SmartProcess®

Plant Optimization

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Issues facing

- Challenged by market conditions?
- Tracking performance metrics?
- Have any constraints with equipment operation?
- Are maintenance factors in your evaluation of your operational strategies?

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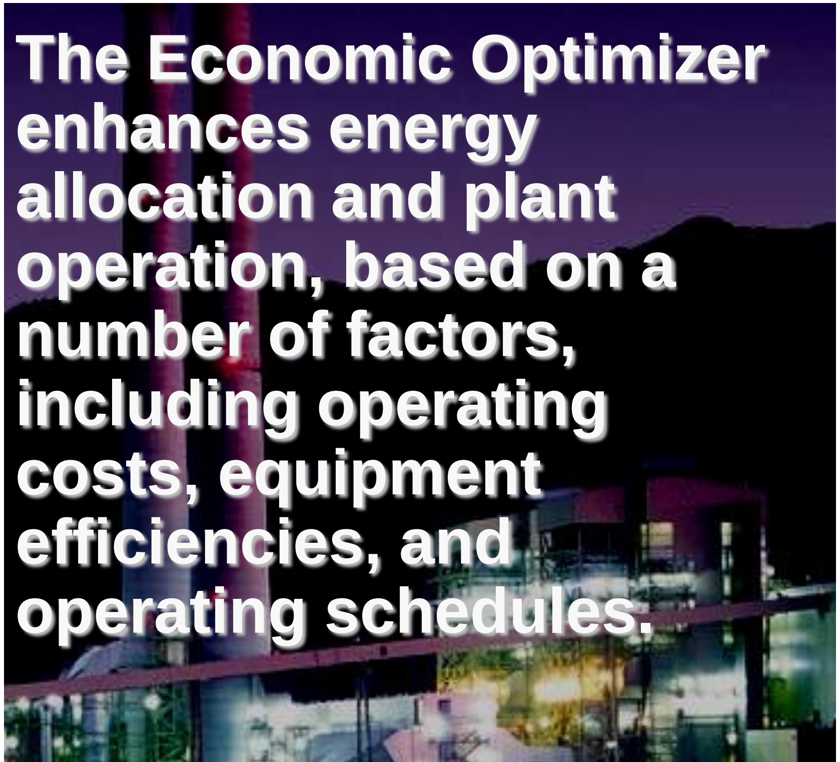
Gas Turbine Optimization



The Economic Optimizer enhances energy allocation and plant operation, based on a number of factors, including operating costs, equipment efficiencies, and operating schedules.

Unify islands of optimization with an overall plant model

- Applications
  - Fleet wide economic analysis
  - Reduces operating costs on multiple equipment type plant configurations
  - CHP, Combined cycle plants, Co-generation facilities
  - Fuel blending strategies
  - Cooling tower optimization
  - Plant profit tool

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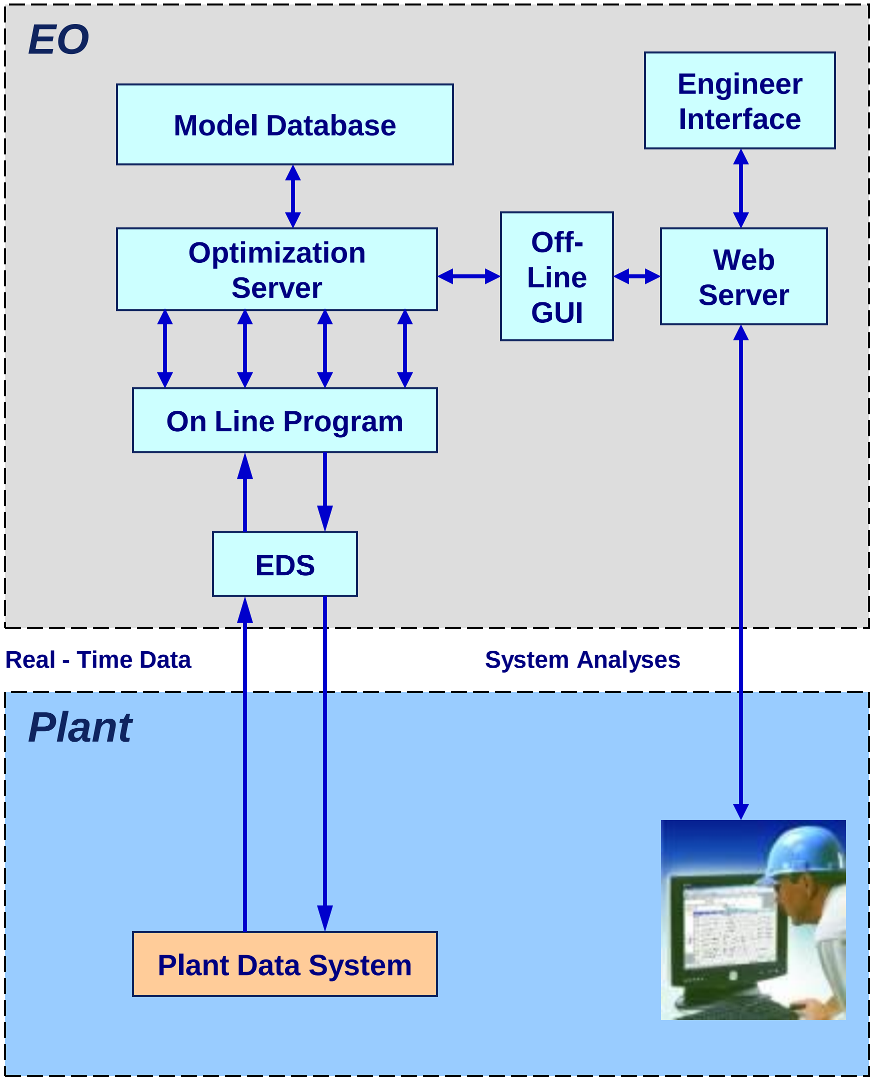
Optimization Components



- The equation based interface
- Easy to “see” what is in the system
- Scalable

Introduction

- Define what is meant by optimization
- Discuss the components of an optimization problem
  - MVs
  - DVs
  - Constants
  - Objective function
- Examples
  - Minimize Cost
  - Maximize Profit

What does this mean ?

- The Solver finds a solution – that is, values for the manipulated variables – that satisfies the constraints and that maximizes or minimizes the objective function
- Variable Types
  - Manipulated Variables (MV) – variables that can be adjusted
  - Coefficients or Constants – variables that do not change
  - Dependent Variables – their value is dependent on the values of MVs, Constants, or other Dependent Variables

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Variable Type Examples

- Combined Cycle plant with 2 CTG/HRSG and 1 STG
- MVs
  - CTG1 and CTG2 Fuel Flow, IGV’s, Duct Burners
- Coefficient/Constants
  - Compressor Inlet Temp
  - Heating value of fuel
  - Cost of Fuel
- Dependent Variables
  - Power produced on the CTGs and STG

What is an Objective Function ?

- Objective Function – the quantity that is to be maximized or minimized
  - Example: Minimize $/HR operating cost. If the manipulated variables are the gas flow on CTG1 and CTG2
  - J = FUEL_COST*(CTG1_FF+CTG2_FF)
  - Where
    - J = objective function
    - FUEL_COST = $/SCF of Gas
    - CTG1_FF = SCF/Hr Gas flow on CTG1
    - CTG2_FF = SCF/Hr Gas flow on CTG2

What are constraints ?

- Constraints are relations such as: CTG1_FF >= 0
- A constraint is satisfied if the condition it specifies is true
- Constraints are used to define the process that is being optimized
- Ensure the solution is valid for the problem that is being optimized

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Solver Types

- The SmartProcess Optimizer has the following types of solvers
  - LP/Quadratic – This solver is used when all the constraints and dependent variable functions are linear. The objective function can be linear or quadratic.
  - GRG Nonlinear – finds solutions to problems where the objective function and/or constraint and dependent equations are non-linear but smooth (no breaks)
  - Evolutionary – is good for problems that are non-linear and contain non-smooth functions

Mixed Integer Programming

- All of the solver engines available in the optimizer support integer variables
- Most of the MVs, Coefficient, and Dependent variables are real numbers but they can also be integer (0,1,2,3..) or binary (0,1)
- This is necessary for modeling equipment that can be ON or OFF – or for sequencing problems
- Example: A CTG can be ON or OFF this can be represented by a binary variable. 1=ON , 0 = OFF

How to Construct Optimization Problem

- The user must be able to:
  - Define Manipulated Variables
  - Define Coefficient or Constant Variables
  - Define Dependent Variables
  - Define Constraints
- Different values of the coefficients determine different cases or scenarios of the same problem
- The SmartProcess Optimizer GUI provides this capability

Two Modes of Operation

- Offline and Online Modes
- Offline contains a GUI to build the optimization problem (plant model)
- Multiple optimization problems can be created
  - Provides “What If” capability
- Online version uses live plant data from the DCS
  - Closed Loop
  - Advisory
- The Online version is configurable from Offline GUI
- Optimizer has an EDS interface

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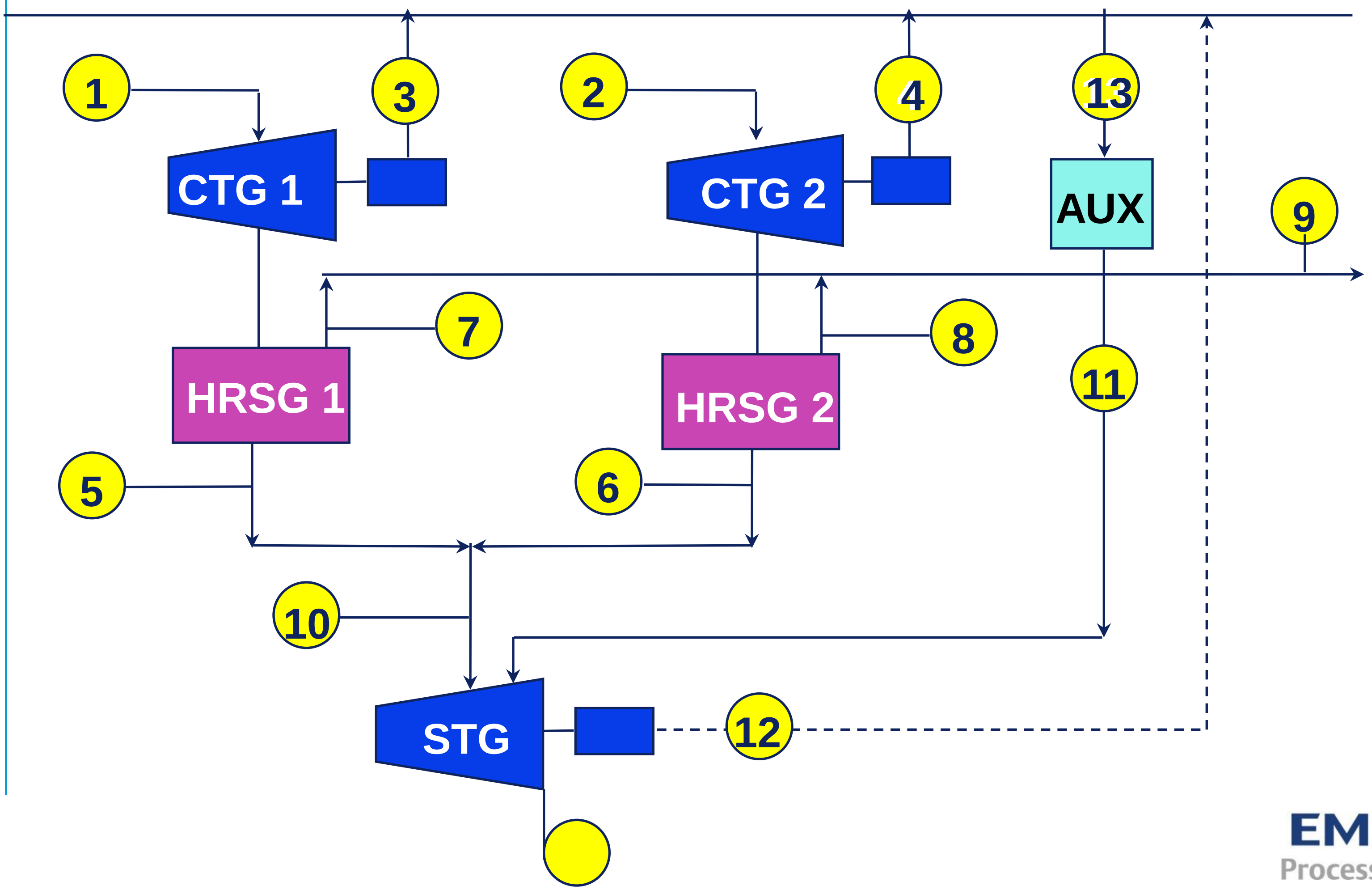
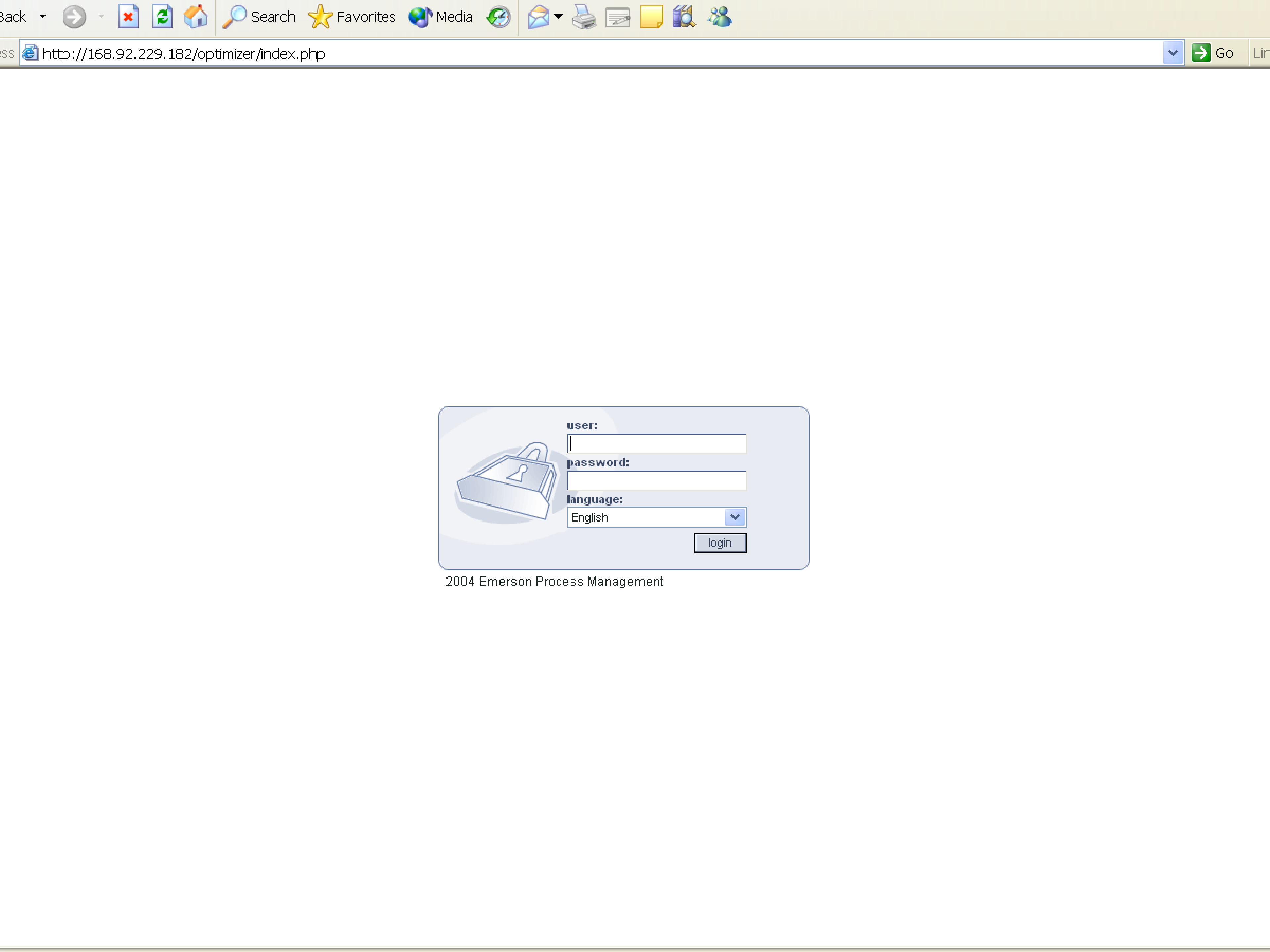
Sample Plant Configuration

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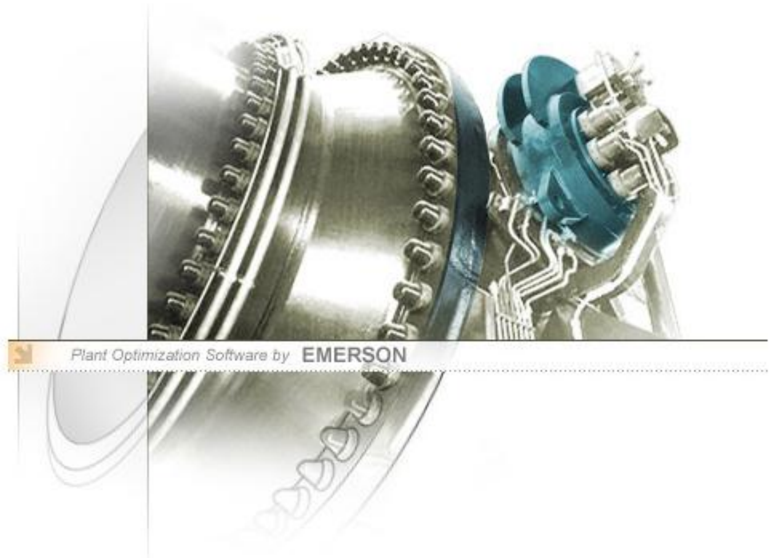

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Loaded model

Model name : Nevada

Logged as De

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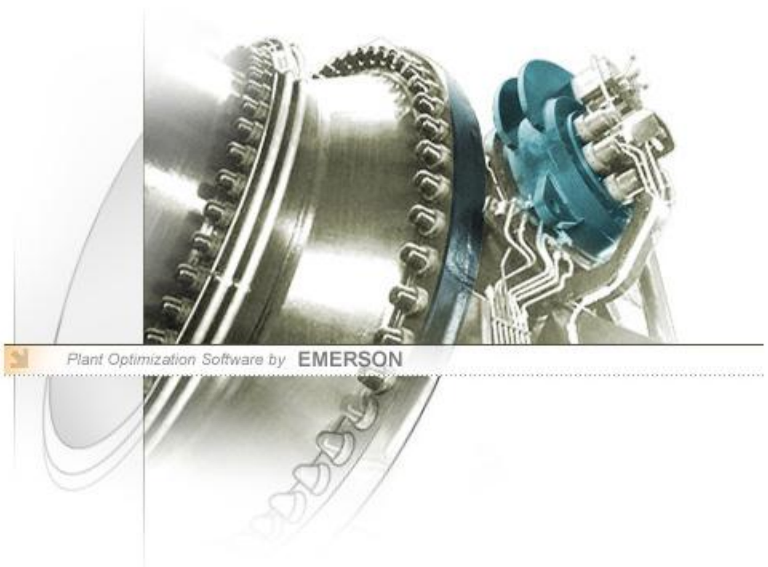
- Dependent Variables
- Objective function
- Execute
- Online execute
- Results
- Results statistical data
- Irreducible infeasible set
- Engine settings
- Point mapping
- Plant configuration
- Print preview

Configuration

Administration



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Logout

Loaded model/ Manipulated Variables

Model name : **Nevada**

Logged as De

Name	Alias	Description	VarType	MinConstr	InitialVal	MaxConstr
X1	G1HEAT	GT1 Heat (MBTU/HR)	float	0	1	1000
X2	G2HEAT	GT2 Heat (MBTU/HR)	float	0	1	1000
X3	G1ON	GT1 ON	boolean	0	1	1
X4	G2ON	GT2 ON	boolean	0	1	1
X5	STGON	STG ON	boolean	0	1	1

Name

Alias [ ] Initial Value [1] Add new Apply

Description [ ] Variable type [float] Delete selected Delete all

Min constraint [ ] Max constraint [ ] Copy

Unbounded [ ] Unbounded [ ]

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Loaded model/ Coefficients

Model name : **Nevada**

Logged as De

Name	Alias	Description	Formula	ValueAtEnd
C1	AMBTMP	Ambient Temp (DEG F)	80.0	80
C2	G1FCOST	CTG1 Fuel Cost ($/MBTU)	2.0	2
C3	G2FCOST	CTG2 Fuel Cost ($/MBTU)	3.0	3
C4	CTG_MA...	CTG Maximum power (MW)	95.019-0.1334*AMBTMP	84.347

Name

Alias

Description

Value / Formula

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- Irreducible infeasible set
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- Plant configuration
- Print preview

Configuration

Administration

Loaded model/ Dependent Variables

Model name : **Nevada**

Logged as De

Name	Alias	Description	Formula	ValueAtEnd
T1	G1MW	CTG 1 Power (MW)	(G1HEAT-G1ON*204.29)/...	84.34702308
T2	G2MW	CTG 2 Power (MW)	(G2HEAT-G2ON*204.29)/...	62.22892006
T3	HPSTM1	HRSG1 HP Steam (KLB/H)	2.15*G1MW + 103.25*G1...	303.7960996
T4	HPSTM2	HRSG2 HP Steam (KLB/H)	2.15*G2MW + 103.25*G2...	256.2421781
T5	LPSTM1	HRSG1 LP Steam (KLB/H)	25.148*G1ON+0.708*G1M...	81.77769234
T6	LPSTM2	HRSG2 LP Steam (KLB/H)	25.148*G2ON+0.708*G2M...	66.1180754
T7	TOTSTM	Total Steam (KLB/H)	HPSTM1 + HPSTM2 +LPST...	707.9340454
T8	DEAR	DEAR Steam Flow (KLB/H)	((4.118/2)*(G1ON+G2ON...	22.98503009
T9	GROSS_MW	GROSS Plant MW	G1ON*G1MW+G2ON*G2MW+S...	231.3007569
T10	STGHPSTM	STGHP Steam (KLB/H)	HPSTM1+HPSTM2	560.0382777

Name

Alias

Description

Value / Formula

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- Graphic Viewer
- Graphic Builder
- Neural Networks
- Privileges

Configuration

Administration

Loaded model/ Constraints Model name : **Nevada** Model description : **Nevada** Logged as Fre

Name	Description	LHS	RHS	LHSValAtEnd	Operator	RHSValAtEnd
E1	Power demand	GROSS_MW - AUXMW	230	- 1	=	230
E2	Steam turbine On	STGON - (G1ON + G2ON)	0	- 1	<=	0
E3	CTG1 Minimum power	G1MW - (G1ON * 20)	0	- 1	>=	0
E4	CTG2 Minimum power	G2MW - (G2ON * 20)	0	- 1	>=	0
E5	STG Minimum power	STGMW - (STGON * 14)	0	- 1	>=	0
E6	CTG1 Maximum power	G1MW	CTG_MAX_MW	- 1	<=	84.347
E7	CTG2 Maximum power	G2MW	CTG_MAX_MW	- 1	<=	84.347

Name LHS Add new Apply

Description Operator <= Delete selected Delete all

RHS Copy

Legend

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Loaded model/ Results

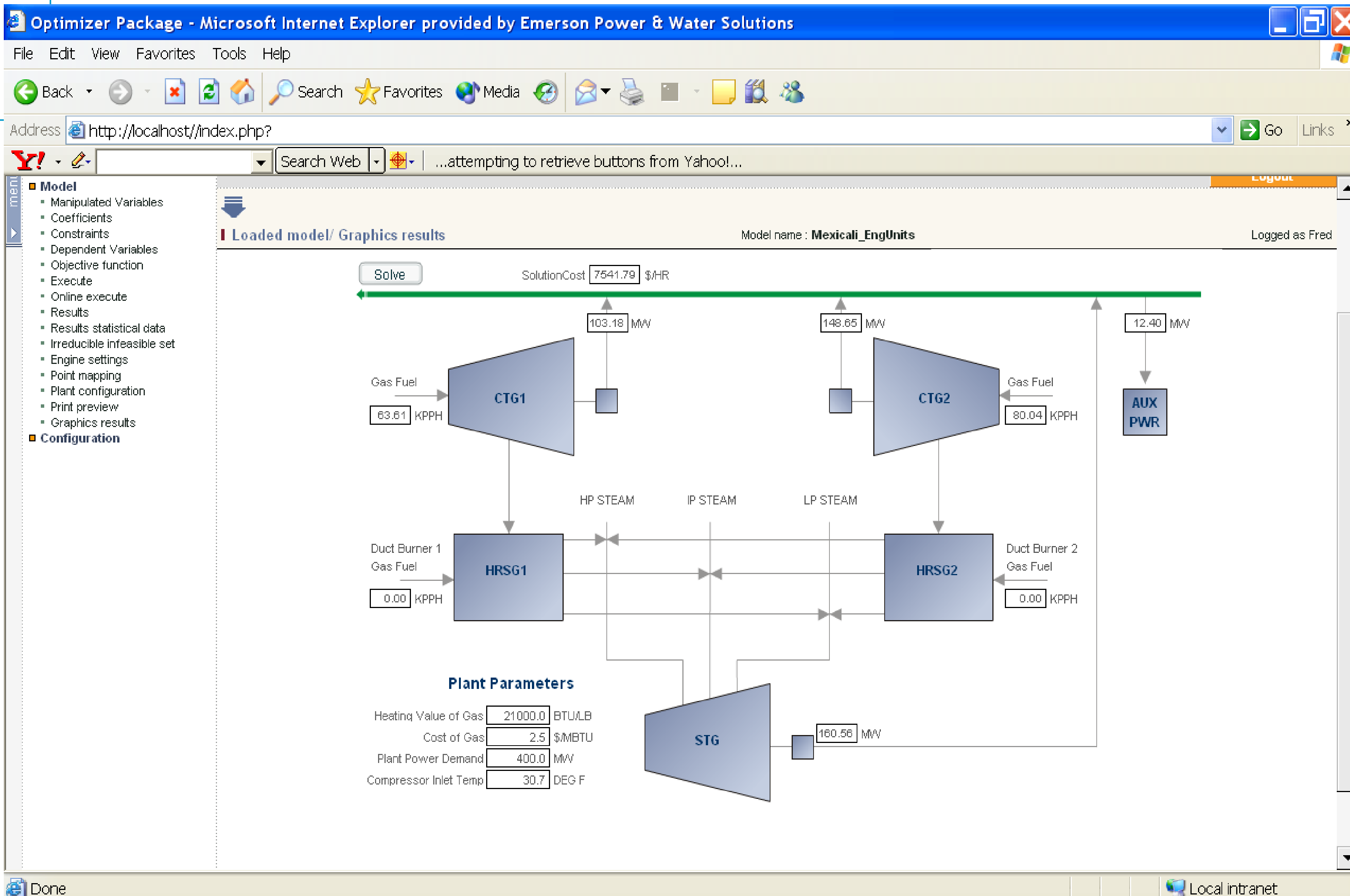
Model name : **Nevada**

Logged as De

Name	Alias	Description	OptimumValue	MinConstr	MaxConstr
X1	G1HEAT	GT1 Heat (MBTU/HR)	951.0141953	0	1000
X2	G2HEAT	GT2 Heat (MBTU/HR)	755.2026293	0	1000
X3	G1ON	GT1 ON	1	0	1
X4	G2ON	GT2 ON	1	0	1
X5	STGON	STG ON	1	0	1

Solution cost **4167.636279**

Solution status **Optimal integer solution found**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Irreducible infeasible set
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Print preview
Graphics results
Configuration
Loaded model/ Graphics results
Model name : Mexicali_EngUnits
Logged as Fred
Solve
SolutionCost 7541.79 $/HR
103.18 MW
148.65 MW
12.40 MW
Gas Fuel
63.61 KPPH
CTG1
CTG2
Gas Fuel
80.04 KPPH
AUX PWR
HP STEAM
IP STEAM
LP STEAM
Duct Burner 1
Gas Fuel
0.00 KPPH
HRSG1
HRSG2
Duct Burner 2
Gas Fuel
0.00 KPPH
Plant Parameters
Heating Value of Gas 21000.0 BTU/LB
Cost of Gas 2.5 $/MBTU
Plant Power Demand 400.0 MW
Compressor Inlet Temp 30.7 DEG F
STG
160.56 MW
Done
Local intranet

Print

Model name Nevada

Description Nevada

Objective (c2*x1) + (c3*x2)

Opt direction minimize

Manipulated Variables

Name	Alias	Description	Variable type	Min constraint	Initial Value	Max constraint
X1	G1HEAT	GT1 Heat (MBTU/HR)	Float	0	1	1000
X2	G2HEAT	GT2 Heat (MBTU/HR)	Float	0	1	1000
X3	G1ON	GT1 ON	Bool	0	1	1
X4	G2ON	GT2 ON	Bool	0	1	1
X5	STGON	STG ON	Bool	0	1	1

Coefficients

Name	Alias	Description	Value / Formula
C1	AMBTMP	Ambient Temp (DEG F)	80.0
C2	G1FCOST	CTG1 Fuel Cost ($/MBTU)	2.0
C3	G2FCOST	CTG2 Fuel Cost ($/MBTU)	3.0
C4	CTG_MAX_MW	CTG Maximum power (MW)	95.019-0.1334*AMBTMP

Constraints

Name	Description	LHS	Operator	RHS
E1	Power demand	GROSS_MW - AUXMW	=	230
E2	Steam turbine On	STGON-(G1ON+G2ON)	<=	0
E3	CTG1 Minimum power	G1MW-(G1ON*20)	>=	0
E4	CTG2 Minimum power	G2MW-(G2ON*20)	>=	0
E5	STG Minimum power	STGMW-(STGON*14)	>=	0
E6	CTG1 Maximum power	G1MW	<=	CTG_MAX_MW
E7	CTG2 Maximum power	G2MW	<=	CTG_MAX_MW

Dependent Variables

Name	Alias	Description	Value / Formula
T1	G1MW	CTG 1 Power (MW)	(G1HEAT-G1ON*204.29)/8.853
T2	G2MW	CTG 2 Power (MW)	(G2HEAT-G2ON*204.29)/8.853
T3	HPSTM1	HRSG1 HP Steam (KLB/H)	2.15*G1MW + 103.25*G1ON + (0.24*G1ON*AMBTMP)
T4	HPSTM2	HRSG2 HP Steam (KLB/H)	2.15*G2MW + 103.25*G2ON+ (0.24*G2ON*AMBTMP)
T5	LPSTM1	HRSG1 LP Steam (KLB/H)	25.148*G1ON+0.708*G1MW-(0.0386*AMBTMP*G1ON)
T6	LPSTM2	HRSG2 LP Steam (KLB/H)	25.148*G2ON+0.708*G2MW-(0.0386*AMBTMP*G2ON)
T7	TOTSTM	Total Steam (KLB/H)	HPSTM1 + HPSTM2 +LPSTM1 + LPSTM2
T8	DEAR	DEAR Steam Flow (KLB/H)	((4.118/2)*(G1ON+G2ON))+0.0329*TOTSTM-((0.0553/2)*AMBTMP*(G1ON+G2ON))
T9	GROSS_MW	GROSS Plant MW	G1ON*G1MW+G2ON*G2MW+STGON*STGMW
T10	STGHPSTM	STGHP Steam (KLB/H)	HPSTM1+HPSTM2
T11	STGLPSTM	STGLP Steam (KLB/H)	LPSTM1+LPSTM2-DEAR
T12	STGMW	STG Power (MW)	0.16564*STGHPSTM+0.0115*STGLPSTM-STGON*9.4764
T13	AUXMW	Auxillary power (MW)	0.00424*GROSS_MW+0.00169*AMBTMP+0.00001*GROSS_MW*AMBTMP

Summary

- SmartProcess Optimization
  - Provides “What If” capability in Off-Line Mode
  - On-Line can be Closed-Loop or Advisory
  - OPC Interface
- Can help reduce operating costs or increase profits in deregulated market

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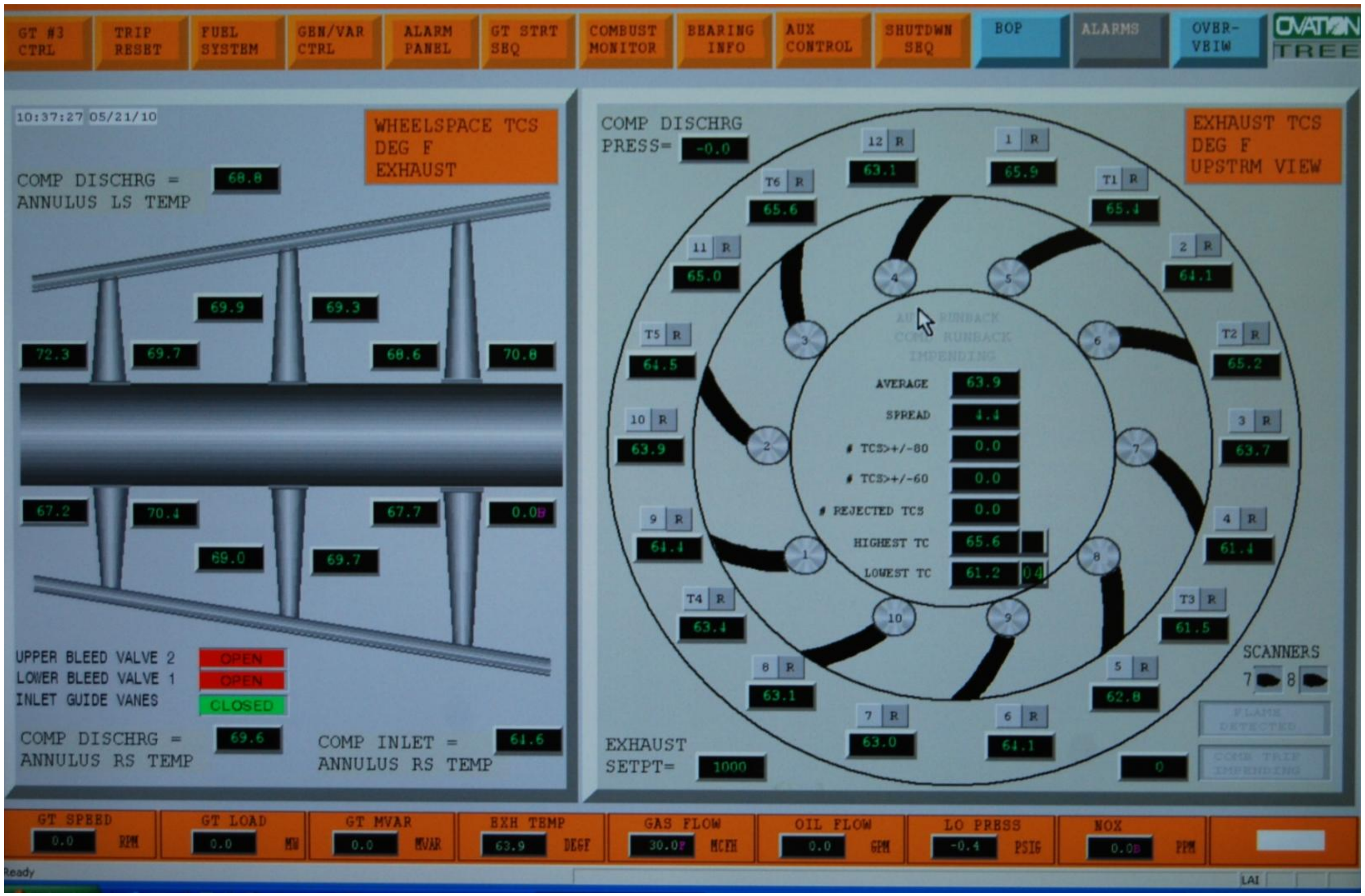
Combustion monitor



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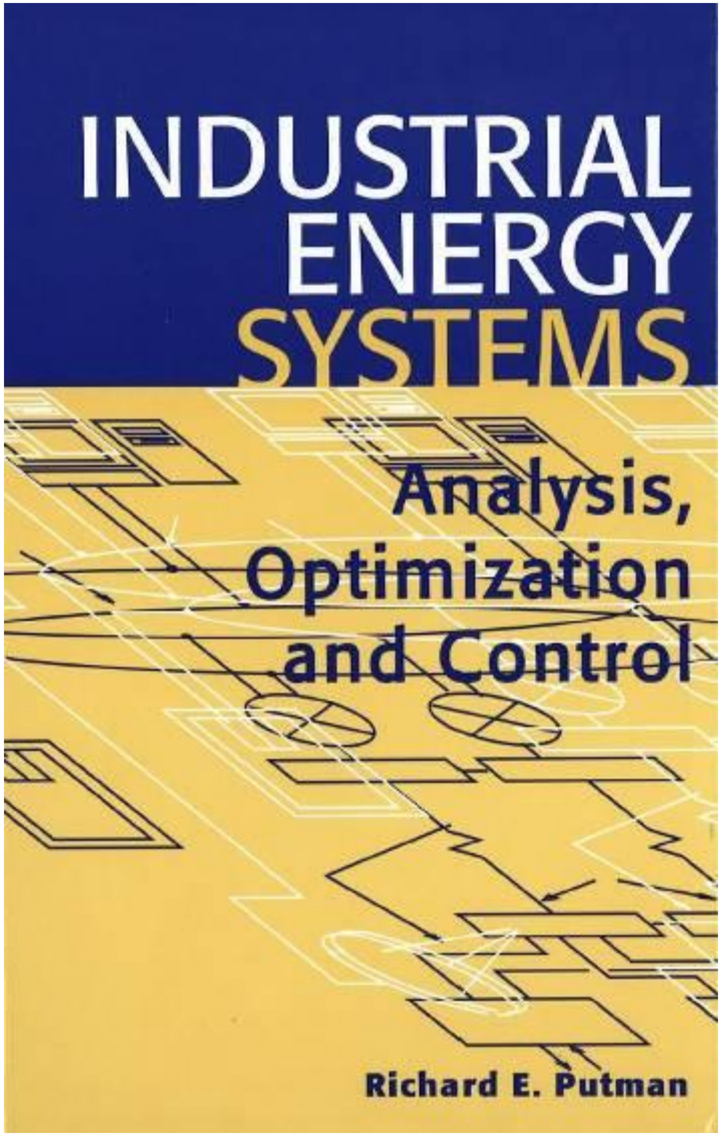
Resource



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