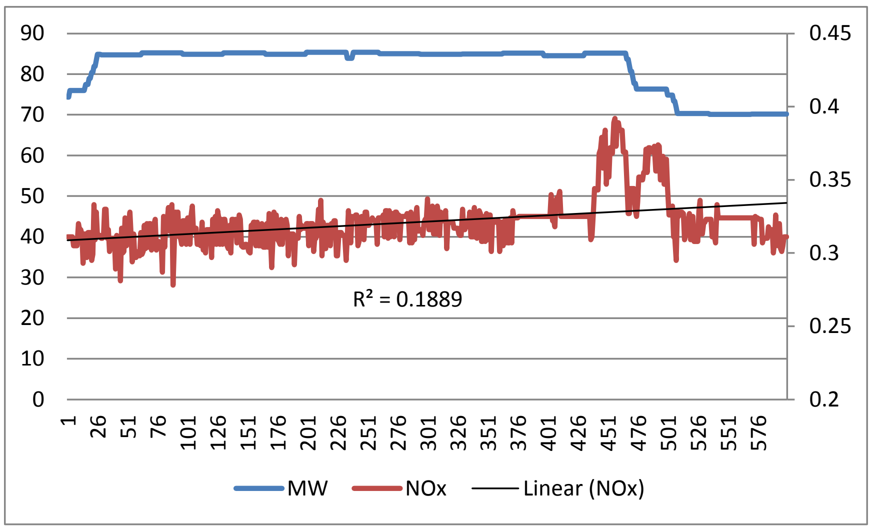
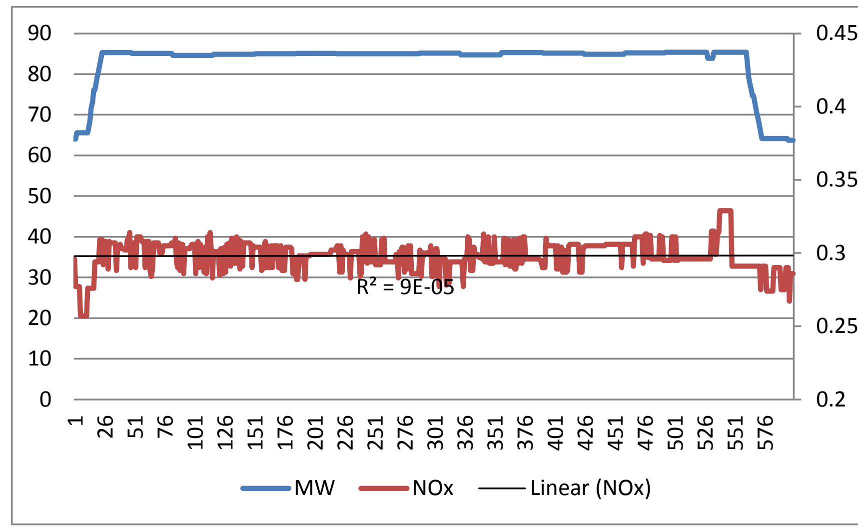
Old vs New

- Combustion optimization
- **Ovation Model-based combustion**





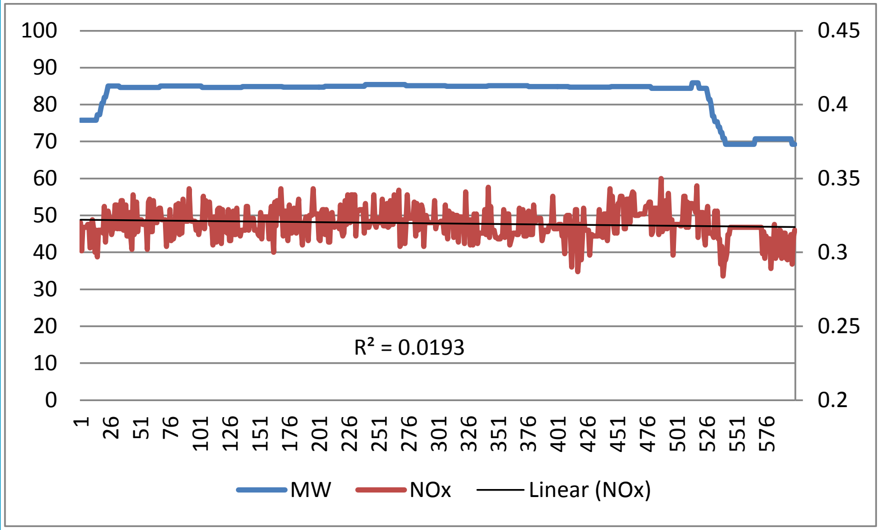
.321 Average NOx

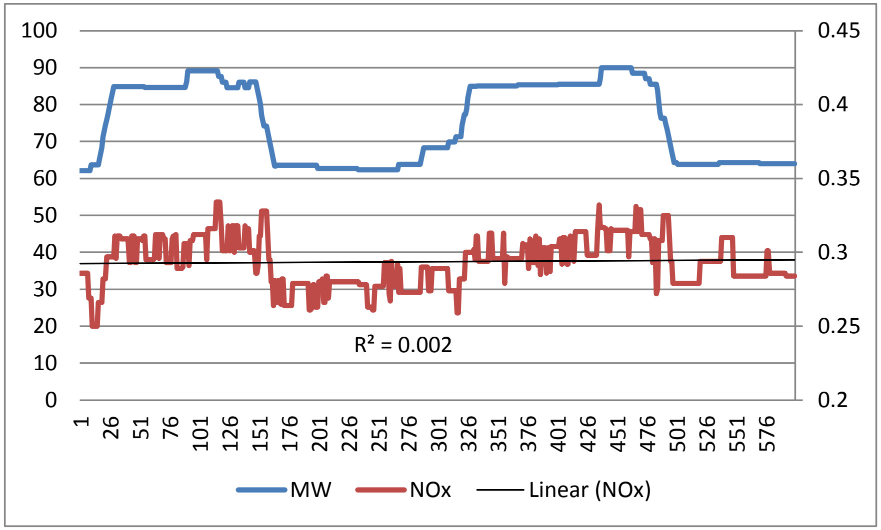
.29 Average NOx

9%
Improvement

Old vs New 3

- Combustion optimization
- **Ovation Model-based combustion**





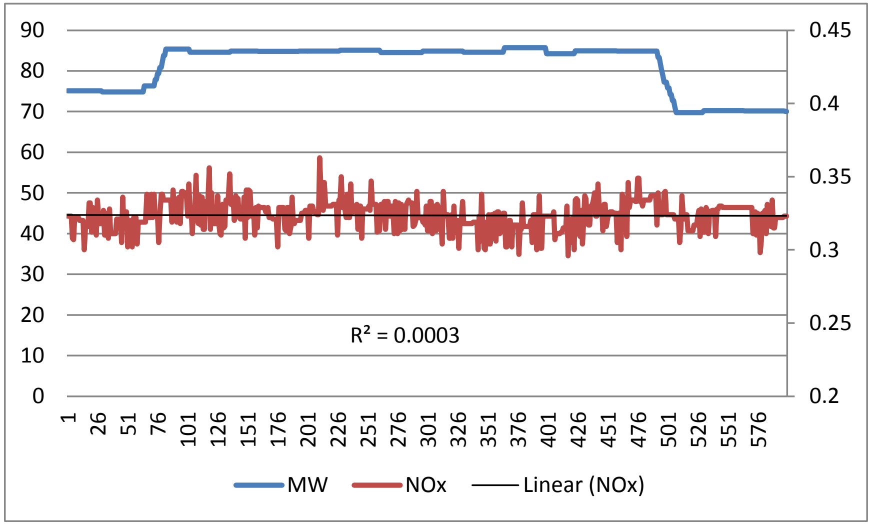
.319 Average NOx

.29 Average NOx

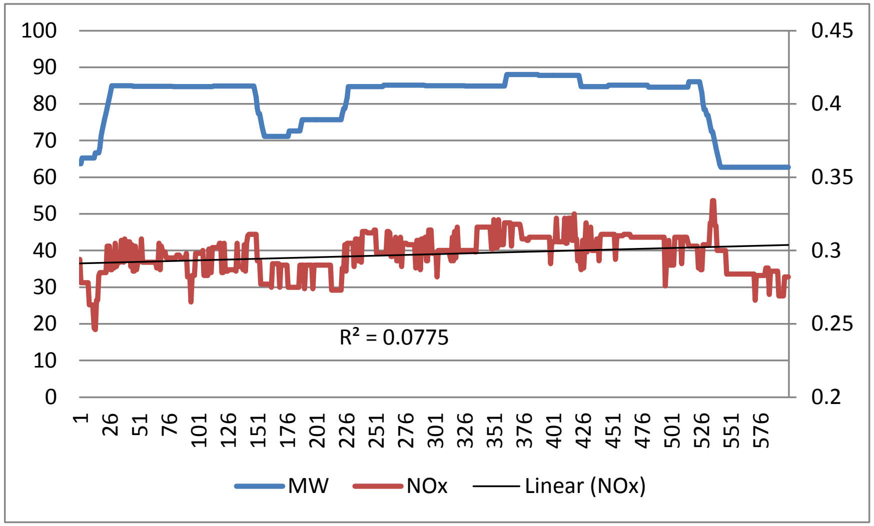
9%
Improvement

Old vs New 4

- Combustion optimization
- **Ovation Model-based combustion**



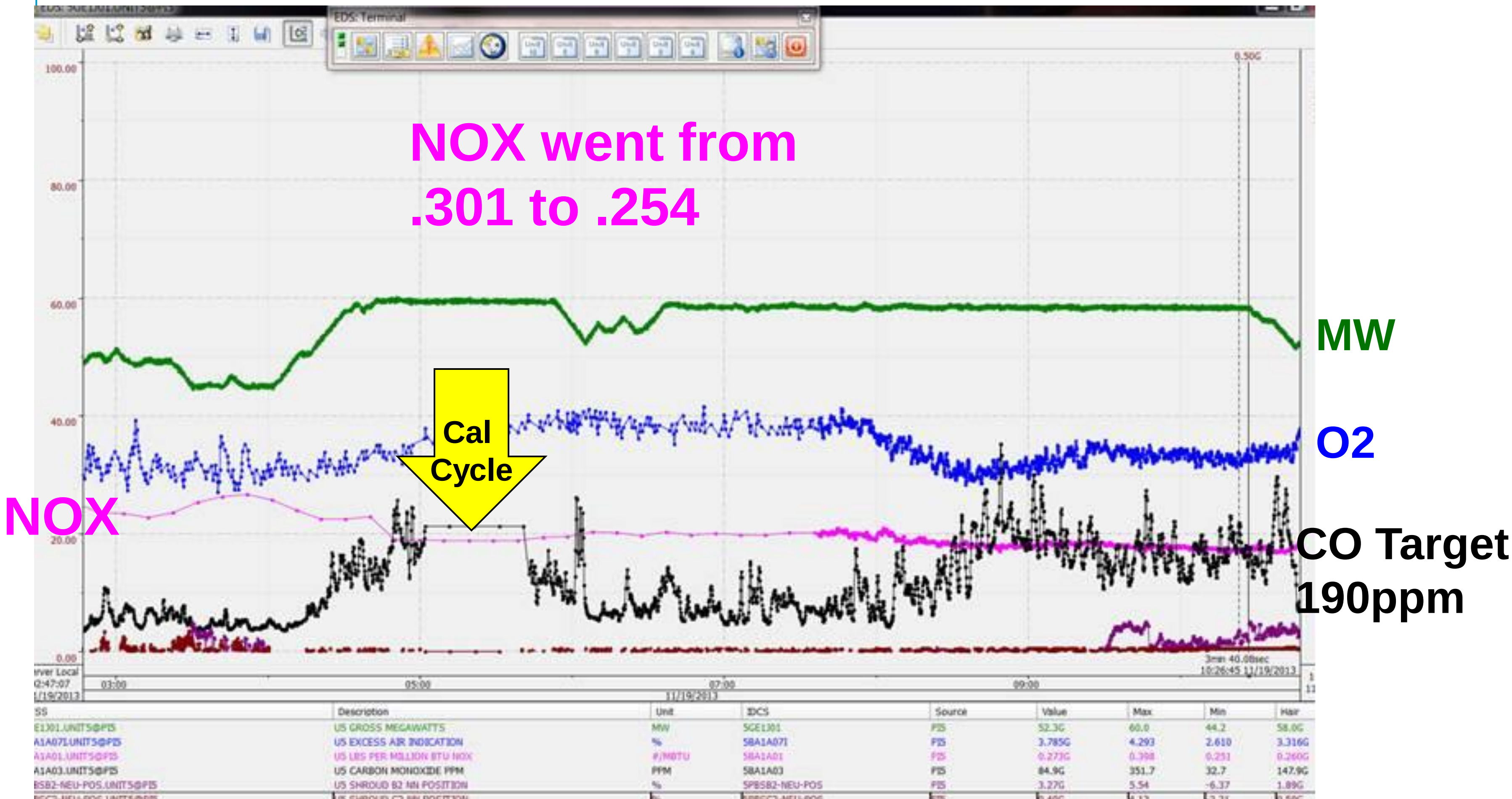
.324 Average NOx



.297 Average NOx

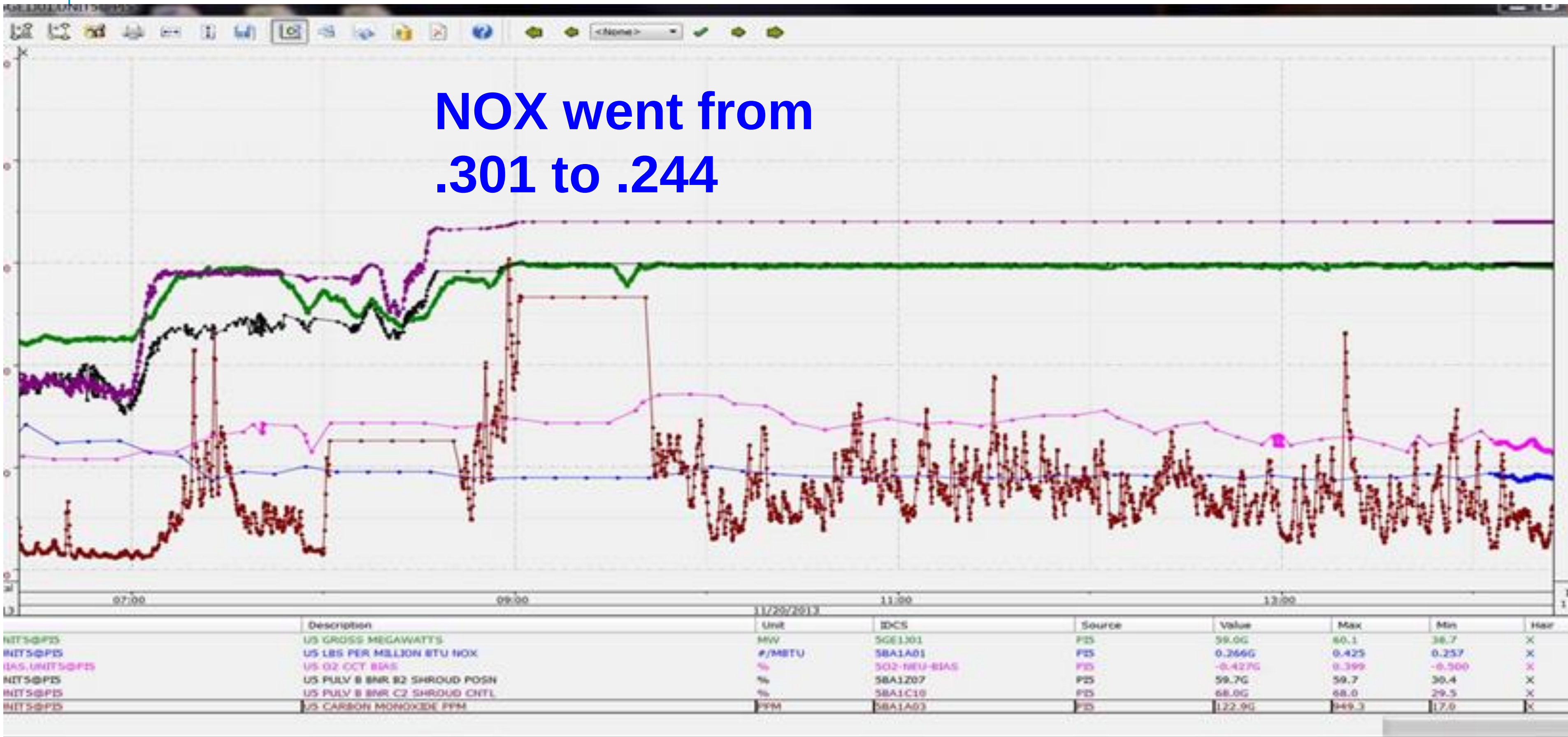
8%
Improvement

Implementation Results



15% Improvement !

Implementation 2



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Pleasant Prairie Power Plant (P4)

- **2x 617 MW units**
- **1190 Net MW**
  - **Unit 1 is a 1980 Riley Turbo-fire boiler and GE turbine**
  - **Unit 2 is a 1985 Riley Turbo-fire boiler and GE turbine**
  - **Power Magazine Coal Fired Top Plant in 2007**

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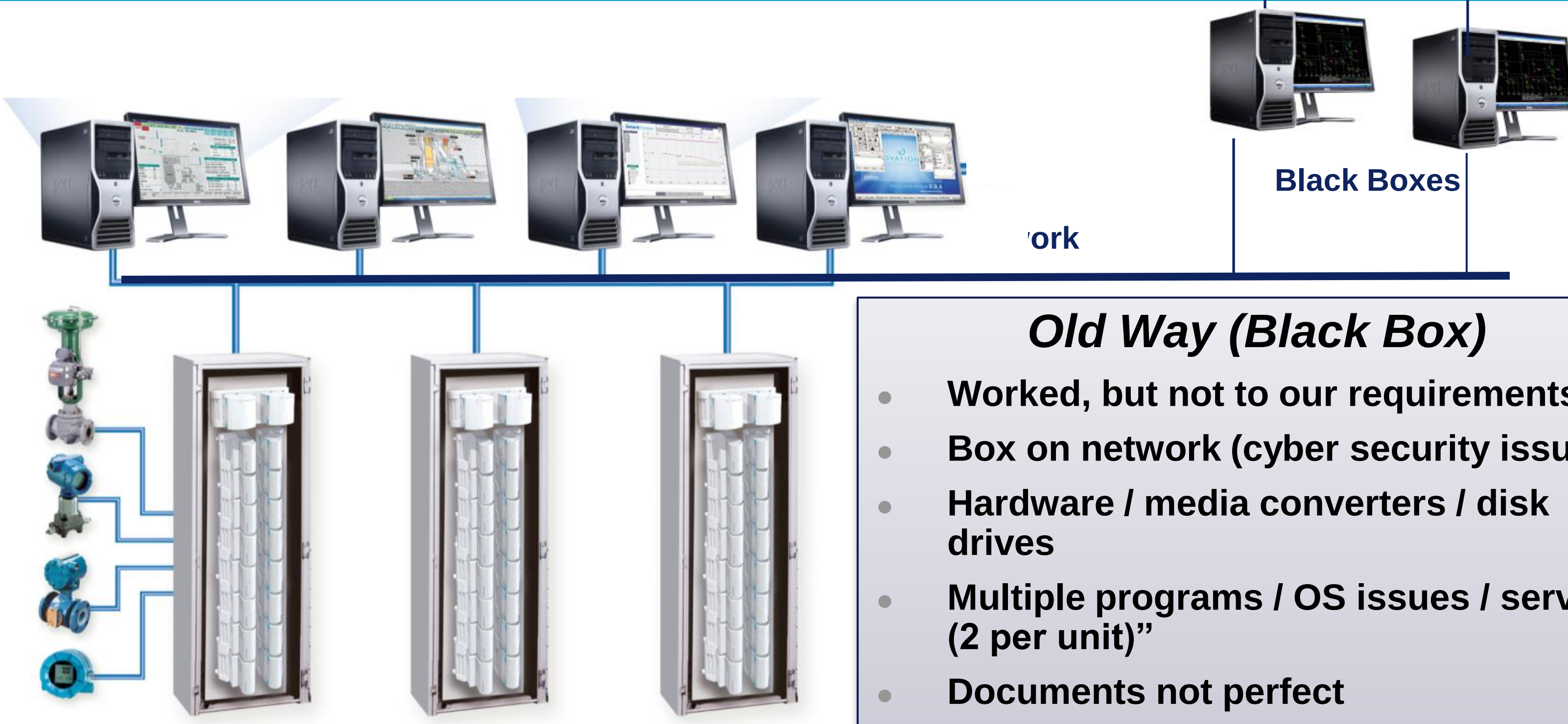
Old Way – NOx Optimization



Old Way (Black Box)

- Worked, but not to our requirements
- Box on network (cyber security issue)
- Hardware / media converters / disk drives
- Multiple programs / OS issues / servers (2 per unit)”
- Documents not perfect
- 3rd Party parts / software
- Support / response can be less than ideal
- Updating/ patching a concern in today’s cyber secure IT architectures

Problems With 3rd Party System

- No in house expertise or ability to make changes
- System was controlled/configured remotely
- No buy in by control operators
  - Lost confidence in the system
  - System turned off most of the time!

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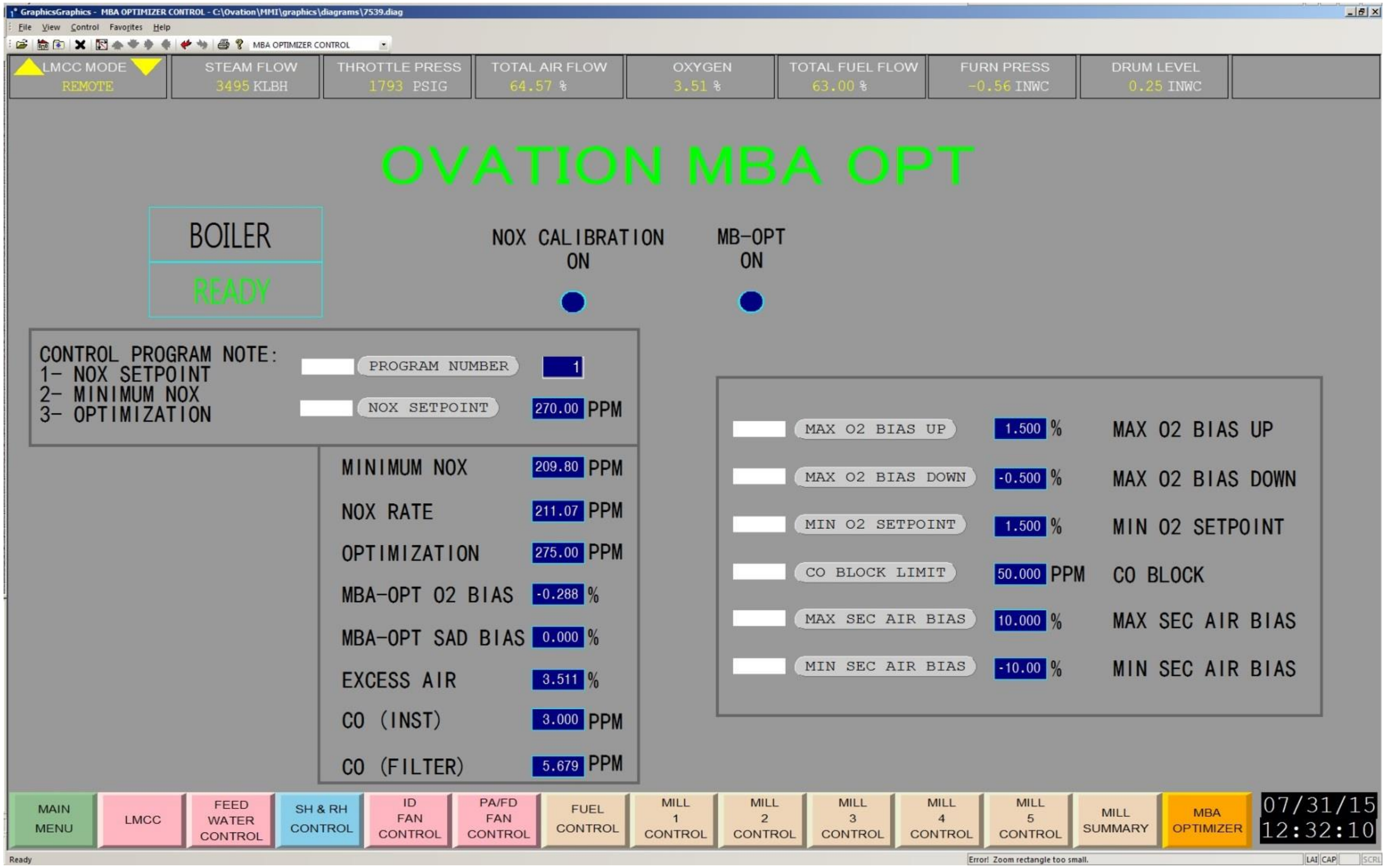
Operator View



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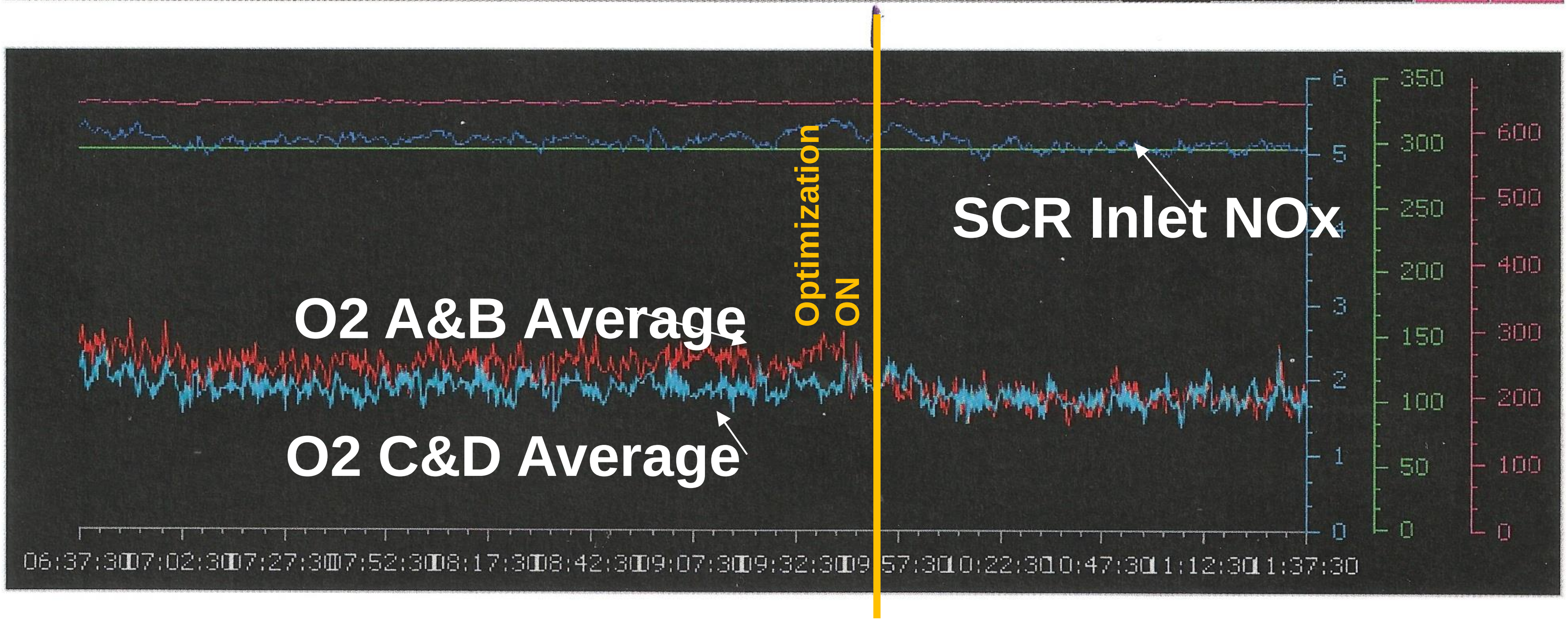
Results to Date
Closed-loop Test at High Load

Start Time : 04/16/2015 06:37:30
End Time : 04/16/2015 11:37:30

	G	Point Name	Historian	Description	End Value	Units	S	Low S	High S
1	☑	(A) 20BA0040.UNIT2@PPPP2	Auto Historian	FLUE GAS O2 A&B AVG	1.612	%	☑	0	6
2	☑	(A) 20BA0041.UNIT2@PPPP2	Auto Historian	FLUE GAS O2 C&D AVG	1.605	%	☑	0	6
3	☑	(A) 2MBA_DMCNOX_SP.UNIT2@PPP	Auto Historian	@ Ovation Control Builder @	295.000		☑	-1	350
4	☑	(A) U2-SCRIN-NOX-AVG.UNIT2@PPP	Auto Historian	@ Ovation Control Builder @	298.909		☑	-1	350
5	☑	(A) 20MPJ004.UNIT2@PPPP2	Auto Historian	GENERATOR 2 GROSS MW	641	MW	☑	-1	680

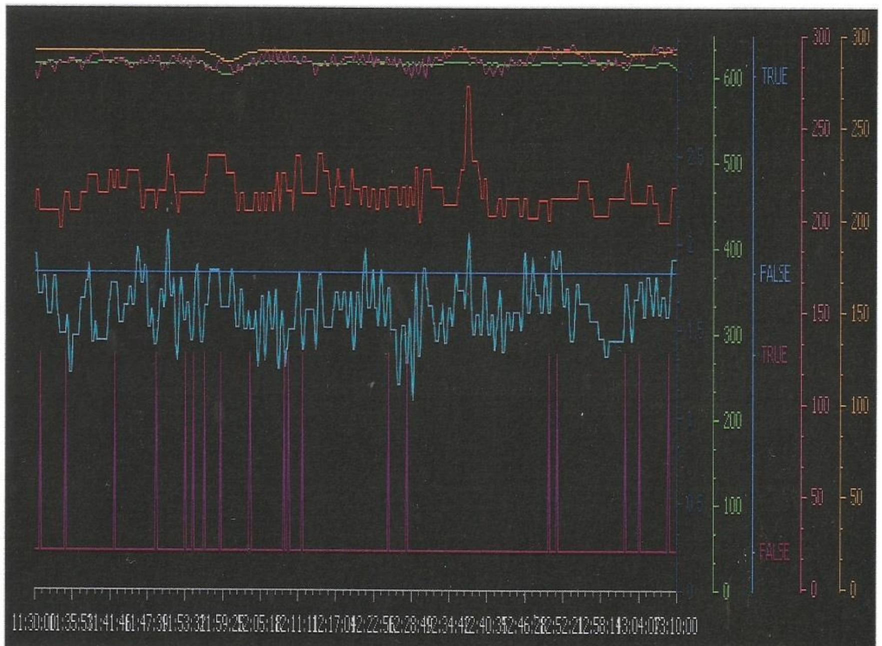


Results #3 O2 balance

Start Time : 06/04/2015 11:30:00
End Time : 06/04/2015 13:10:00

Before

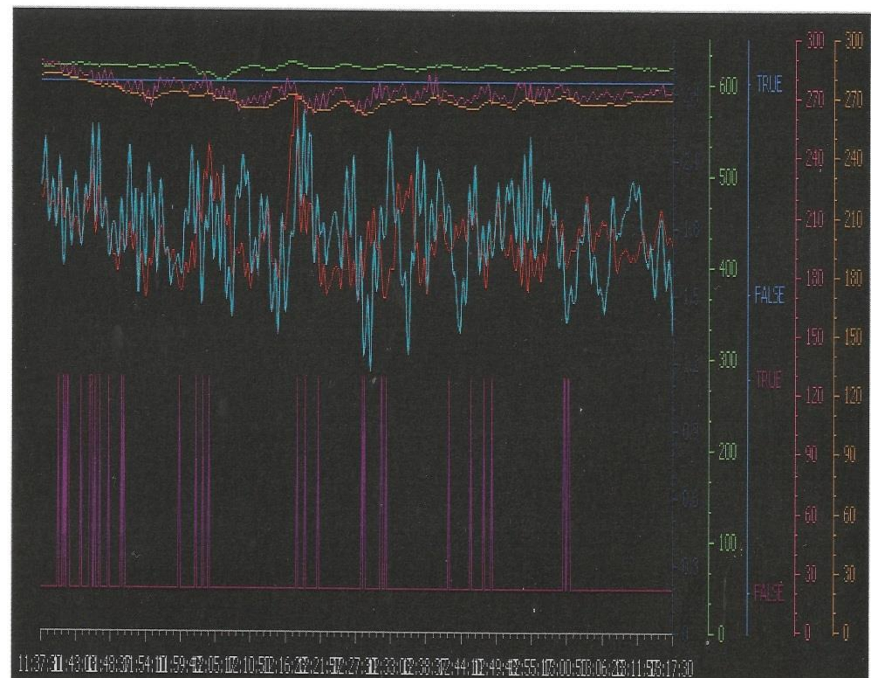
	G	Point Name	Historian	Processing	Description	End Value	Units	S	Low Scale	High Sc
1	✓	(A) 20BA0040.UNIT2@PPPP2	Auto Historian	Actual	FLUE GAS O2 A&B AVG	2.330	%	✓	0	[illegible]
2	✓	(A) 20BA0041.UNIT2@PPPP2	Auto Historian	Actual	FLUE GAS O2 C&D AVG	1.904	%	✓	0	[illegible]
3	✓	(A) 20MPJ004.UNIT2@PPPP2	Auto Historian	Actual	GENERATOR 2 GROSS MW	612	MW	✓	0	650
4	✓	(A) 2MBA_OPT_ON.UNIT2@PPPP2	Auto Historian	Actual	@ Ovation Control Builder @	FALSE 0		✓	FALSE	TRUE
5	✓	(A) U2-SCRIN-NOX-AVG.UNIT2@PPPP2	Auto Historian	Actual	@ Ovation Control Builder @	293.238		✓	-1	300
6	✓	(A) 2MBA_DMCNOX_SP.UNIT2@PPPP2	Auto Historian	Actual	@ Ovation Control Builder @	290.302		✓	-1	300
7	✓	(A) U2_FLAME_LOW.UNIT2@PPPP2	Auto Historian	Actual	@ Ovation Control Builder @	FALSE 0		✓	FALSE	TRUE



Start Time : 06/10/2015 11:37:30
End Time : 06/10/2015 13:17:30

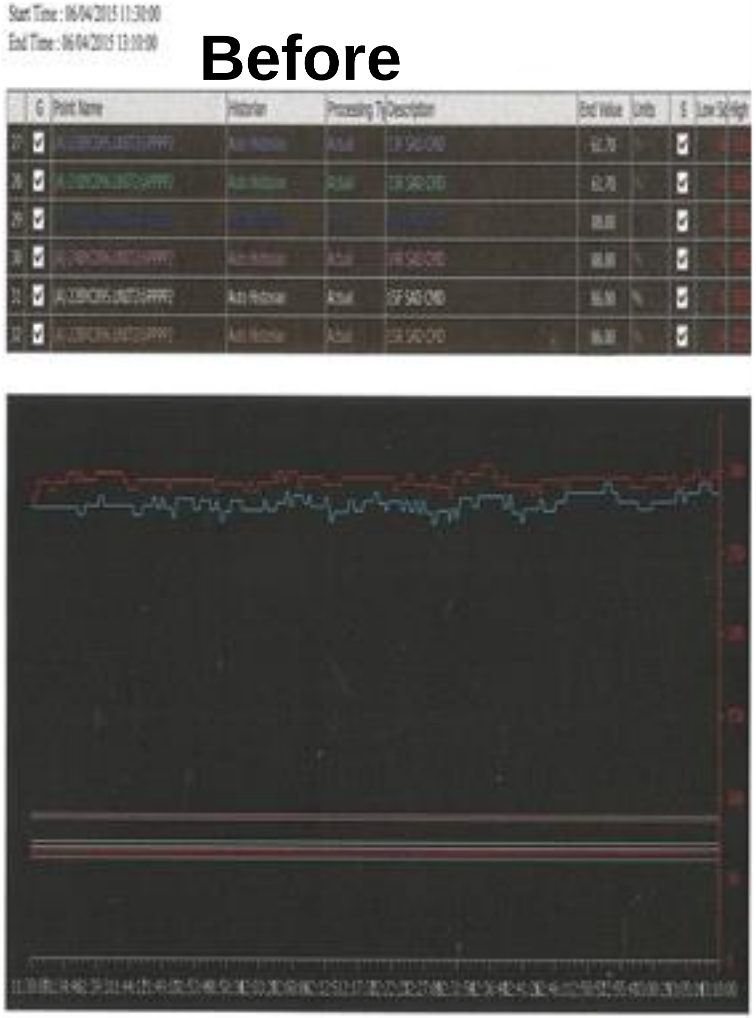
After

	G	Point Name	Historian	Description	End Value	Units	S	Low Scale	High Sc
1	✓	(A) 20BA0040.UNIT2@PPPP2	Auto Historian	FLUE GAS O2 A&B AVG	1.713	%	✓	0	[illegible]
2	✓	(A) 20BA0041.UNIT2@PPPP2	Auto Historian	FLUE GAS O2 C&D AVG	1.305	%	✓	0	[illegible]
3	✓	(A) 20MPJ004.UNIT2@PPPP2	Auto Historian	GENERATOR 2 GROSS MW	621	MW	✓	0	650
4	✓	(A) 2MBA_OPT_ON.UNIT2@PPPP2	Auto Historian	@ Ovation Control Builder @	TRUE 1		✓	FALSE	TRUE
5	✓	(A) U2-SCRIN-NOX-AVG.UNIT2@PPPP2	Auto Historian	@ Ovation Control Builder @	274.596		✓	-1	300
6	✓	(A) 2MBA_DMCNOX_SP.UNIT2@PPPP2	Auto Historian	@ Ovation Control Builder @	268.853		✓	-1	300
7	✓	(A) U2_FLAME_LOW.UNIT2@PPPP2	Auto Historian	@ Ovation Control Builder @	FALSE 0		✓	FALSE	TRUE

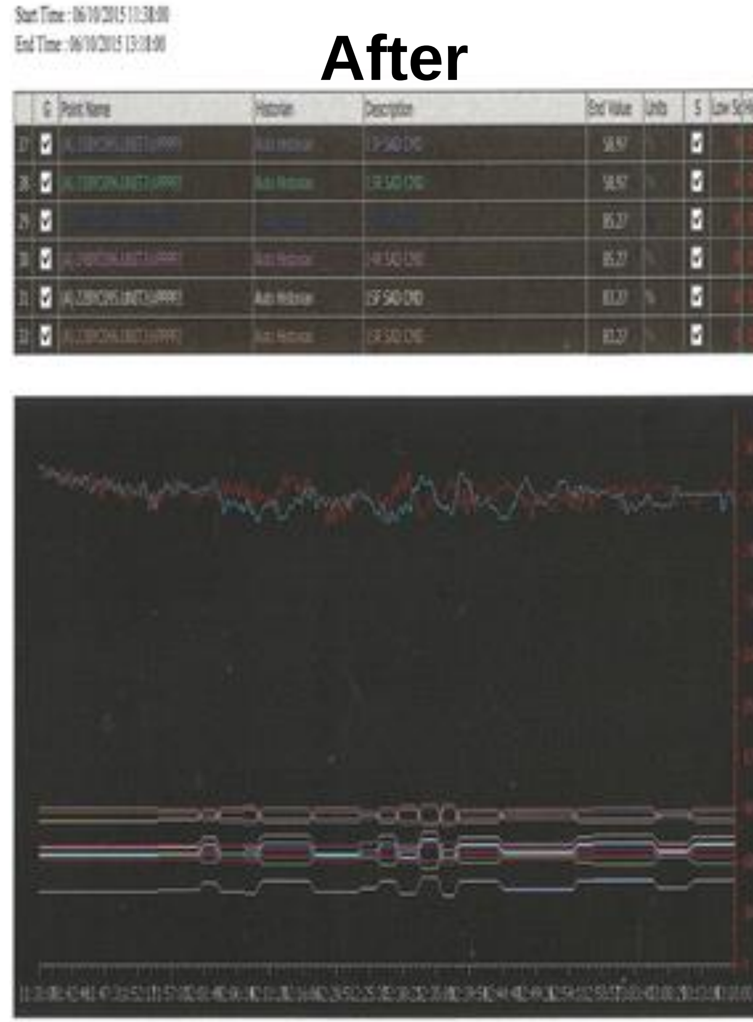


Results #3 SCR inlet NOx

Before



After



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