ΔE3 Boiler Combustion Optimization System
ΔE3 锅炉燃烧优化系统

Applying Artificial Intelligence, Advanced Control, and Optimization Technologies In Coal Fired Generating Units

应用神经网络，先进控制理论和优化技术于燃煤机组

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Pegasus Technologies, Inc

飞马技术公司

Leaders in Combustion Optimization for the Power Industry

Pegasus Technologies

- **Headquarters in Ohio, USA 总部设于美国俄亥俄州**
- **Globally established 世界各地设有分支机构**
  - **North America 北美**
  - **Asia 亚洲**
  - **Europe 欧洲**
- **Experienced Staff for Power Market由丰富电力行业经验的人员组成**
  - **Engineers: Combustion, Advanced Controls, IT 燃烧工程师，先进控制工程师，计算机工程师**

Power Generating Unit
发电机组

- Complex System, Consists of many sub-system 系统复杂, 包括多个子系统
  - Air/Fuel/Gas 风烟/燃煤
  - Steam Cycle 蒸汽循环
  - BOP
- Hundreds of pieces of Equipment make up these systems 这些系统由众多设备组合而成

Current DCS System
当前DCS控制系统现状

- Efficiently Control the Unit 有效地控制机组
- Doing Good in Managing Safety Interlocks and Operating Sequence 对安全闭锁及运行顺序有良好的管理

- Based mainly on Feedback Controls 基本以PID返馈控制为主
- Inherently Single Input/Single Output 本质上是单一输入单一输出

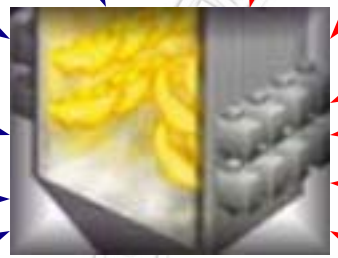
Keeping Unit at Optimal Condition Is a Complex Task

维持机组时刻在最优化的工况是一个复杂的任务

- Coupling Among Various Parameters
  各参量的联关
- Unmeasured Disturbances 未测量的干扰量
- Transients 时刻存在的动态过程
- Nonlinearities 系统的非线性

Combustion Dynamics 动态的燃烧过程

The Complex Relationships of Multiple Variables That Are Continuously Changing …
Dramatically Impact Combustion 复杂多元的关系不断变化… 动态地影影响燃烧过程



Superheat and Reheat Temp.
过热和再热温度

Furnace DP
炉膛差压

SA Temp. and Flow
二次风温度和流量

Flue Gas NOx
烟气氮化物

PA Temp. and Flow
二次风温度和流量

Excess O_2
过氧

Different Operators
不同的运行人员

Instruments Failure / Drift
仪表误差/偏移

Equipment Conditions
设备状况

Weather 天气状况

Humidity 湿度

Quality/Type of Coal
燃煤质量/种类

Atmospheric Conditions
大气状况

Burner Tilts (T-Fired)
燃烧器摆角(四角切元机组)

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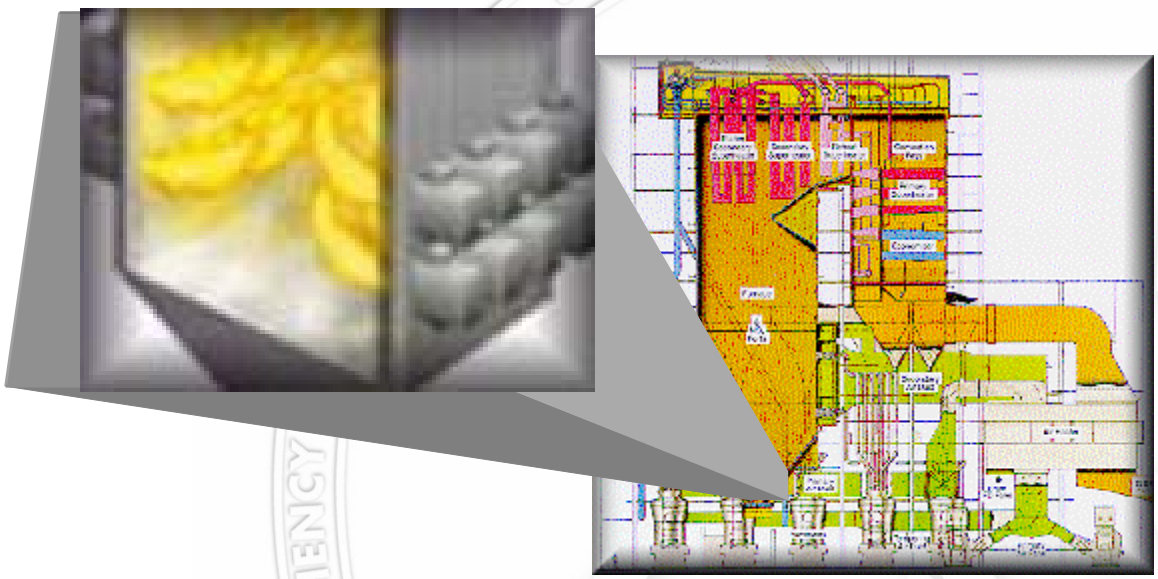
Multiple Objectives 多项目标

Combustion is Continuously Optimized Based On Changing Plant Conditions and your *Unit Specific Operation Objectives*...

燃烧优化是根据*机组*运行情况和指标 对燃烧状况不断的优化调整...

NOx 氮氧化物
Heat Rate 热耗
Capacity 设备能力
Opacity 浊度
LOI 飞灰含碳
Steam Temperatures 汽度
？？



Objectives can be weighted for different seasonal operations.

多项目标相对重要性可因应季节加权调整

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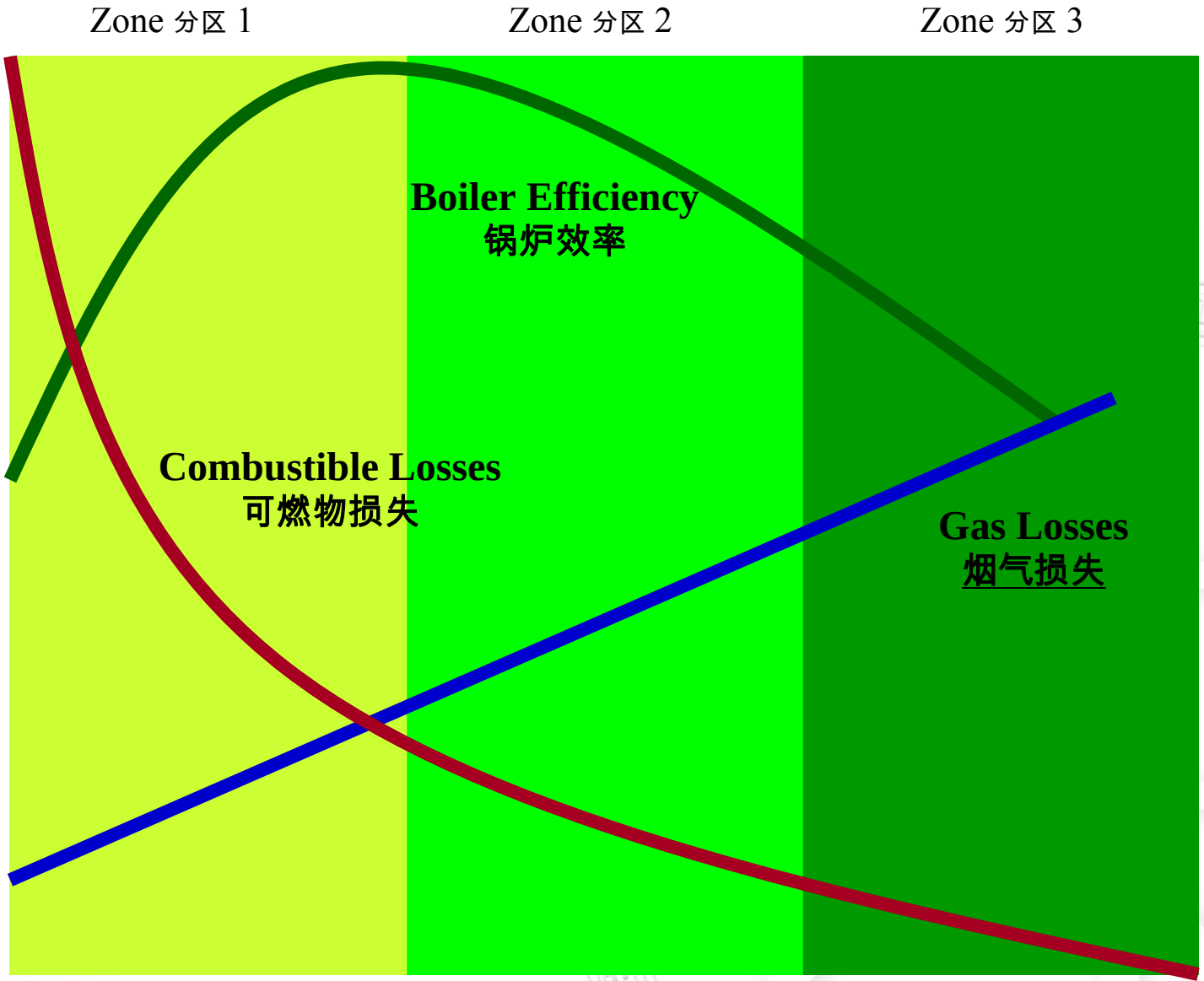
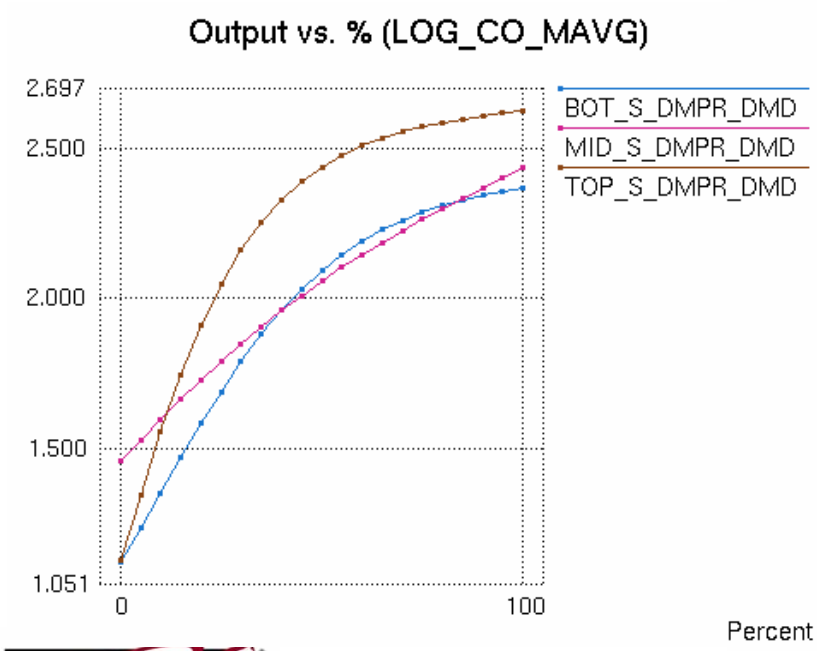
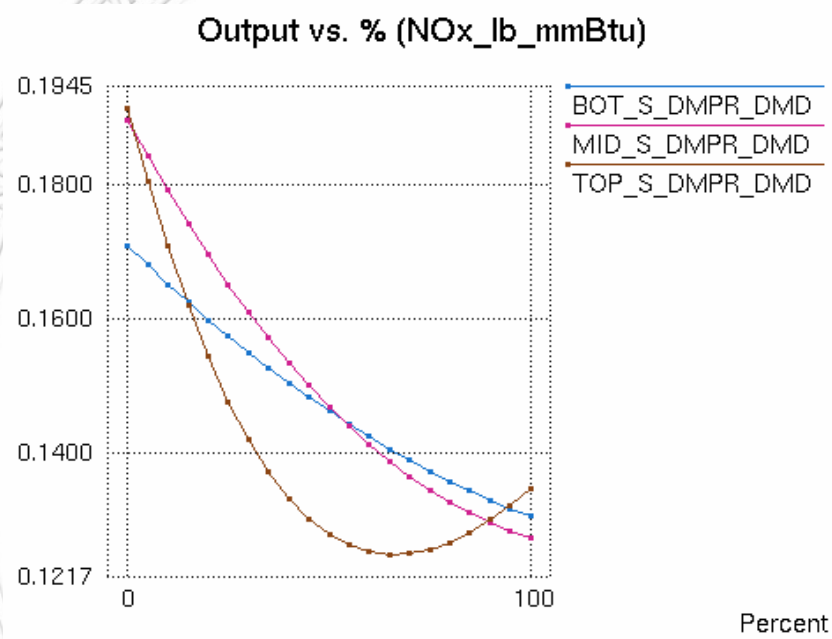


Power Plant Process - Example
变量关系例子

The following are NOx and CO responses with respect to each of the SOFA Dampers at a specific Windbox/Furnace DP. 以下是氮化物和一氧化碳于分离式过燃风挡板在特定风箱/炉膛差压下的关系。





Pegasus Combustion Optimization Technology

Pegasus 燃烧优化技术

Specially Designed to Optimize Power Plants

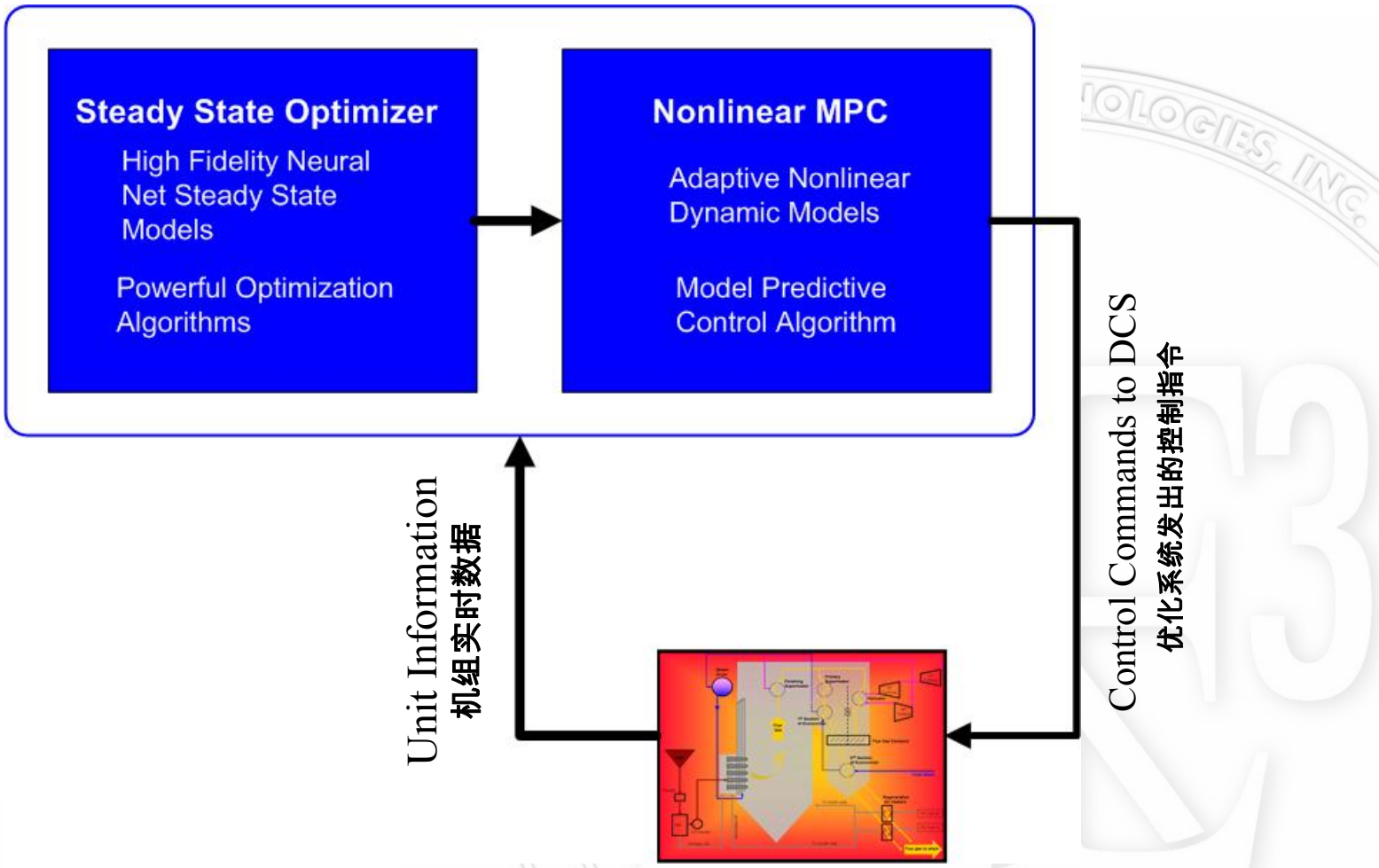
特别为电厂最优化而设计

Intelligent systems can be utilized to control the plant for 智能系统可用于电厂以控制以下方面

- Reduced Coal Consumption 减少燃煤耗
- Reduced Environmental Emissions (NOx, SO2, CO2) 减少环保排放 (NOx, SO2, CO2)
- Ash (C content, heat absorption, slag, fouling) 灰渣成分 (含碳量，热吸收，结渣，结垢)
- Fuel (quality, blending) 煤质控制 (质量， 混合)
- Reduction of Equipment Failures / Unplanned Outages 减少设备故障及非计划停机
- Sootblower (sequencing, optimization) 吹灰 (程序， 优化)

Optimum Benefit through Closed-Loop Operation通过闭环控制取最大效益

ΔE^3 Boiler Optimization
ΔE^3 锅炉优化系统



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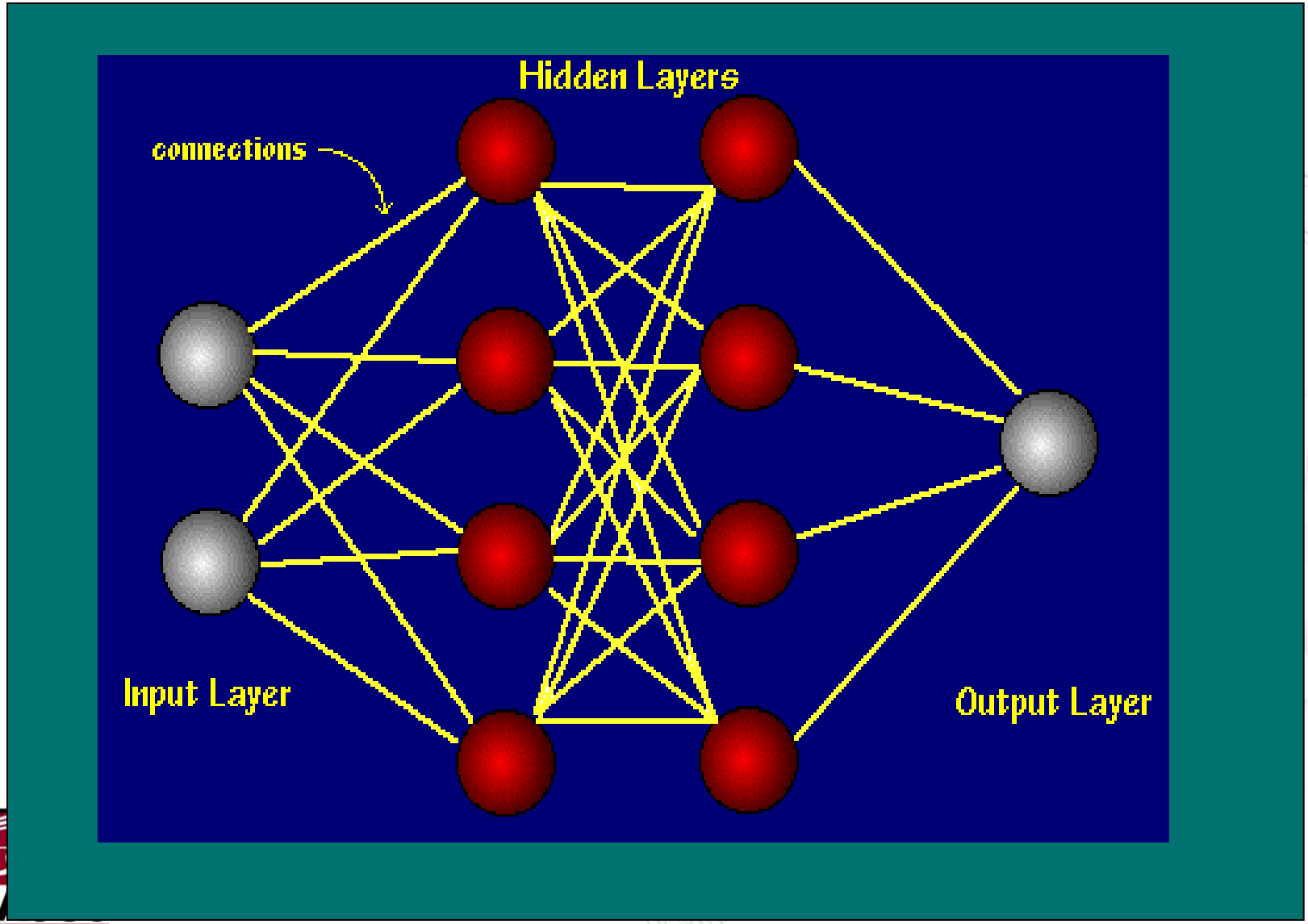
Neural Networks 神经网络

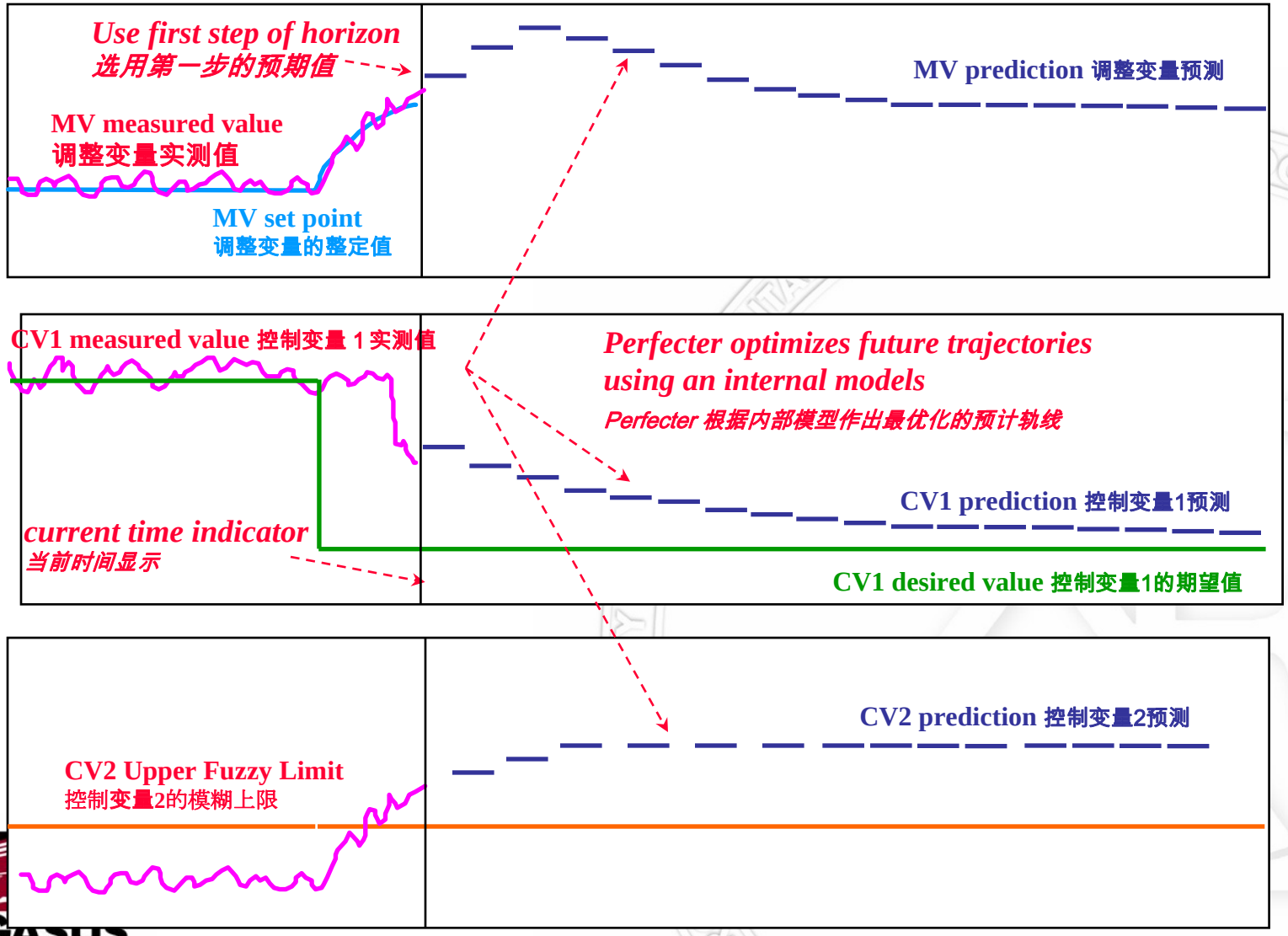
Main Features of Neural Net :神经网络主要特点：

- **Very Powerful Universal Approximating Modeling Tool**
  强大的和适用对象及广的数据建模工具
- **Strong Abilities to Capture Non-Linear Relationships**
  及强的对付非线性数据建模能力
- **F to Model Complex (multi-dimensional) relationships**
  适用于建立从简单（1维，线性〕到 复杂 (多维，非线性)模型

Artificial Neural Networks 神经网络



Model Predictive Control 模型化的预测性控制



Combustion Optimization Challenge
燃烧优化的挑战

- **To achieve the optimal combustion model - the system manages and analyzes up to 1500 or more inputs** 达至优选的燃烧模型 - 系统处理和分析多达一千五百多个的输入点
- **The system accurately models the complex interrelationships among 5-60 controllable parameters** 精确地塑造五至六十个机组变量的复杂关系模型
- **Optimization occurs within constraints of the operating environment** 优化计算绝对遵守操作规程
- **The system responds to changing environmental and operational conditions** 系统对运行环境和设备状况变化作出优化反应

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Pegasus Solution for Dynamic Optimization

Pegasus 动态过程优化系统

- Pegasus's Proven Dynamic Systems

  Pegasus以经过许多实际应用验证：

  - **Model are developed for optimization at various loads and conditions**
    建立高质量模型以用于各种符荷下的燃烧优化控制
  - **Model Predictive Control technology to control the unit at optimal condition on a continuous bases 使用预测性优化控制的技术保证燃烧在最优状况**
  - **System will learn and adapt to new conditions and find new solutions for optimized results 系统会自我调整以适应机组工况变化**
  - **Global optimization for improved control of operating conditions**
    系统会寻找范围内最优点，而不是满足于局部优化点

  Note: Retraining still required for Major control or boiler modifications
  注: 在重大控制或锅炉更改后,模型仍需再行培训

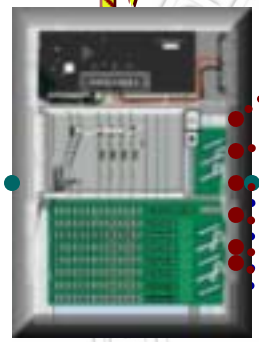
Pegasus Closed-Loop 闭环控制

Up to 1500 Current Inputs From DCS Continuously Collected and Analyzed
对高达一千五百个分控系统的现时输入点,作连续采集和分析

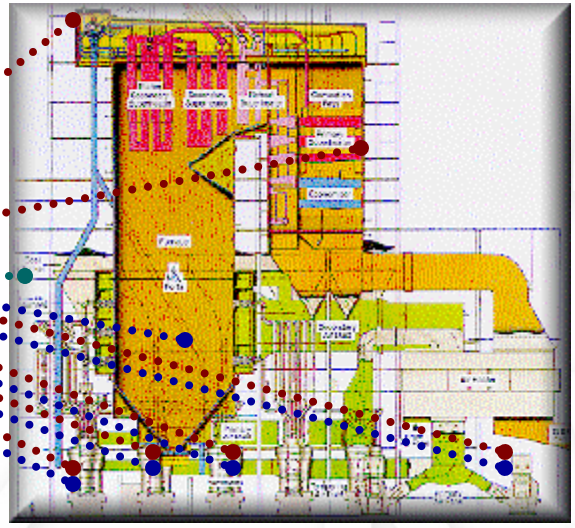
Pegasus Computer

5-60 Manipulated Output Settings Sent To DCS on Fixed Interval
按照需求,五至六十个控制值,送达DCS

Control Room Operator
控制室工作人员



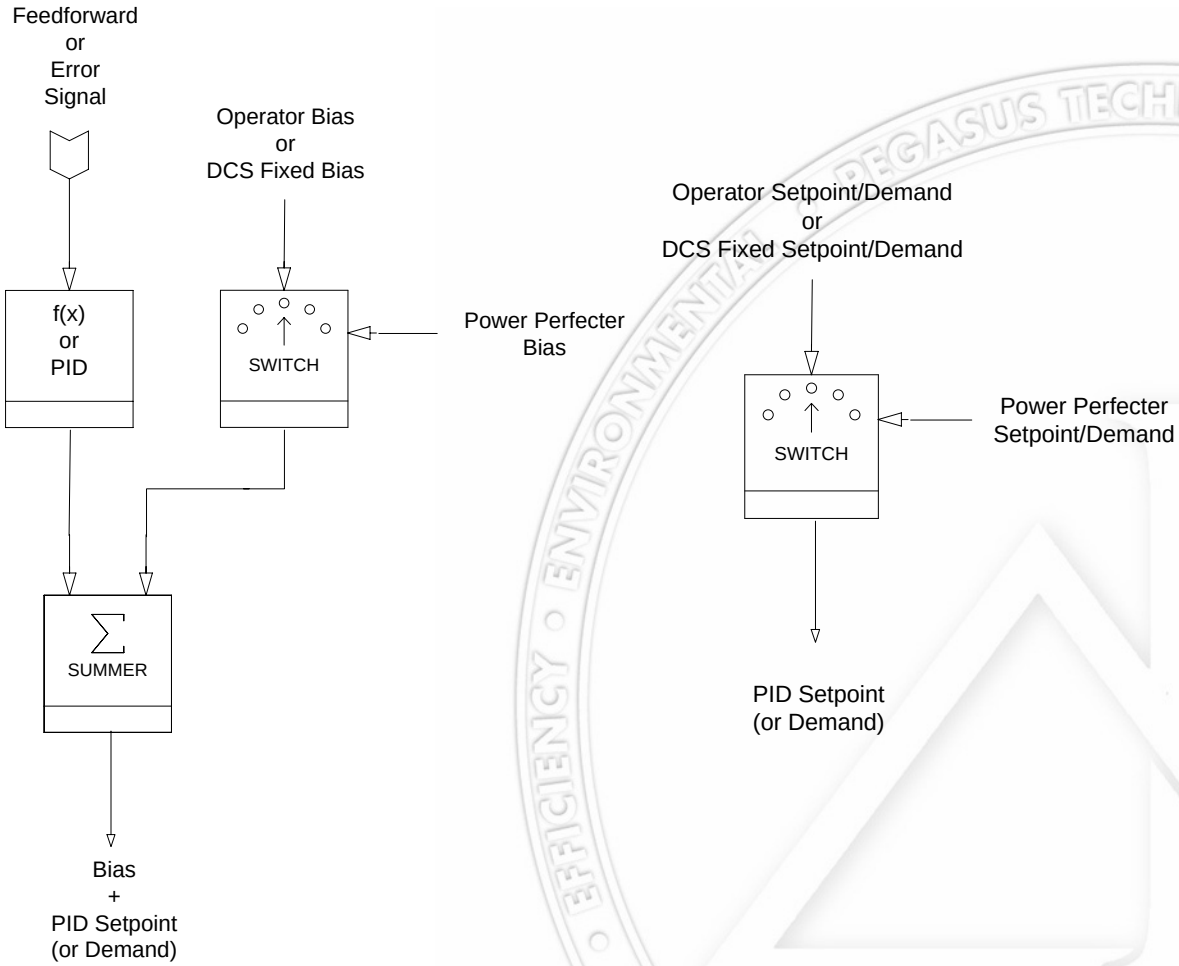
DCS
集散控制系统



Field Sensors and Drives
现场传感器和驱动器

Systems Integration

优化系统指令与DCS控制回路的联接



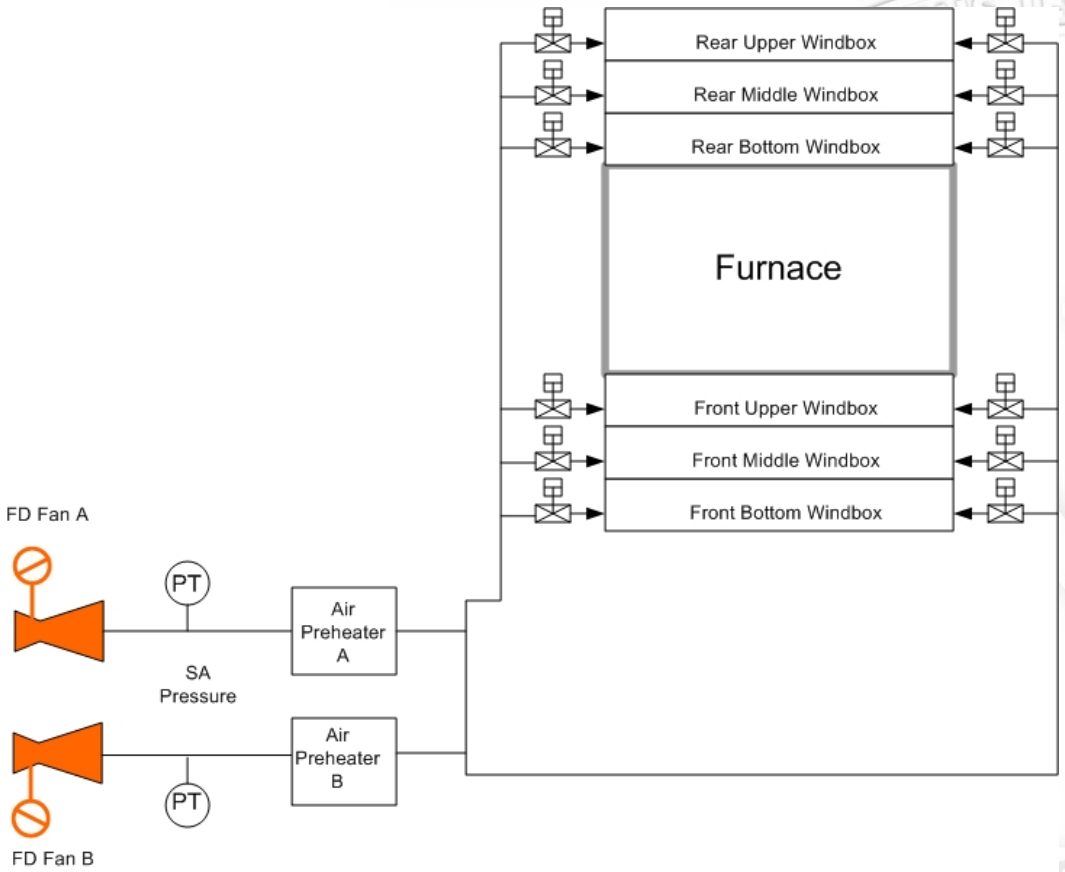
Example1- Xibaipo Unit #3

例证 1 - 西板坡3号机组

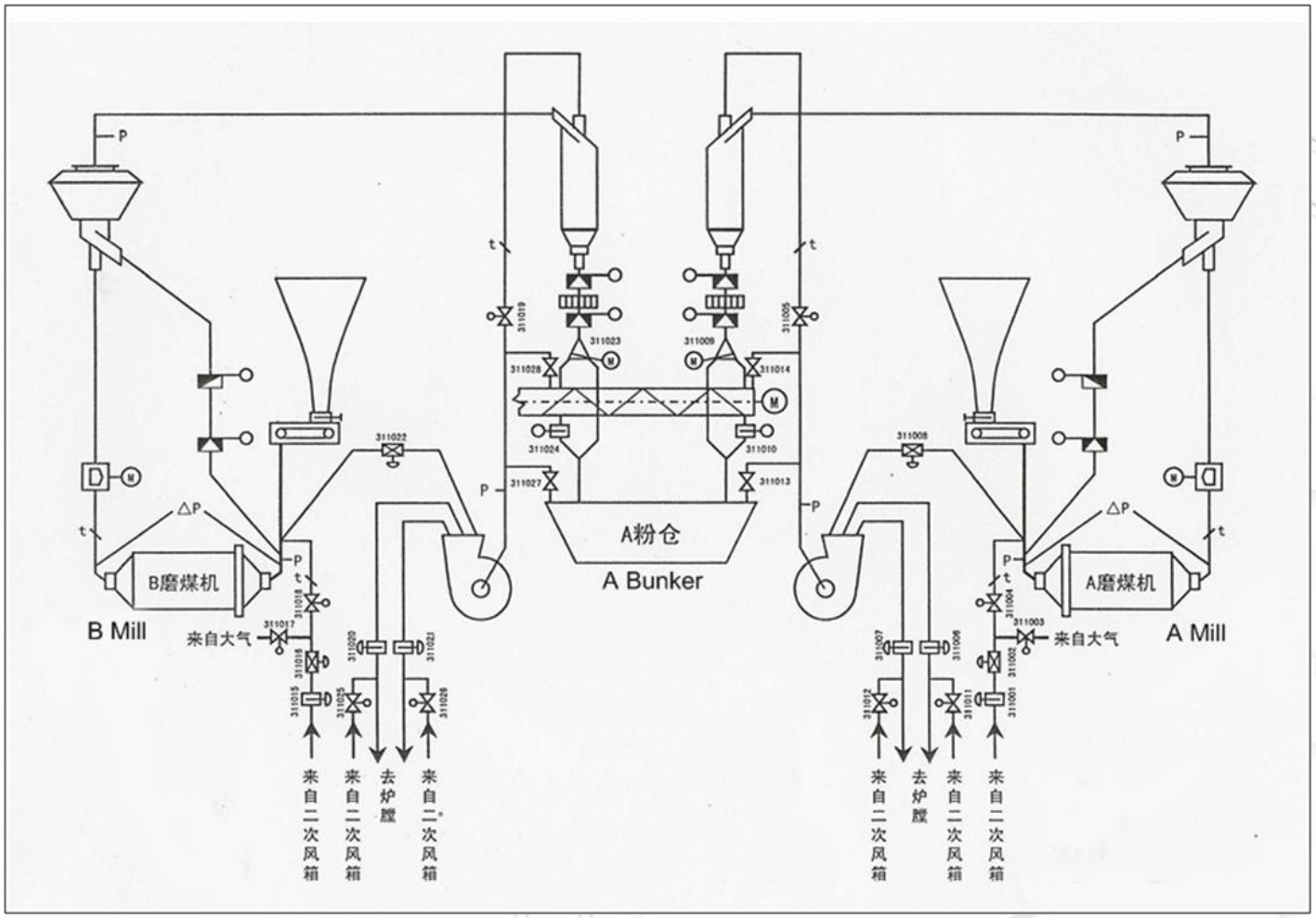
Unit Information 机组资讯

- 300MW **30万千瓦容量**
- Front and Rear Wall Fired **前后墙对冲燃烧**
- Indirectly Fired **中间仓储式热风送粉系统**
- Compartmentrized Windbox **分隔式风箱**
- WDPF DCS **西屋DCS控制系统**

Boiler Configuration 锅炉组态



Mill Configuration 磨煤机组态



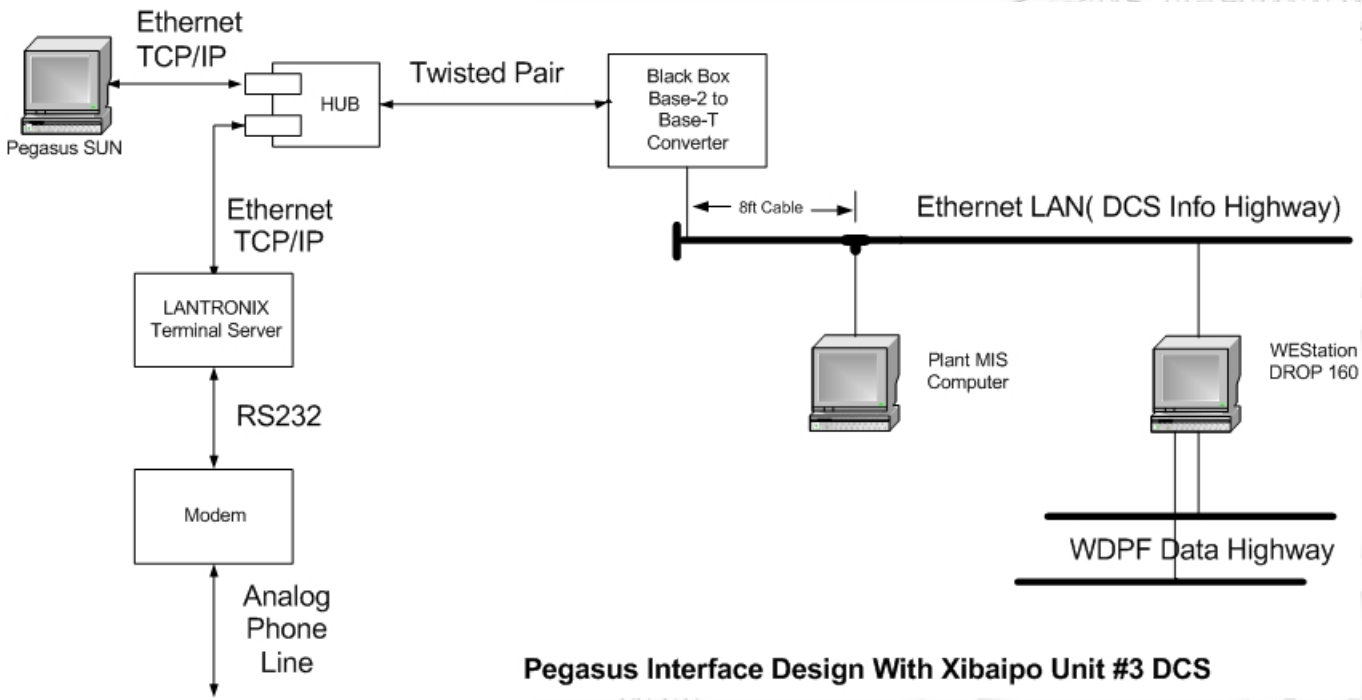
Manipulated Variables 调整变量

1	FD Fan Bias
2	2nd Air Pressure Bias
3	FU 2nd Air Damper Bias
4	FM 2nd Air Damper Bias
5	FD 2nd Air Damper Bias
6	BU 2nd Air Damper Bias
7	BM 2nd Air Damper Bias
8	BD 2nd Air Damper Bias
9	PA Pressure Bias
10	PA Fan Bias
11	Pri SH Temp SP A Bias
12	Pri SH Temp SP B Bias
13	2nd Stage SHT SP A Bias
14	2nd Stage SHT SP B Bias
15	RH Temp SP A Bias
16	RH Temp SP B Bias

Controlled Variables 控制变量

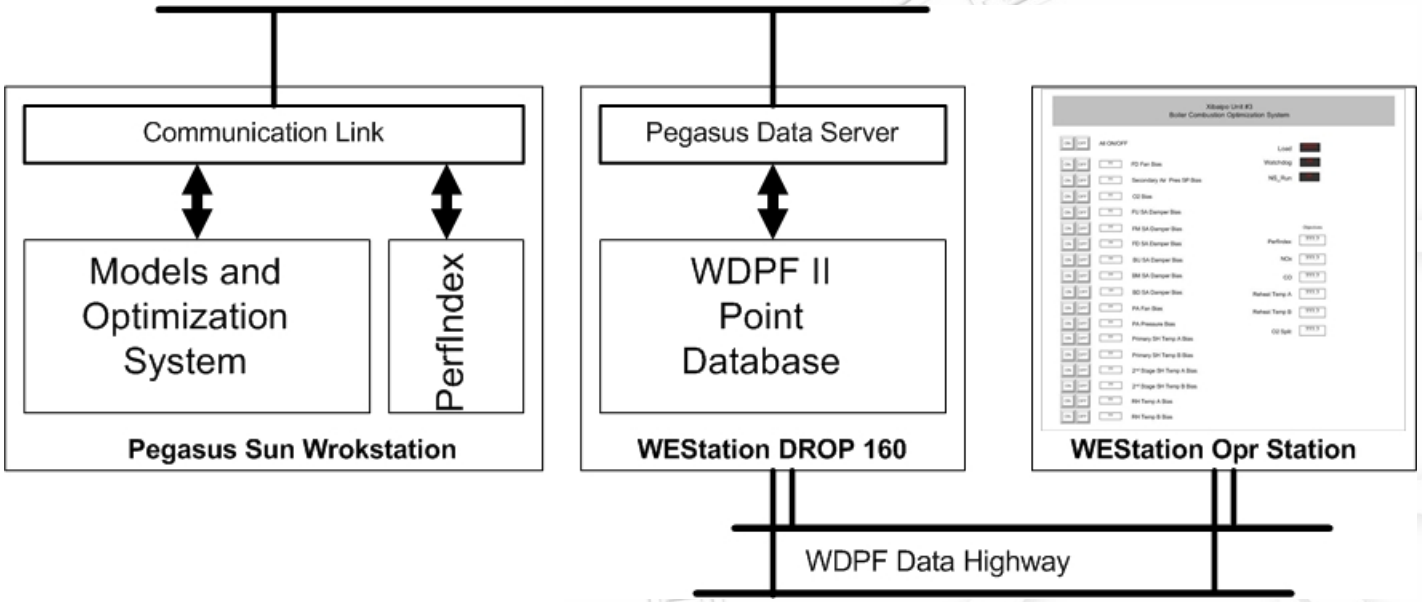
1	Nox	13	PA_AMP_DIF
2	O2_A	14	Pr_Spry_A
3	O2_B	15	Pr_Spry_B
4	Total_SA_Air	16	SH_Spry_A
5	FU_FAR	17	SH_Spry_B
6	FM_FAR	18	RH_Spry_A
7	FD_FAR	19	RH_Spry_B
8	BU_FAR	20	FD__Dmd
9	BM_FAR	21	ID__Dmd
10	BD_FAR	22	FD__Amps
11	O2_DIF	23	ID__Amps
12	FD_AMP_DIF	24	PerfIndex

Pegasus Interface Design
与DCS接口设计



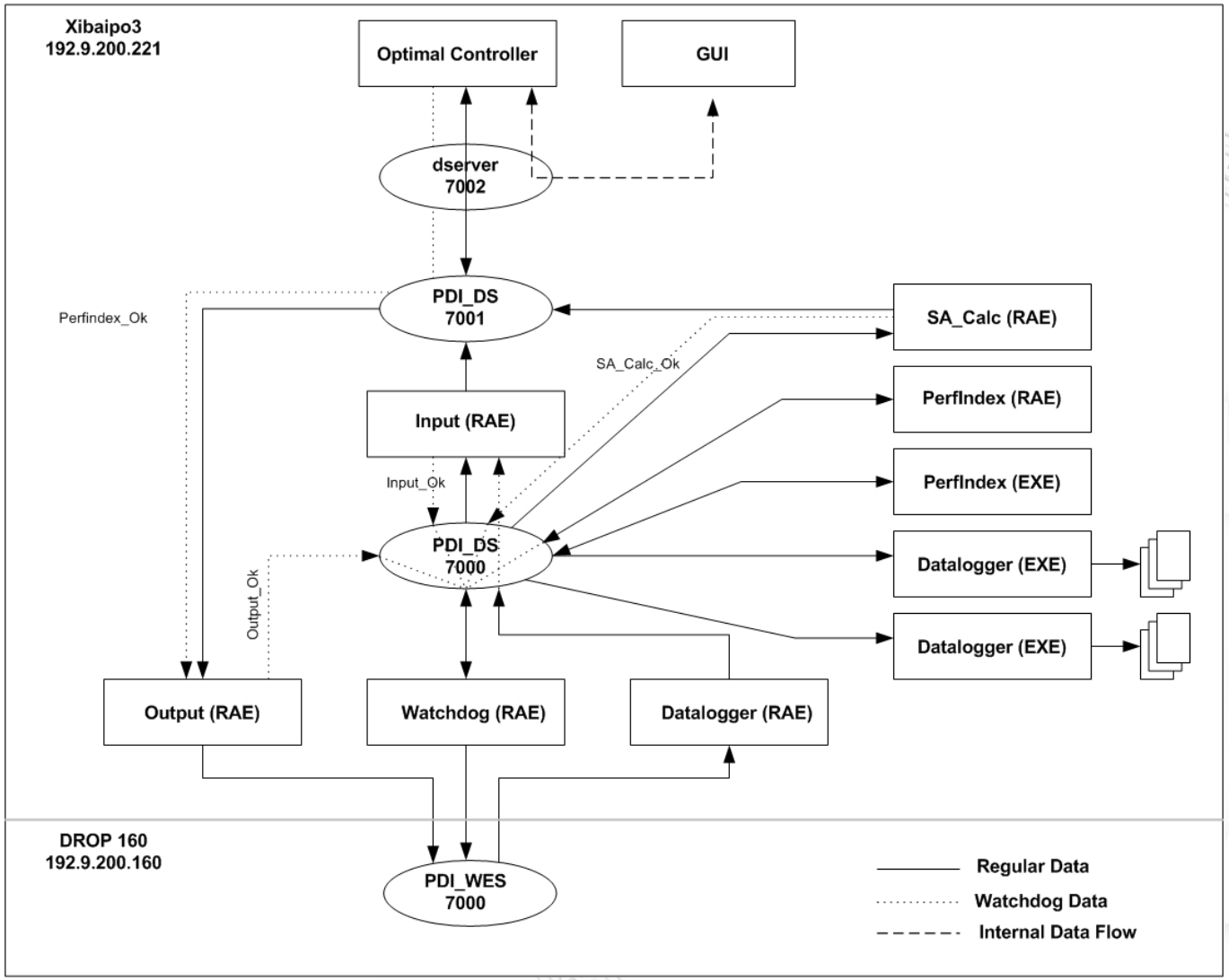
Pegasus Interface Design With Xibaipo Unit #3 DCS

Data Link 数据通道



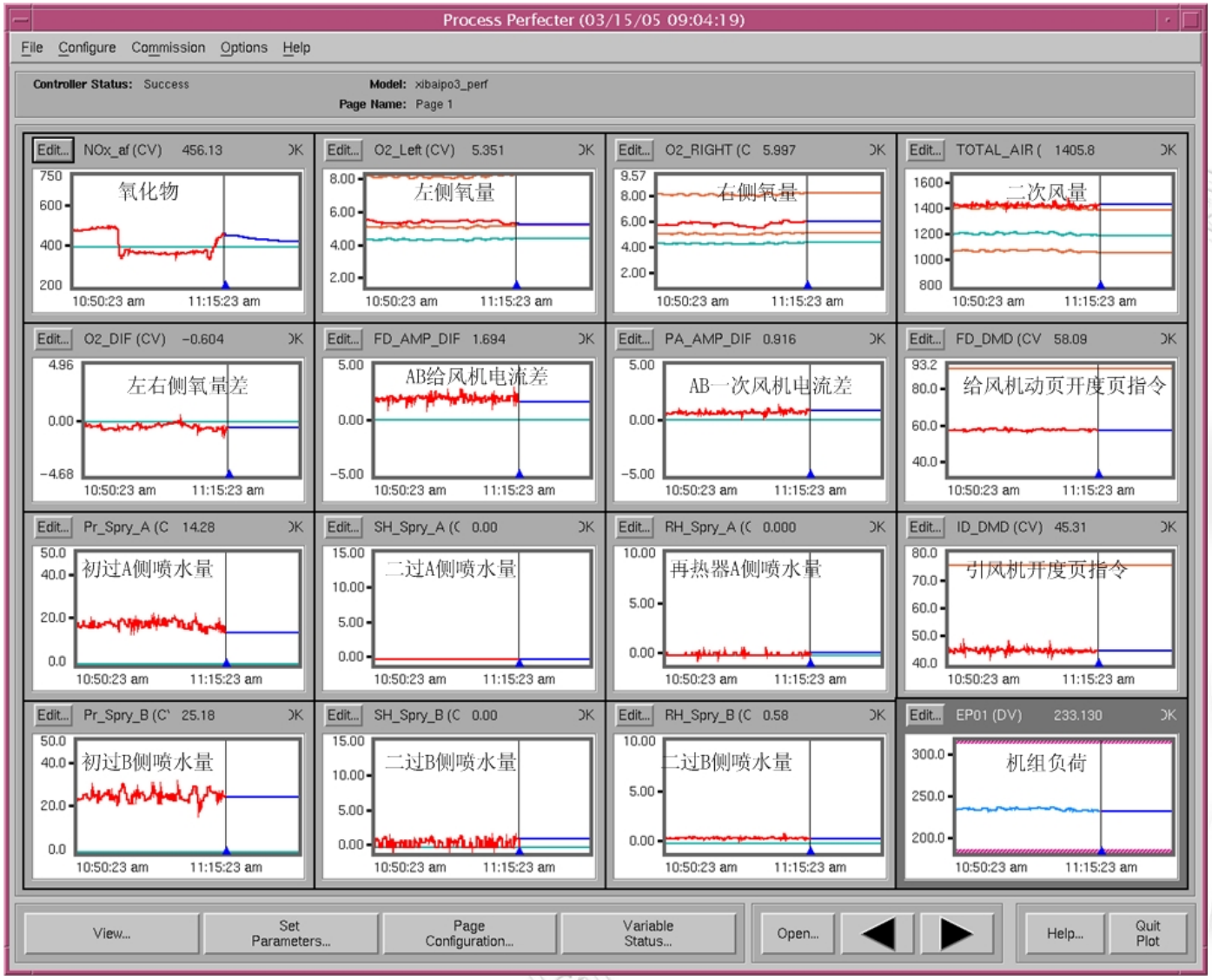
Optimal Controller - Data Flow Diagram

优化控制系统 - 数据流程图



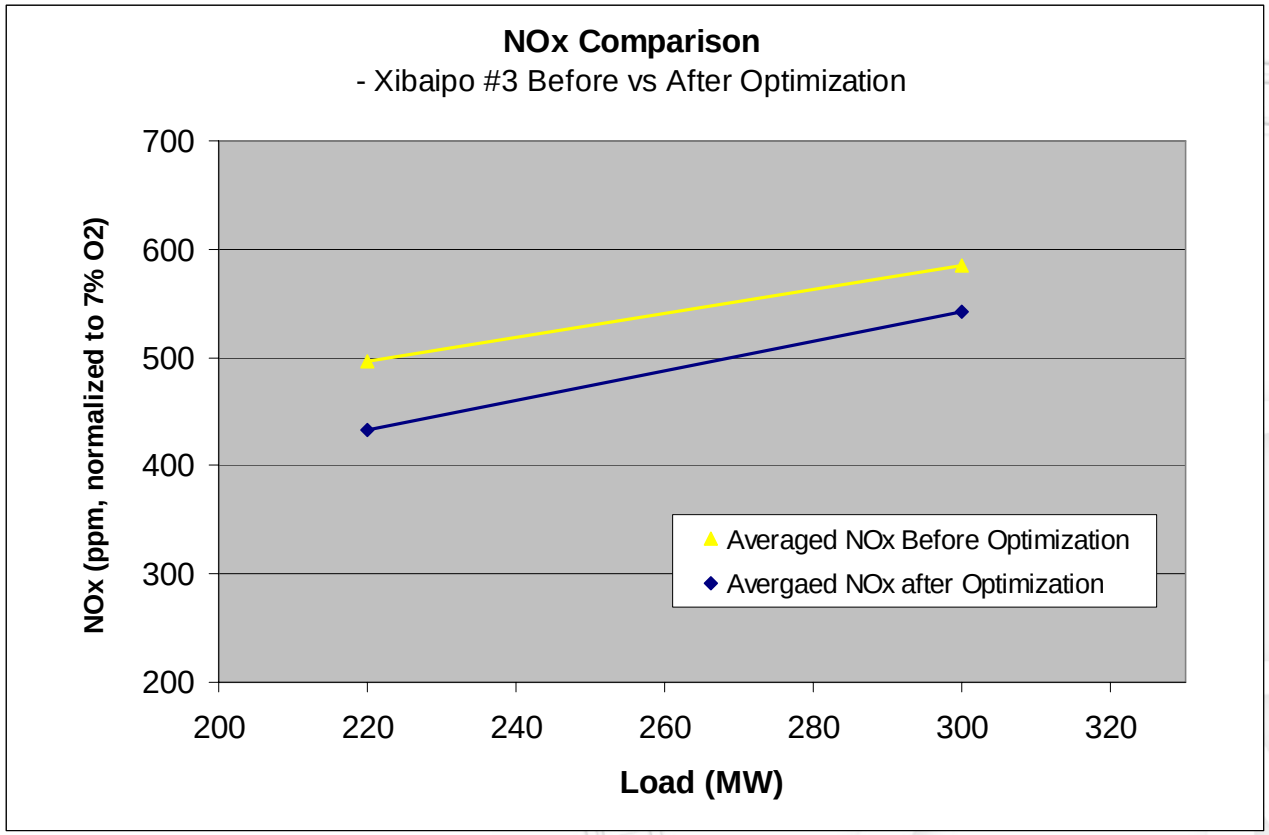
Pegasus Optimal Controller - GUI

优化控制系统 – 工程师图形界面

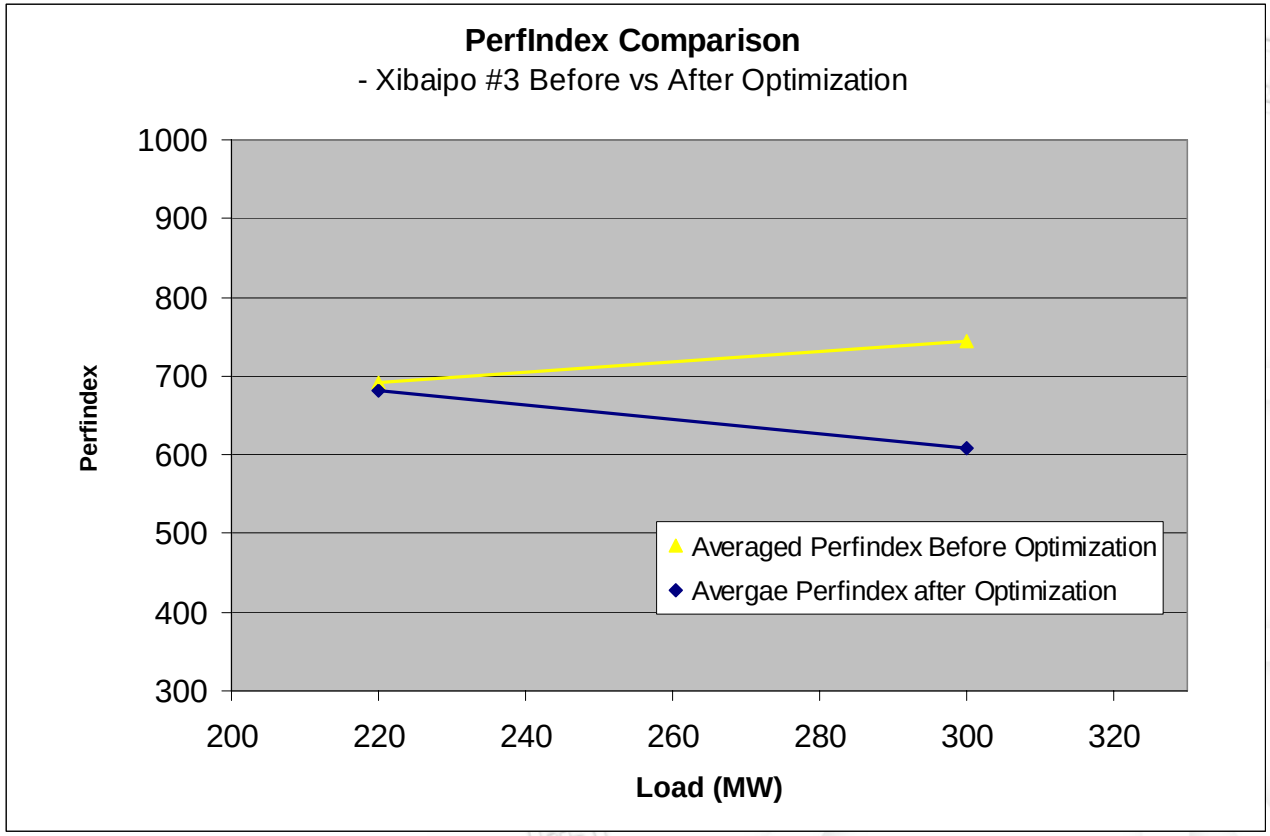


Boiler Combustion Optimization System - GUI
锅炉燃烧优化系统 –运行图形界面

NOx Comparison
优化前后氮氧化物比较



Perfindex Comparison
优化前后效率指标比较



Improvements
优化成效

NOx improvement **氮氧化物改进**	**10.5%**
Heatrate improvement **煤耗量改进**	**0.63% to 0.95%**
Perfindex improvement **效率指标改进**	**0.79%**

Questions?