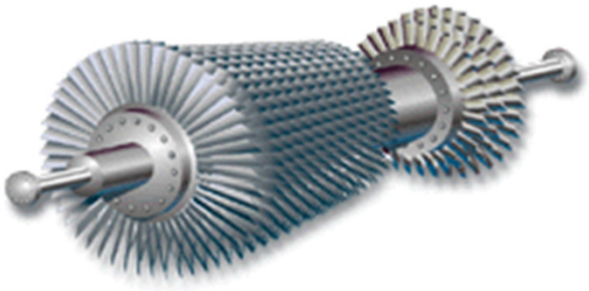
Turbomachinery Controls

ISA Will-DuPage



Presented by Hector Buchelly
May 2013

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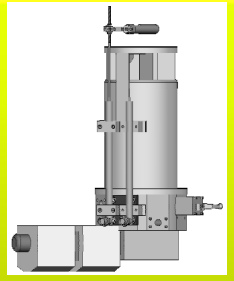
Operations Management

Avantis Eurotherm Foxboro IMServ InFusion SimSci-Esscor Skelta Triconex Wonderware

Objectives

- Turbomachinery Scope
- Technical Solutions
- Surge Control
- Mechanical Retrofit

Rotating Equipment Scope

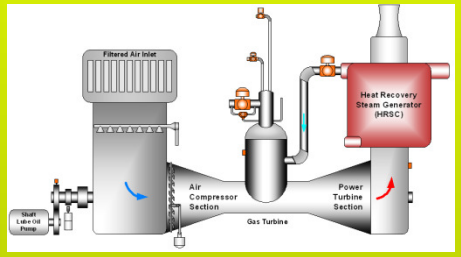


Actuator with LVDTs

Prime Movers

Steam Turbine

Gas Turbine



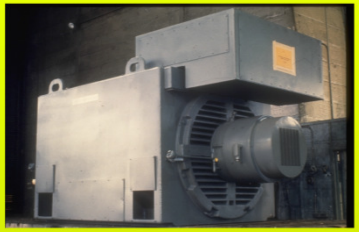
Motor

Hydro-Turbine

Mechanical Retrofit and Protection

Driven Equipment

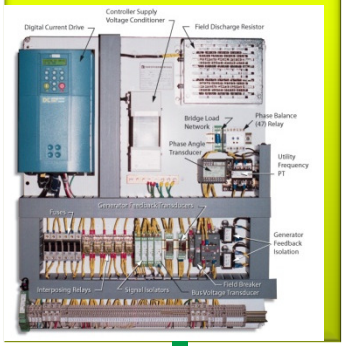
Generator



Compressor

Auxiliaries

AVR



Compressor Performance

Lube Oil
Seal Gas
MCC

TMC Proficiencies

Steam Turbines

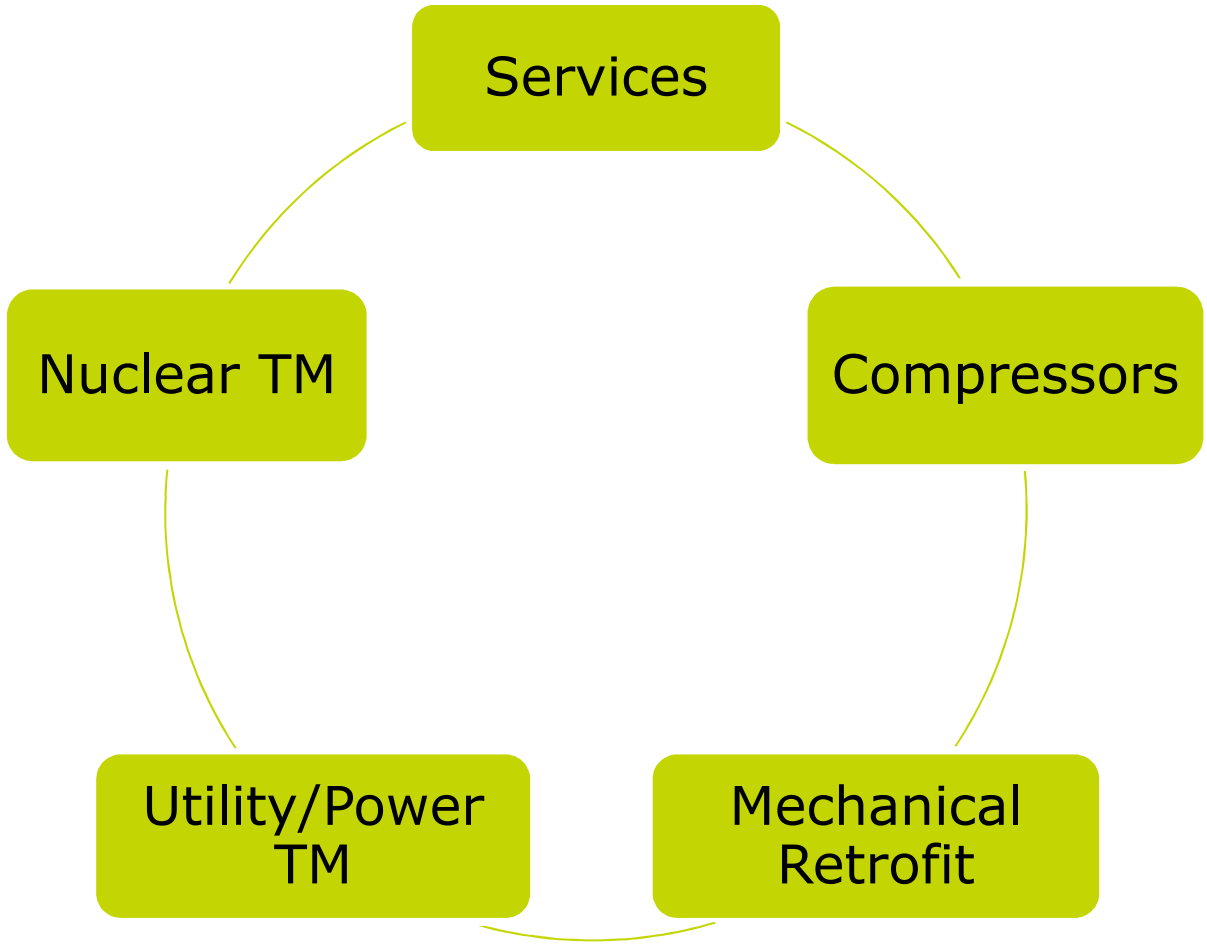
Gas Turbines

Compressors

Generators

Integrated Turbine/ Load Control Solutions

TMC Offering Segmentation



Steam Turbines

AEG-Kanis
Dresser Turbodyne
Mitsubishi Hvy. Ind.
ASEA STAL
Dresser-Rand
Siemens AG

ABB
Dresser-Rand Pwr. A/S
Nuovo Pignone
Allis-Chalmers Corp.
Elliott Company Shin Nippon
Bharat Heavy Ind. Ltd.

Steam Turbines

GEC Turbine Ltd.
Murray Turbomachinery
Borsig
Garrett Turb. Eng. Co.
Terry Corporation
Carrier Corporation

General Electric Co.
Westinghouse
Coppus Engineering
Ingersoll Rand Co.
Worthington
DeLaval
Kawasaki Heavy Ind.

Gas Turbines

- Allison: 501
- Avon: 1533
- BBC: Frame 11
- GE: Frame 3, Frame 5, Frame 7
- GE LM 2500
- Hispano-Suiza: 1202
- Pratt & Whitney: FT4, GG4, Twin Pac, Hi-Cap, ST18
- Rolls-Royce: RB211, Olympus
- Ruston: TB3000, TB4000, TB5000
- Solar: Centaur T48
- Sulzer GT10
- Westinghouse: W50, W101, W191, W251, W352, W501

Process Application

Olefins Plants
- Furnace Gas
- Propylene Refrigeration
- Ethylene Refrigeration

Ammonia/Fertilizer
- Syn Gas
- Process Air
- Ammonia Refrigeration
- Feed Gas
- Carbon Dioxide

Nitric Acid—Process Air

Acrylic Acid—Process Air

Power Plants/Utilities

Process Application

Refinery

- FCCU Air Blower
- Cat Gas
- Hydrogen
- Plant Air

Gas Separation

- Residual Gas
- Propane Refrigeration

Gas Pipeline

LNG

Compressor Test Stand

Turbomachinery Control Solutions

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Project Execution

1. Studies or Assesments
2. Hold Kickoff Meeting
3. Generate Project Basis of Design Document
4. Develop and Test Logic
5. Perform Factory Acceptance Test Procedure (FAT)
6. Ship Equipment
7. Develop Site Acceptance Test (SAT) and Surge Testing
8. Perform SAT and Commissioning

Compressors

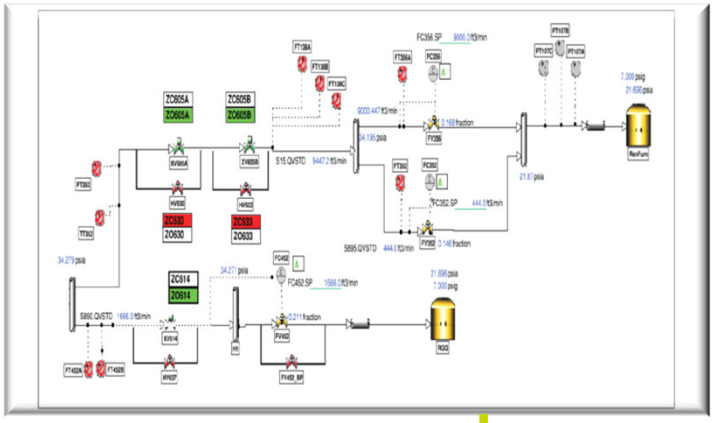
Governor	Performance	Surge
• Steam Turbines • Motors • Gas Turbines • Sequencing	• Pressure • Flow • Decoupling	• Single Valve • Multi Valve • Refrigeration • Load Sharing

Mechanical Retrofit

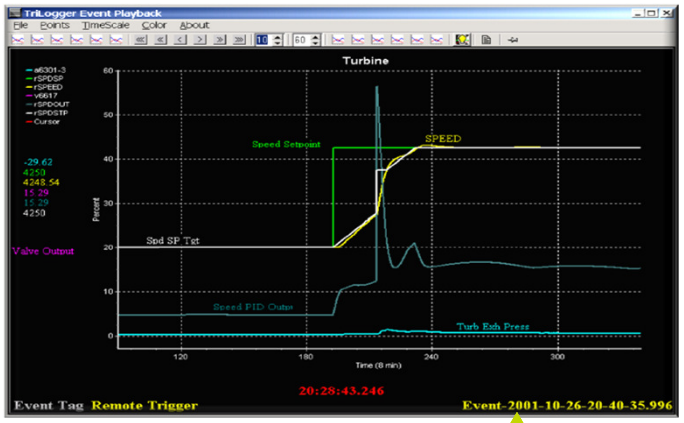
- Single-Valve and Two-Valve Actuators
- Speed Sensing
- Systems: Overspeed, Trip, Multi-Valve
- Hydraulic Pressure Units

TMC Solutions Interaction

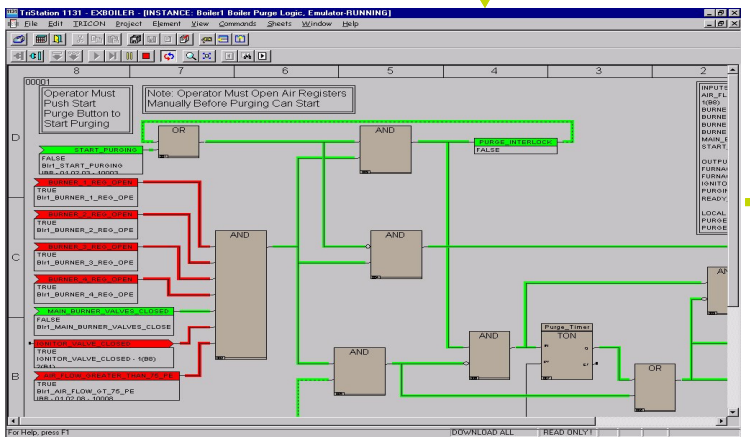
Simulation



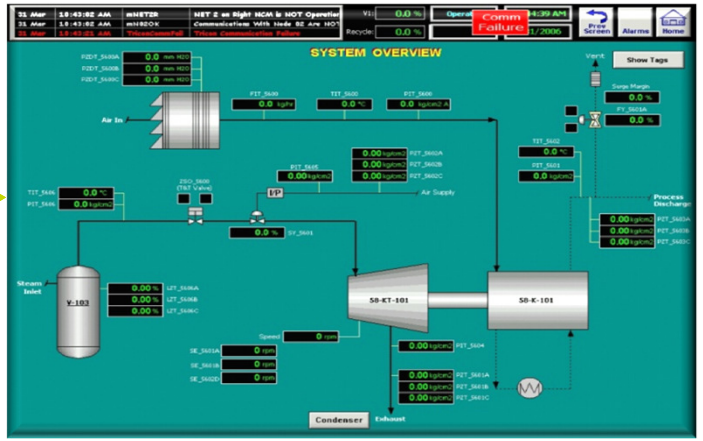
Fast Trending



Control Program



HMI



Critical Project Questions

- System

  Will my compression system perform per the design?

- Control Strategy Development

  What is the best way to control my system?

- Control Checkout and Tuning

  Are the controls configured correctly and tuned well?

- Operator Training

  Can I use my model to train my operators?

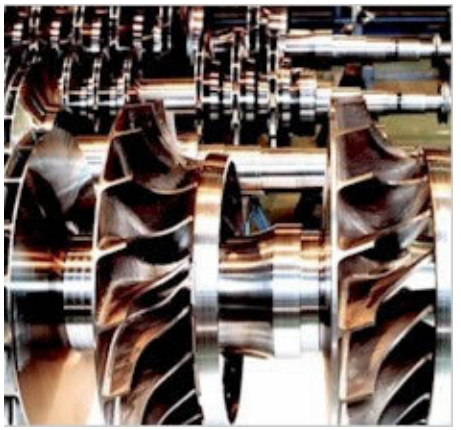
System

Verify the compressor system before the FEED or commissioning:

- Compressor specifications
- Anti-surge valve size, characteristics, stroke time

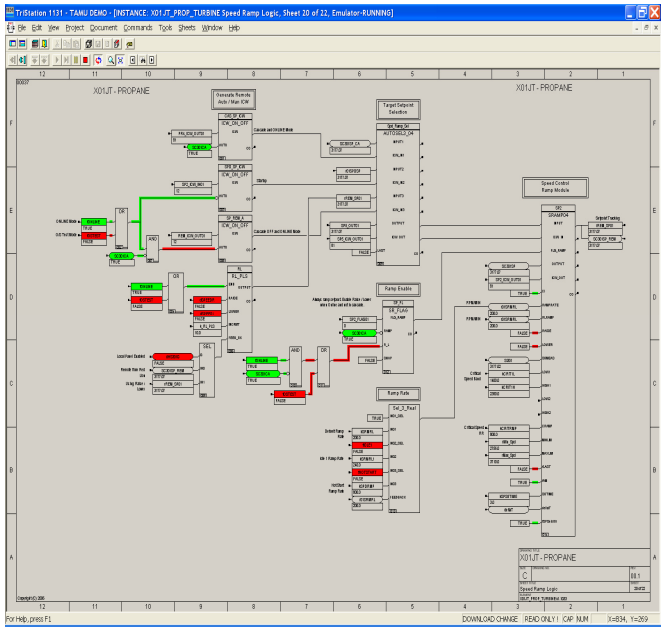
Check system performance at different operating conditions:

- Compressor trips, driver failure, loss of instrument air, etc.
- Valve opening time, changing molecular weight, etc.
- Compressor start-up from cold or hot standby



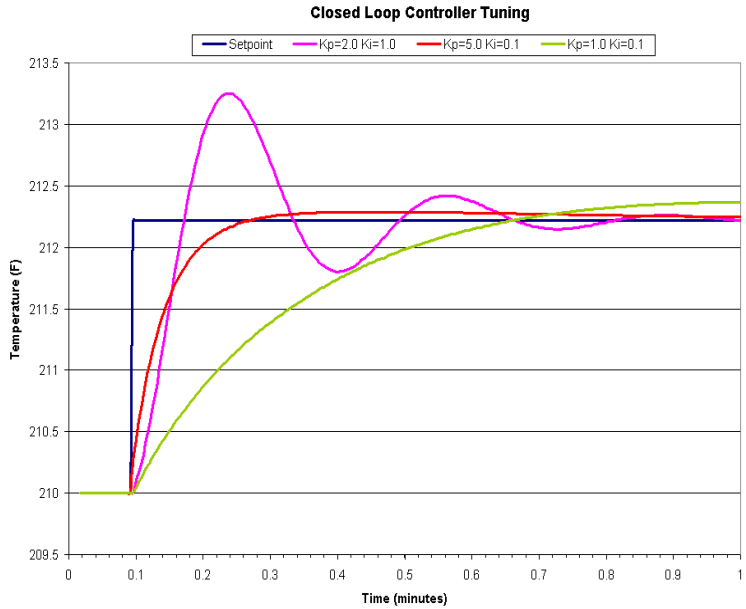
Establish Control Strategy

- Determine the best anti-surge, performance control approaches
- Test decoupling control algorithms
- Establish start-up and shut-down sequencing, start-up guide vane position, T&T valve position



Control Logic Checkout and Tuning

- Determine effectiveness of controls
- Debug control logic on the system rather than in the field
- Establish initial controller tuning
- Evaluate necessary overrides for particular upsets



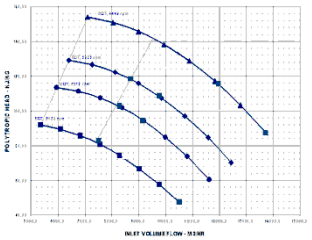
TMC Process Modeling

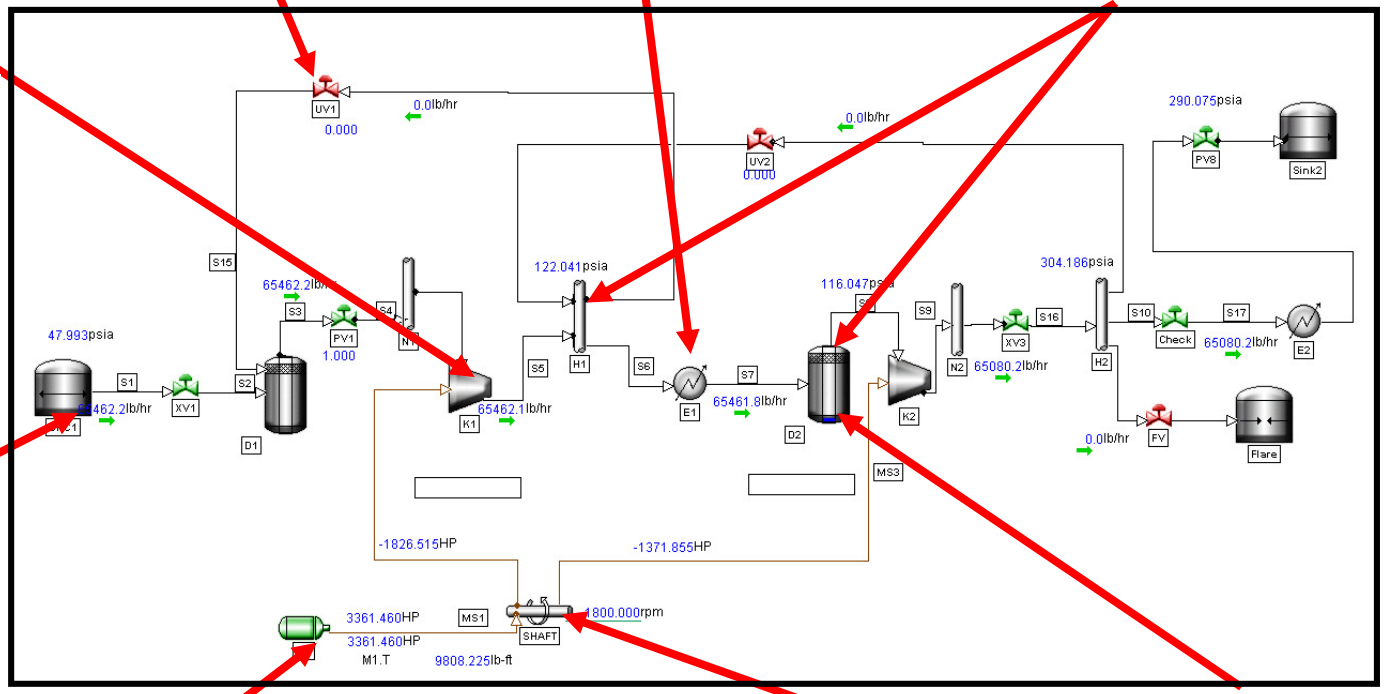
Recycle valve critical flow

Intercoolers

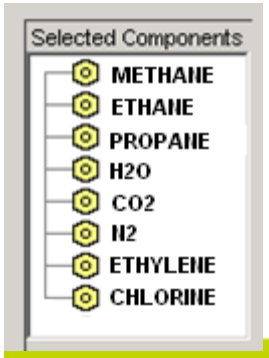
Piping and Knock Out drum volumes for accurate transients

Performance Curves

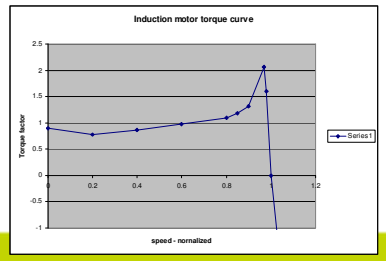




Fluid feed composition



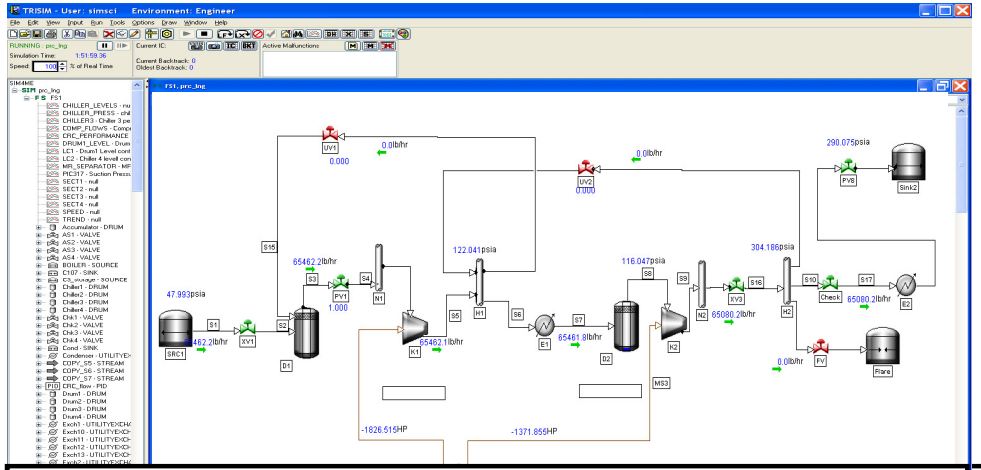
Motor torque curves



Shaft rotating inertia

Vapor-Liquid Equilibrium "Flash"

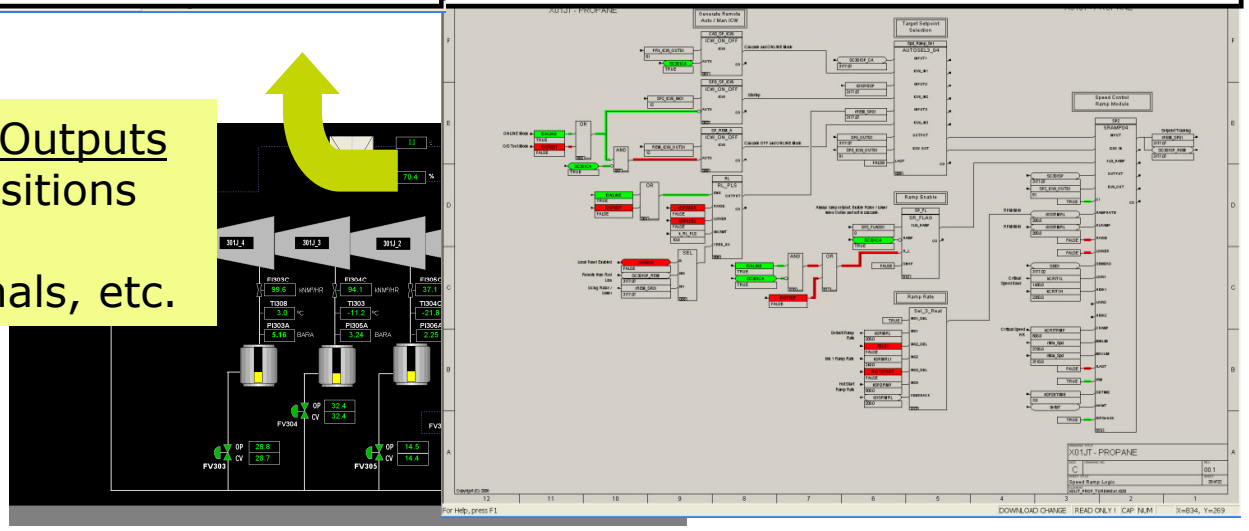
TMC Dynamic Modeling Deliverables



Dynamic Process Model

Transmitter Outputs
- Temperatures
- Pressures
- Flows
- Limit Switches, etc.

Turbomachinery Controls



Controller Outputs
- Valve Positions
- Speed
- Trip Signals, etc.

The Non-Integrated Turbine Control System

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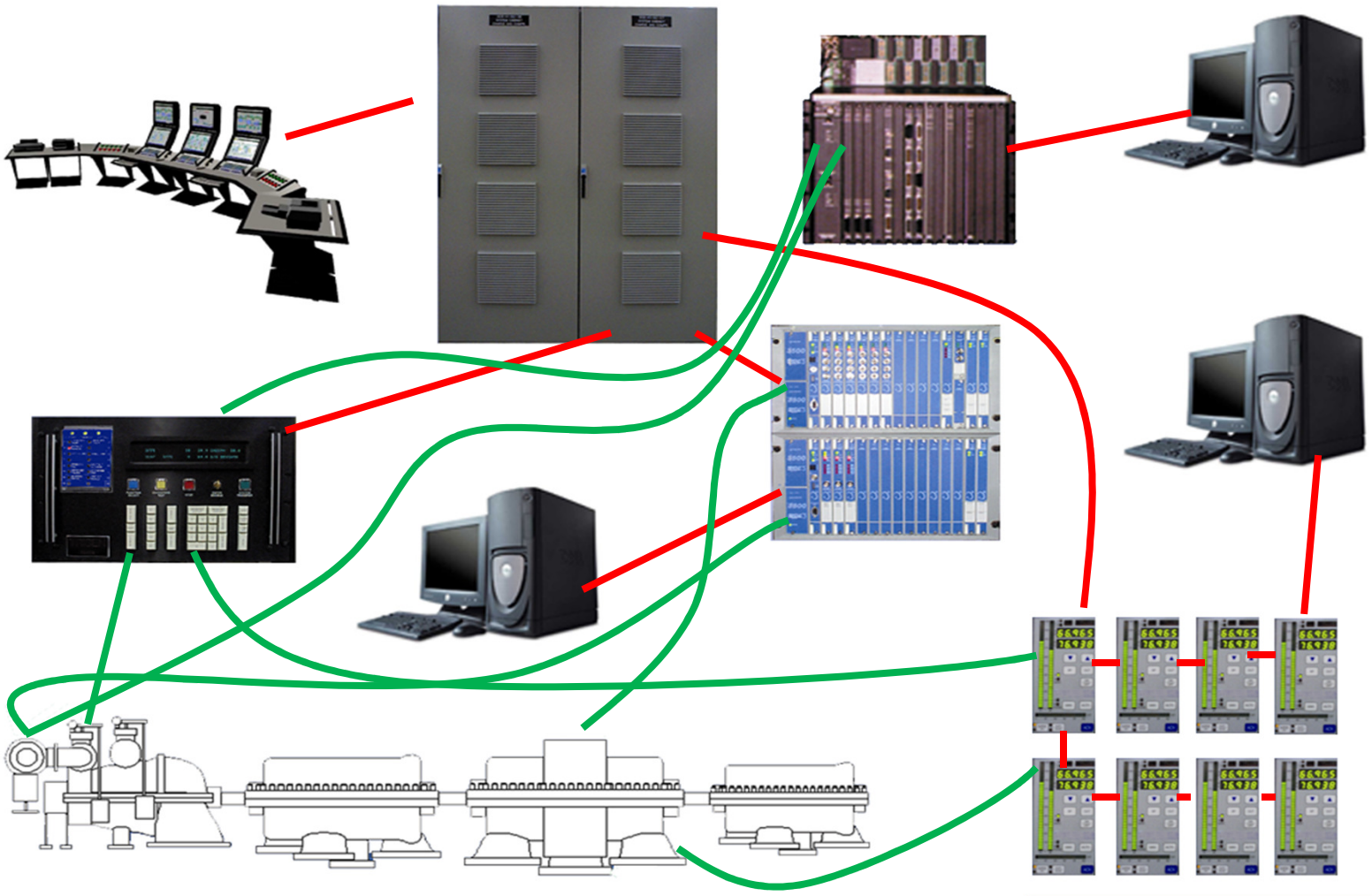
Non-Integrated Turbine Control System

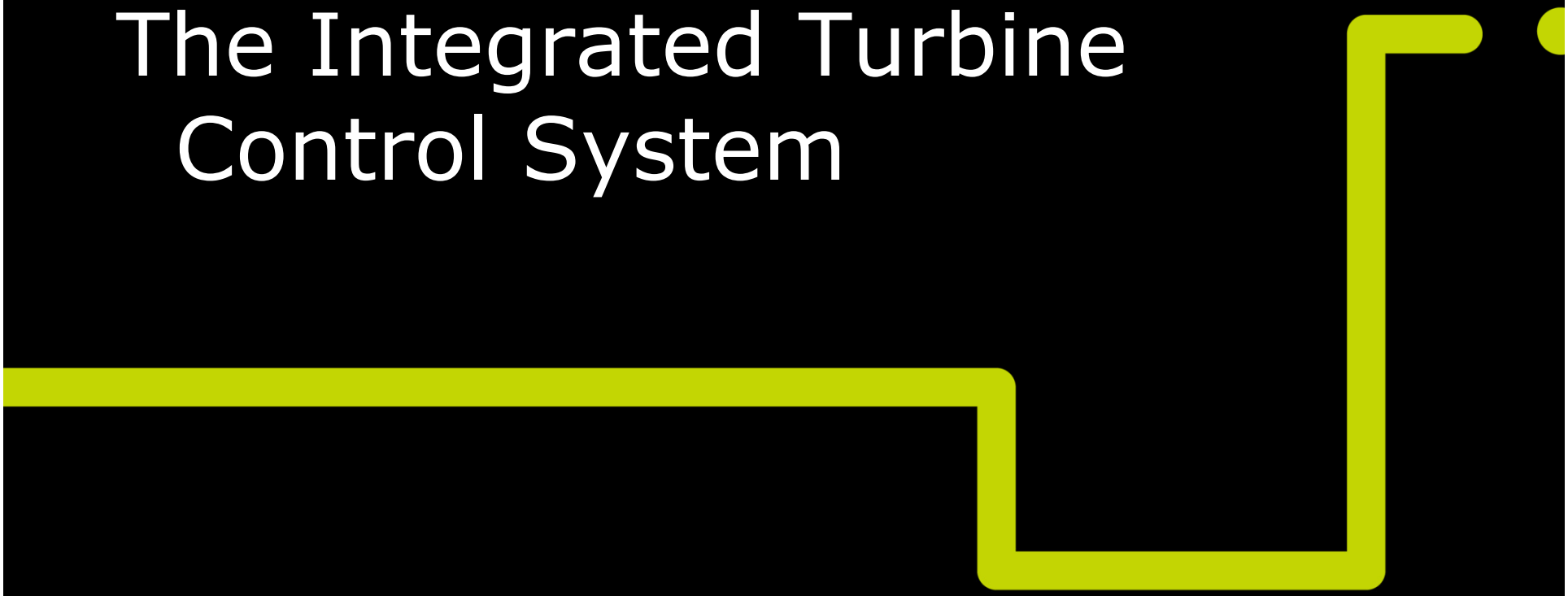


Non-Integrated System

Different vendors are involved in and responsible for control system components:

- Packager provides vibration monitor
- Compressor vendor or EPC contractor provides surge and performance control
- EPC contractor provides interlocks
- Site performs integration testing

The Integrated Turbine Control System



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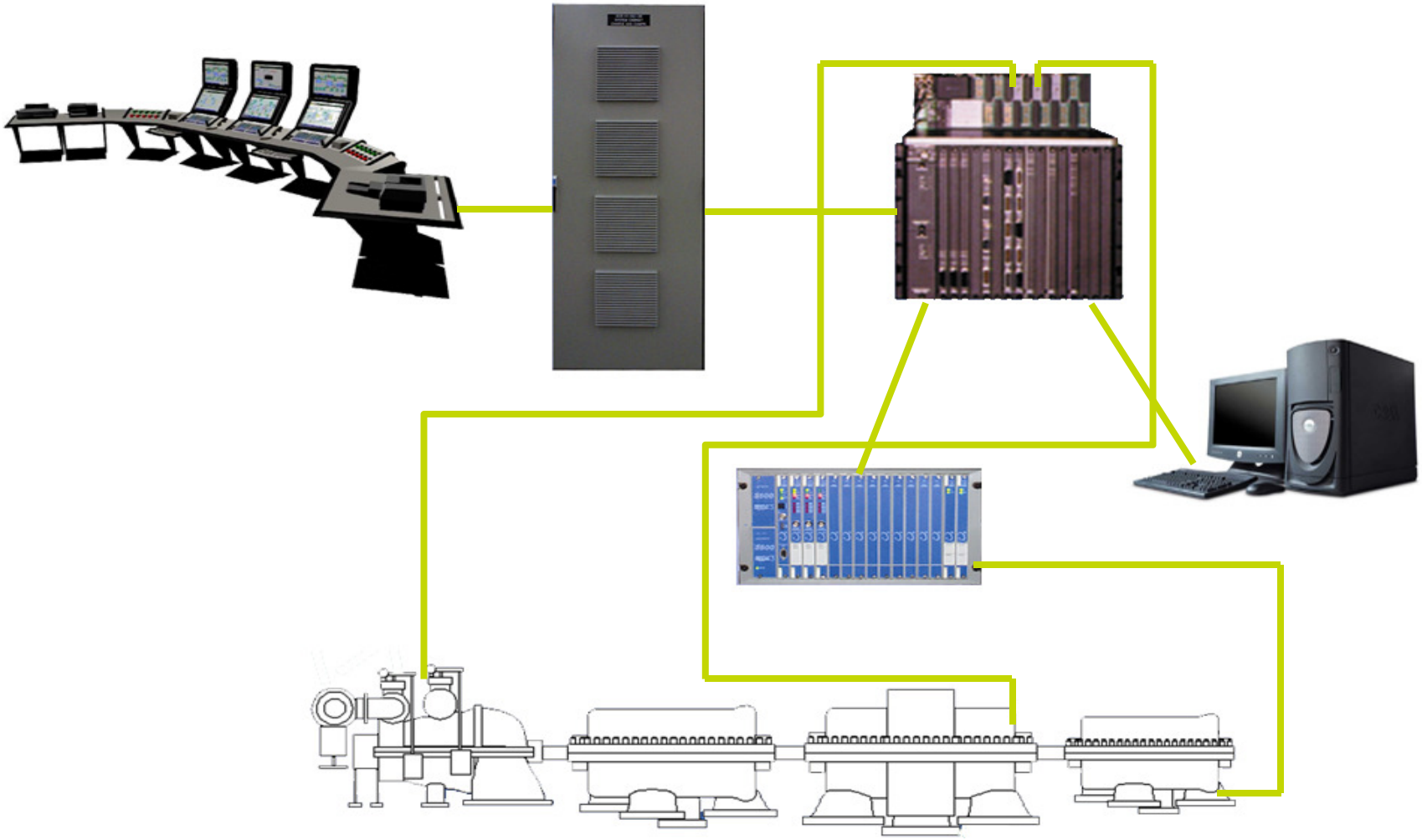
Integrated Control System



Integration Advantages

1. Reduces Space Requirements

2. Lowers Costs For:
   - Procurement
   - Engineering
   - Installation
   - Field Instrumentation

3. Eliminates Controller-Based:
   - Communication Delays
   - Interconnection
   - Conflicts

Rotating Equipment

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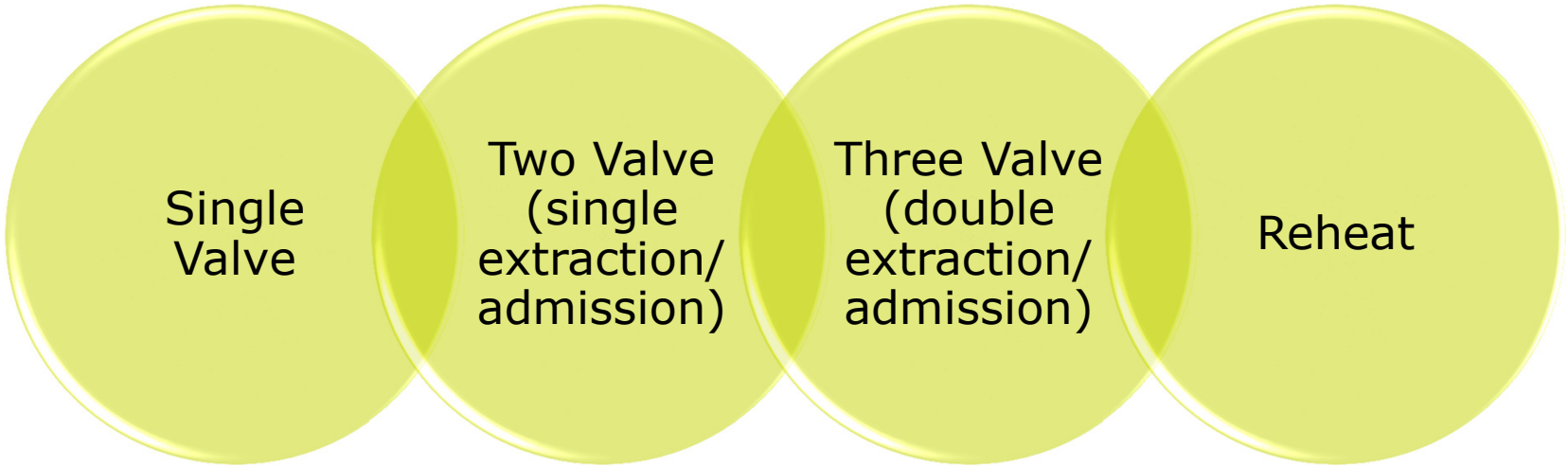
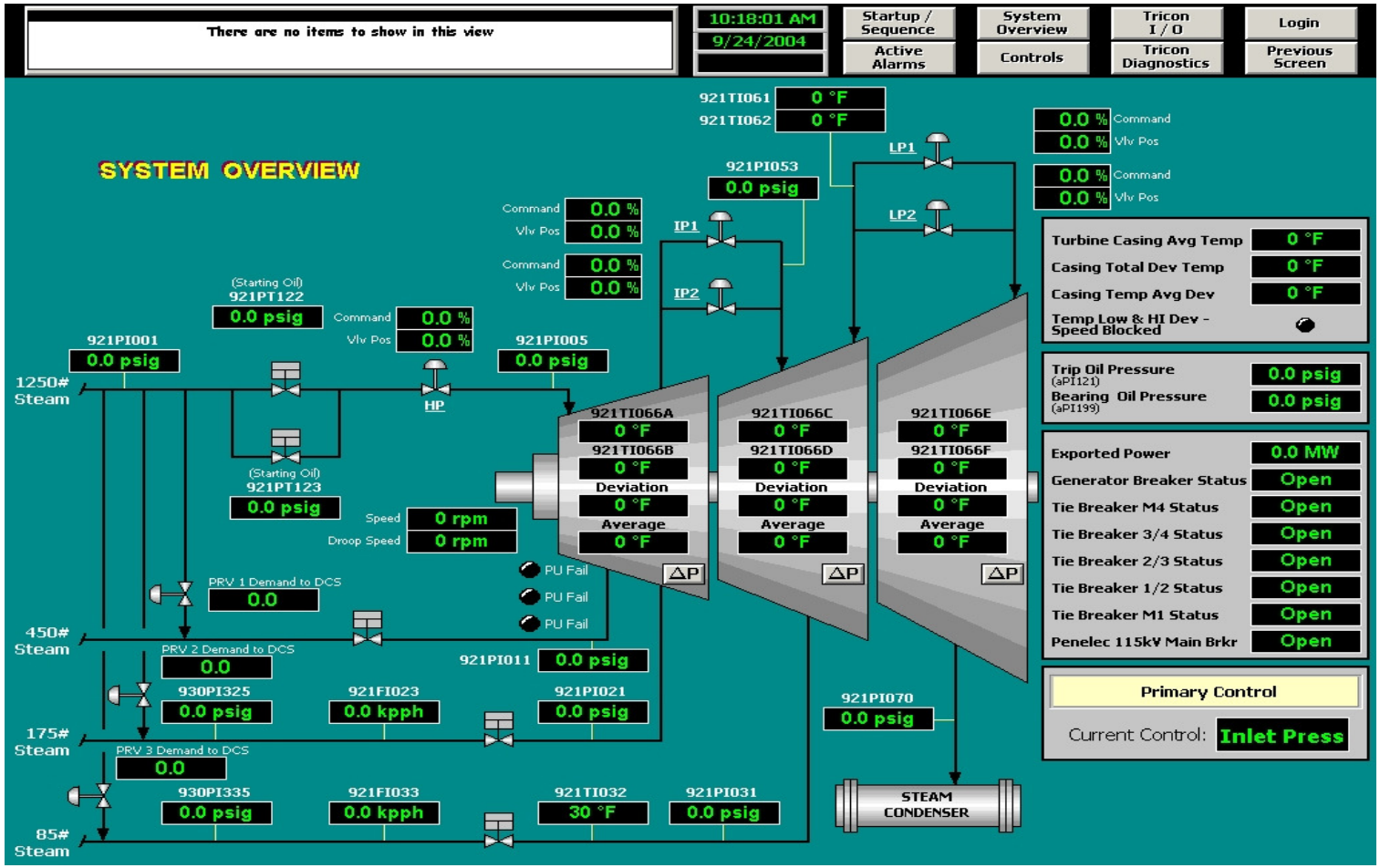
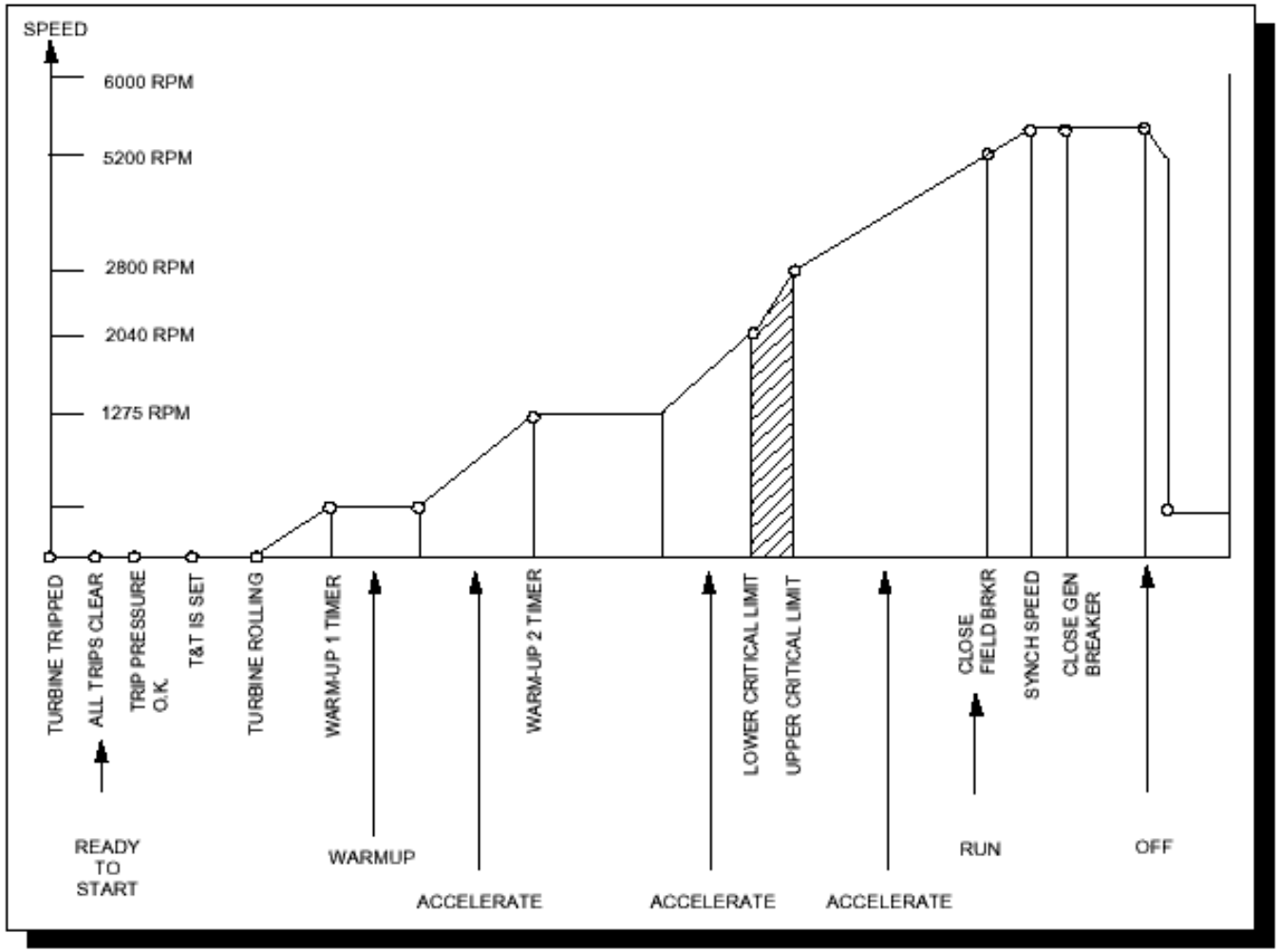
Steam Turbines



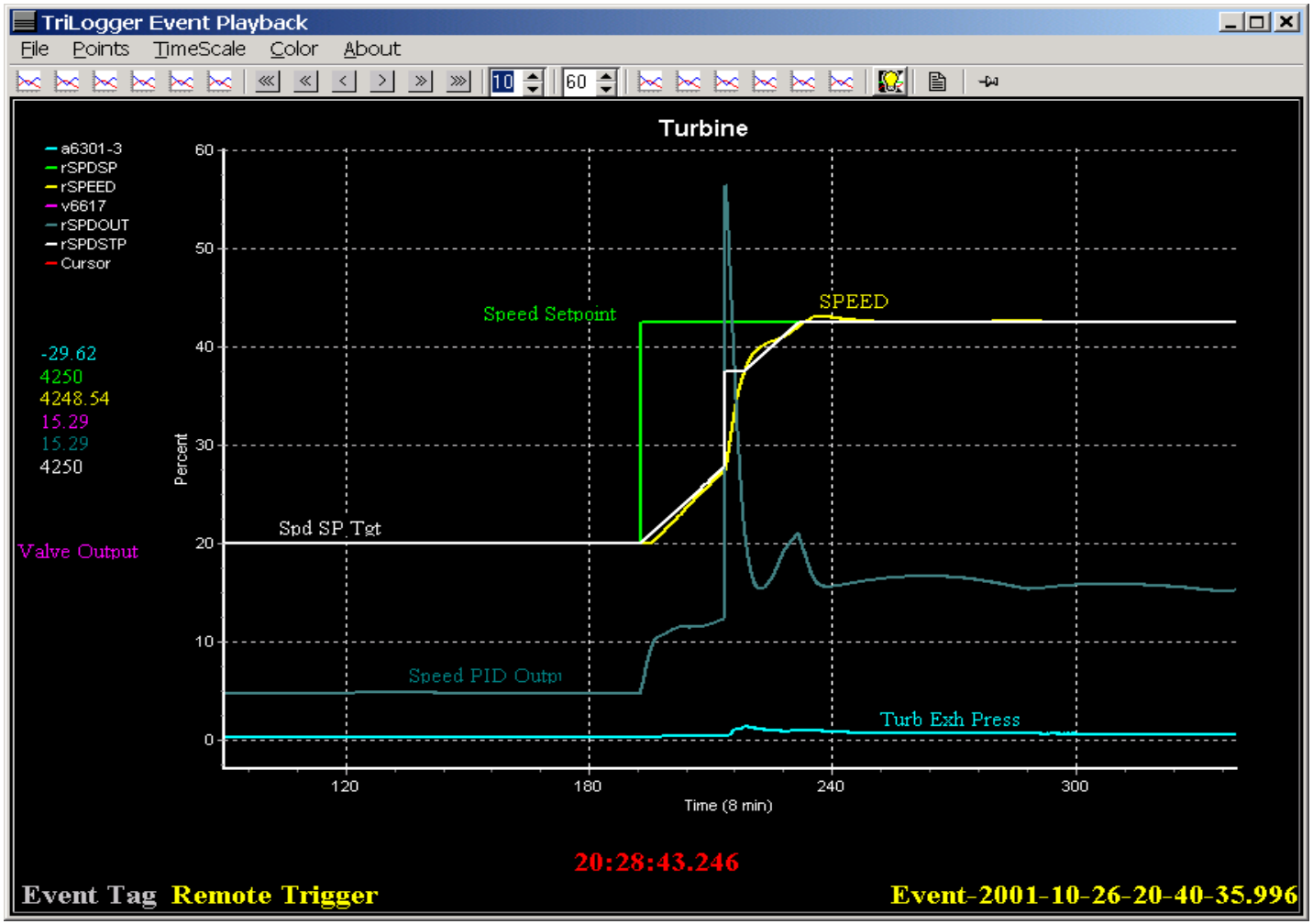
System Overview



Steam Turbine Sequencing



Fast Trending Sequence Capture



Compressor Surge Control Strategies

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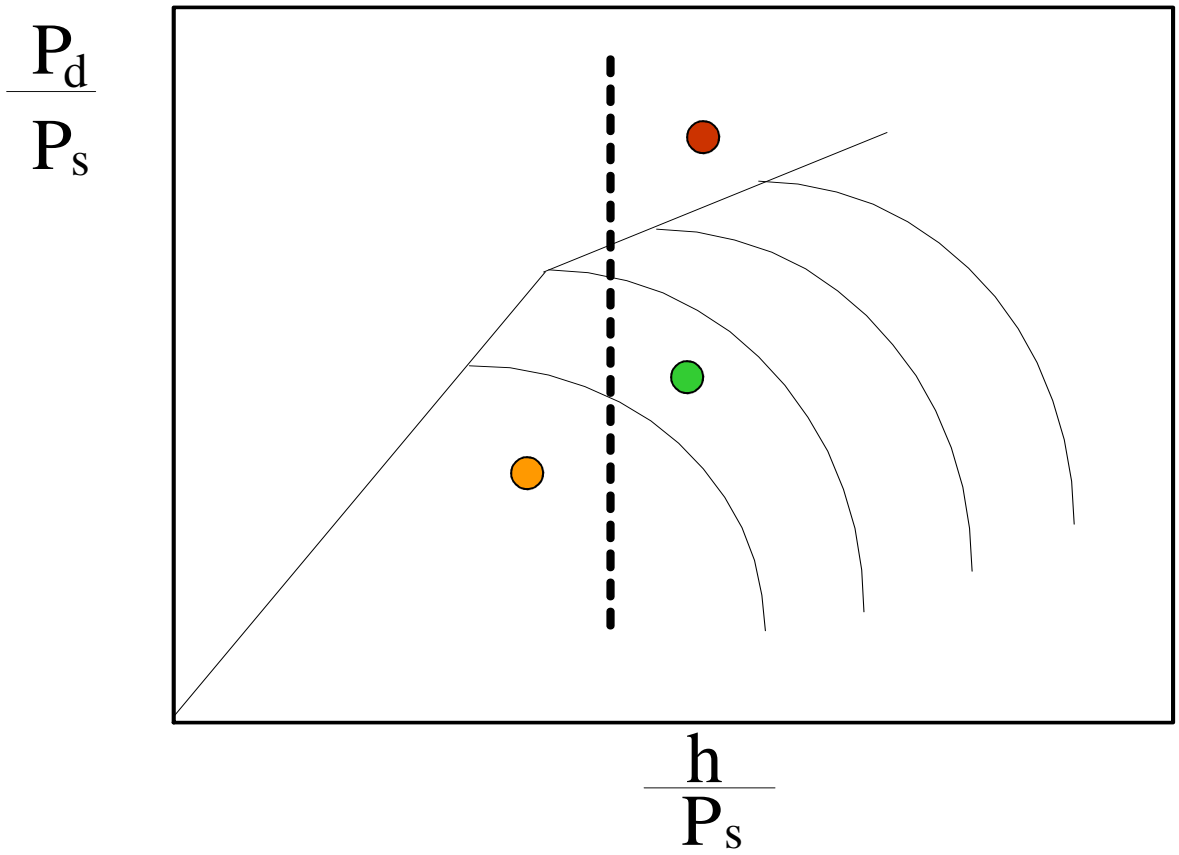
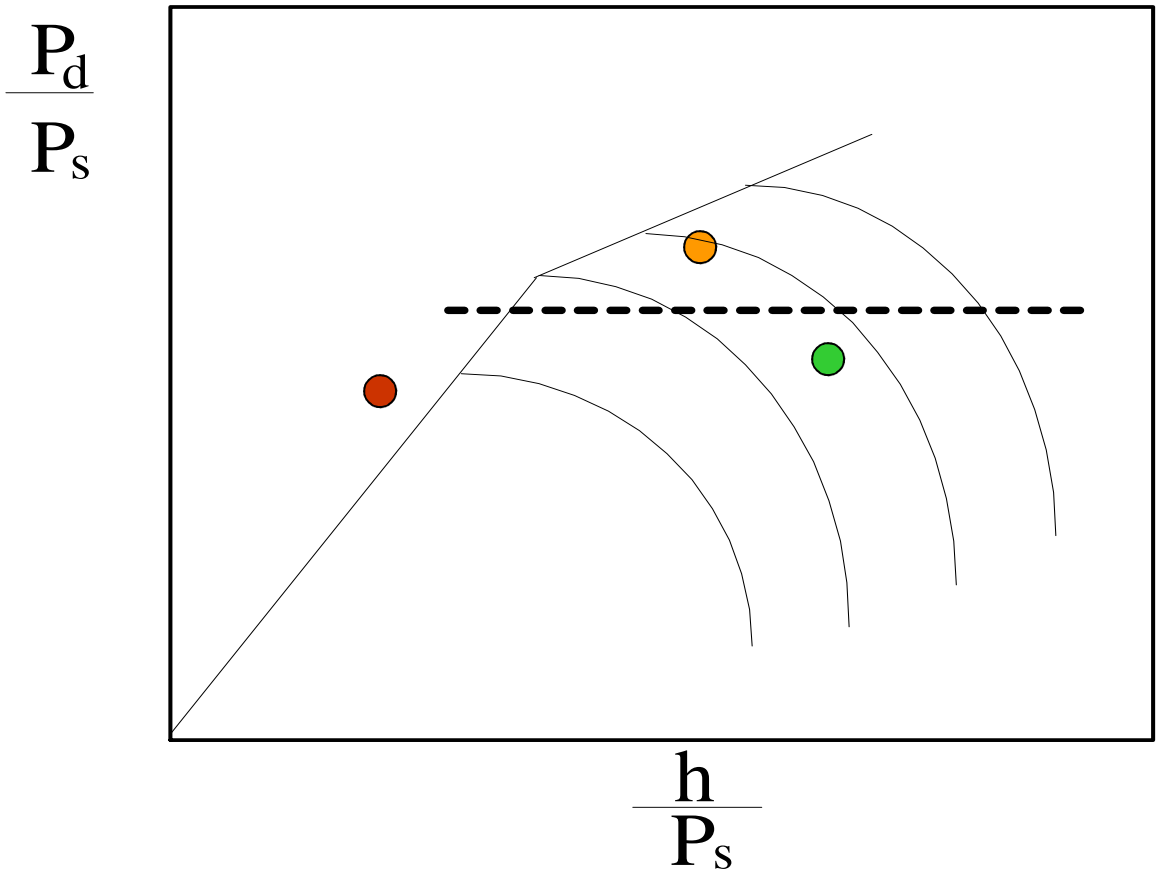
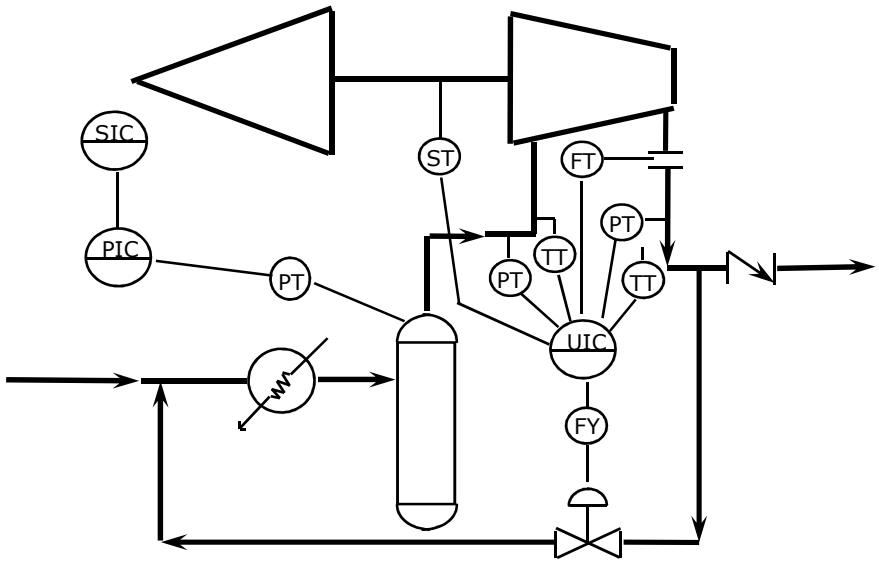
Minimum Flow Control



Maximum Pressure Control

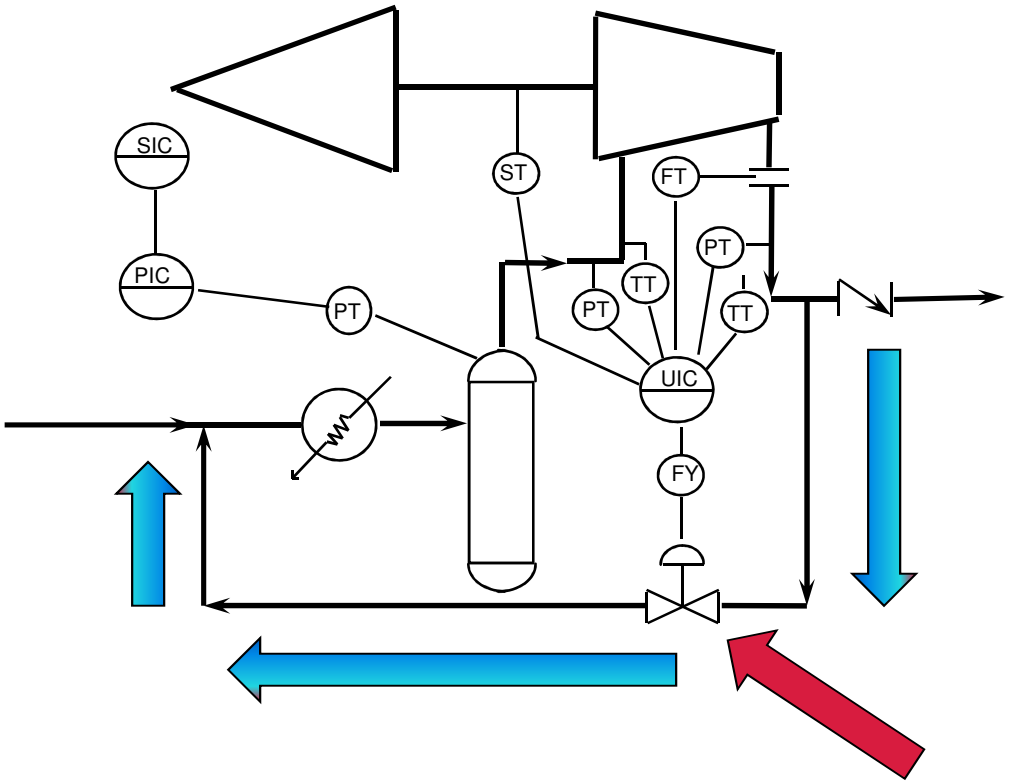


Surge Control Basics



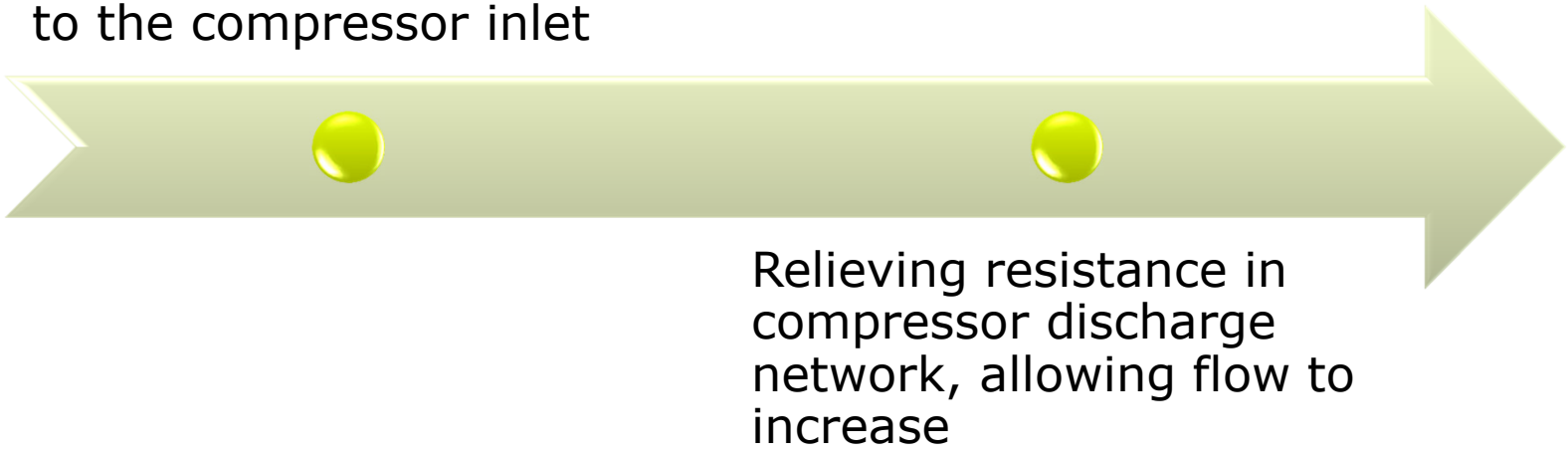
- Define operating point by measuring variables
- Compare with controller setpoint (surge control line)
- Vary recycle (blow-off) to control compressor on surge control line

Recycle Valve? What's That?

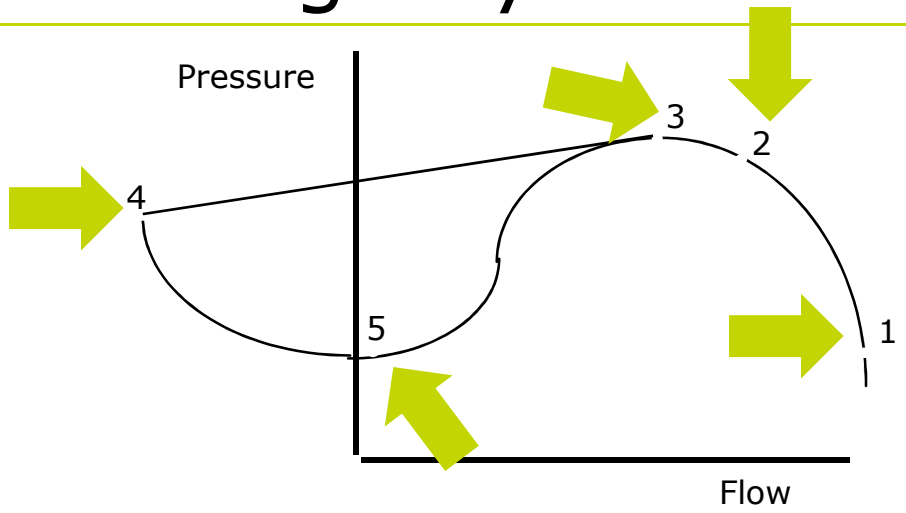


Surge Control Basics

Opening the recycle valve helps the compressor avoid surge by:



The Surge Cycle



1. System resistance increases discharge pressure required (operating point moves up the curve)

2. Operating point nears the surge limit

3. Operating point goes into the surge region

4. Flow reverses as discharge pressure drops

5. Drop in discharge pressure re-establishes forward flow (compressor resumes full flow)

Since resistance has not changed, surge will continue until the cycle is broken.

The Surge Cycle

The operating point can move from stability into surge in fewer than 50 milliseconds.

A complete surge cycle takes from 1/2 to 3 seconds, depending on compressor size and piping volume.

Why is Surge Bad?

It causes process upset because of flow reversals.

It damages seals.

It causes catastrophic failure of the compressor when it is severe.

How Can Surge be Prevented?

- By accurately determining the operating point
- Through the surge controller's anticipatory action
- By opening the recycle valve to decrease pressure ratio and increase flow through compressor

Control Features

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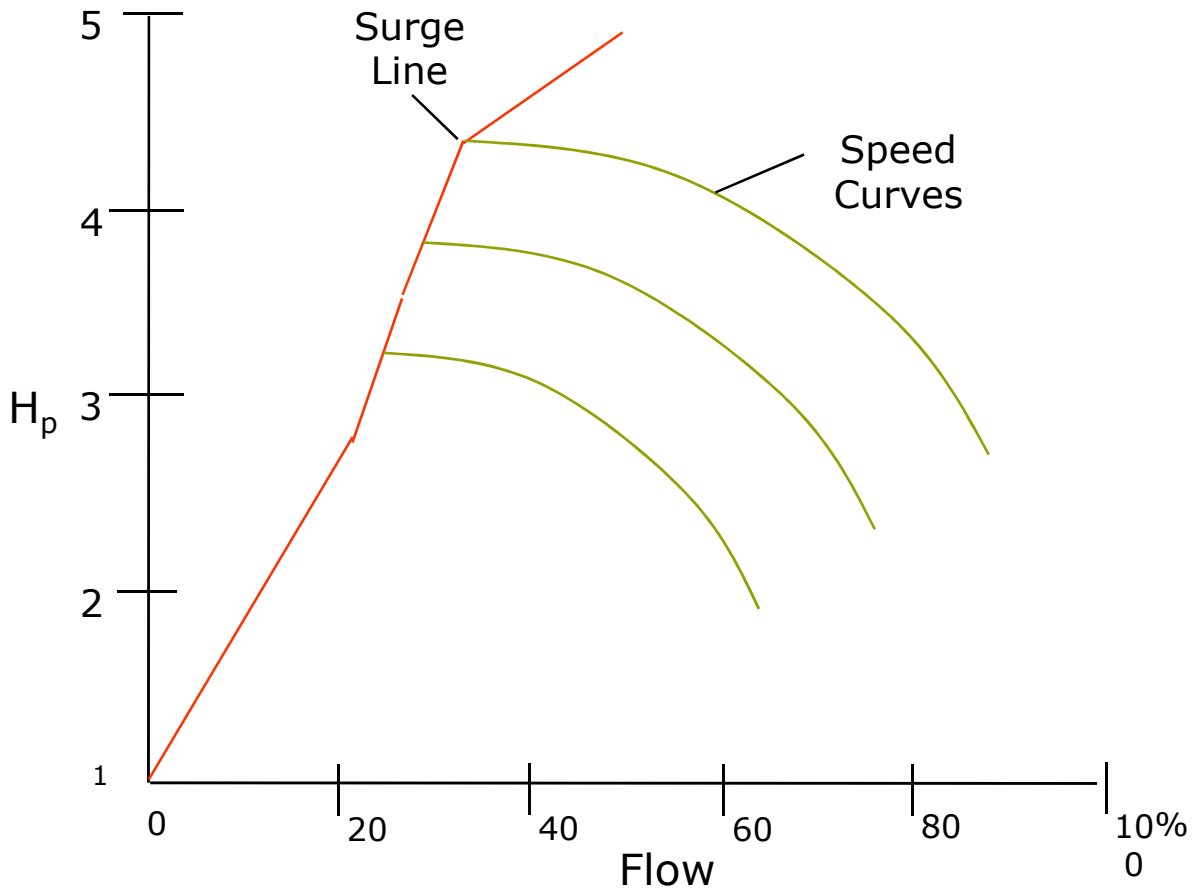
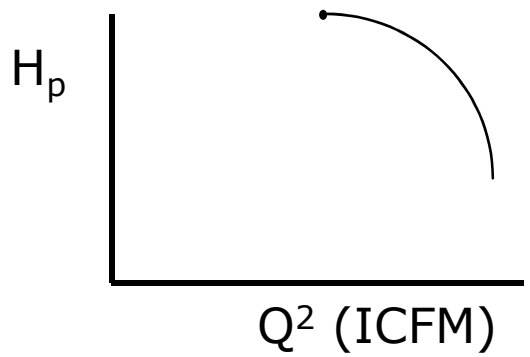
Triconex Surge Control Features

- **Universal Surge Line**
- Surge Controller Setpoint Hover
- Automatic Adjustment of Safety Margin
- Independent Proportional Term
- Adaptive Tuning
- Fast Opening/Slow Closing of Recycle Valve
- Manual Recycle Valve Control Options

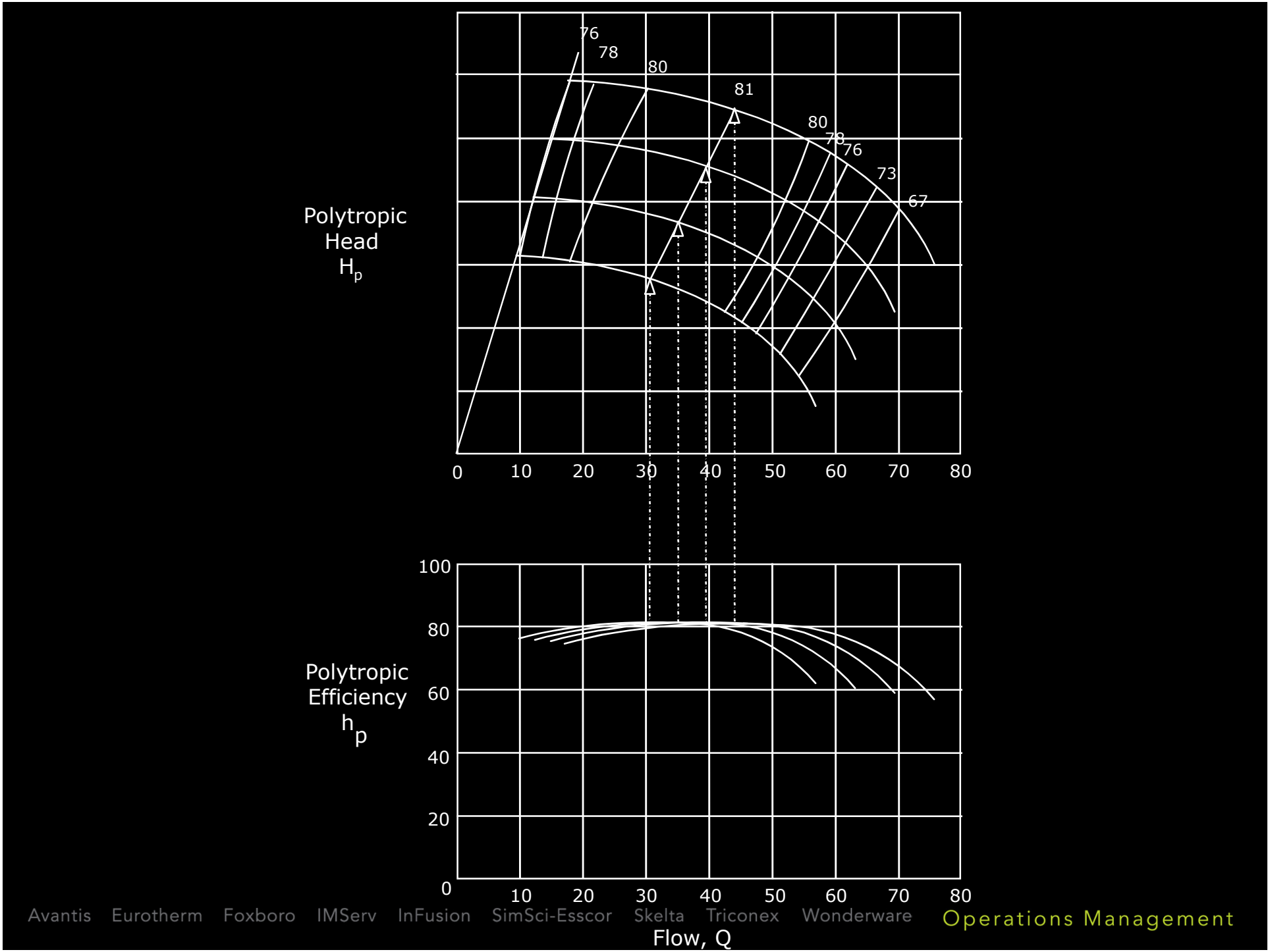
Traditional Surge Line



Compressor Performance

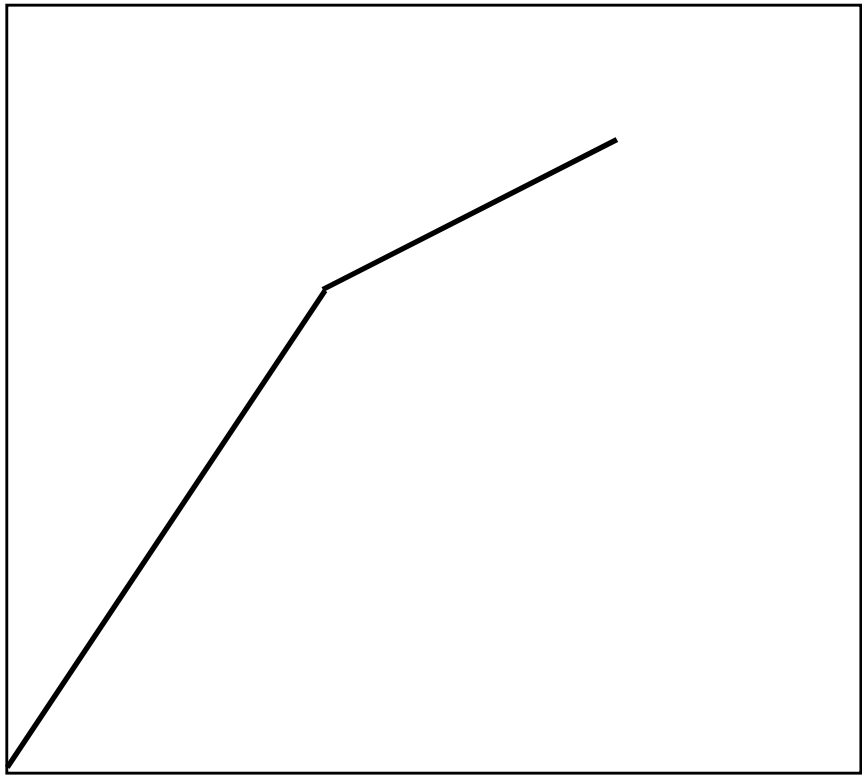


- The compressor performance map can be redrawn as the polytropic head vs. the inlet volume flow squared.
- The relationship between head and flow is not changed by this modification.


Polytropic
Head
H_p
76
78
80
81
80
78
76
73
67
0
10
20
30
40
50
60
70
80
Polytropic
Efficiency
h_p
100
80
60
40
20
0
10
20
30
40
50
60
70
80
Flow, Q

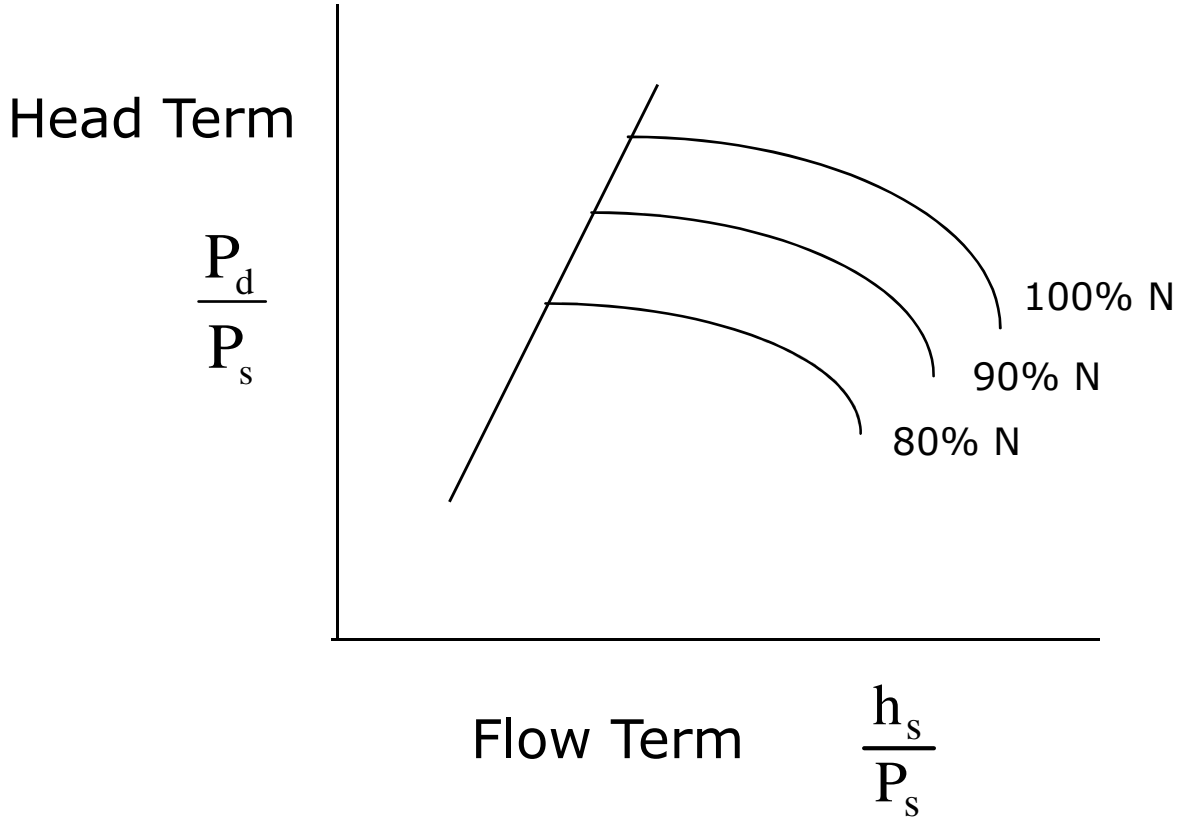
The Universal Surge Curve

$$\left(\frac{P_2}{P_1}\right) - 1$$



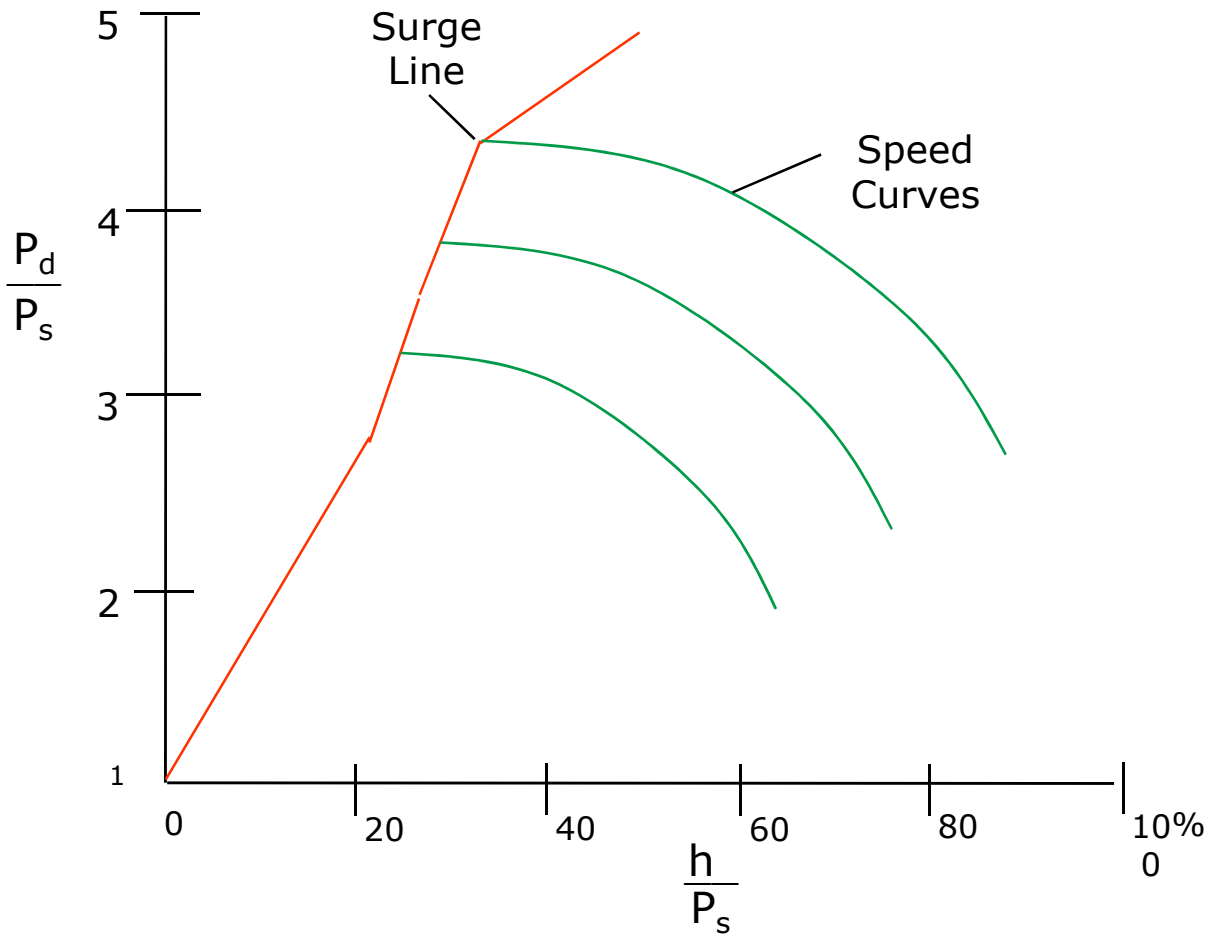
$$\frac{h}{P_1}$$

Universal Surge Line

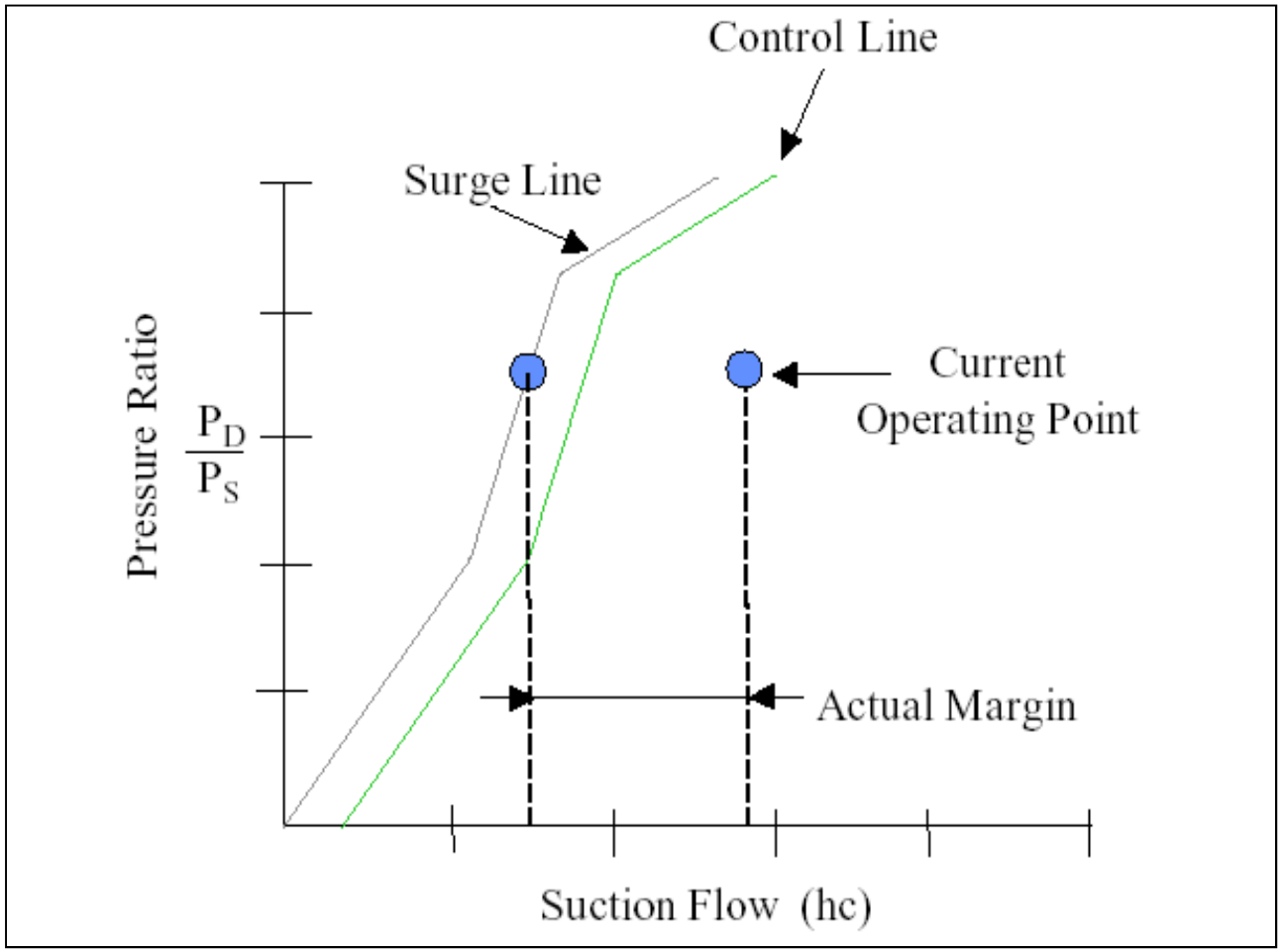


The universal surge line is valid for all changes in molecular weight and suction pressure.

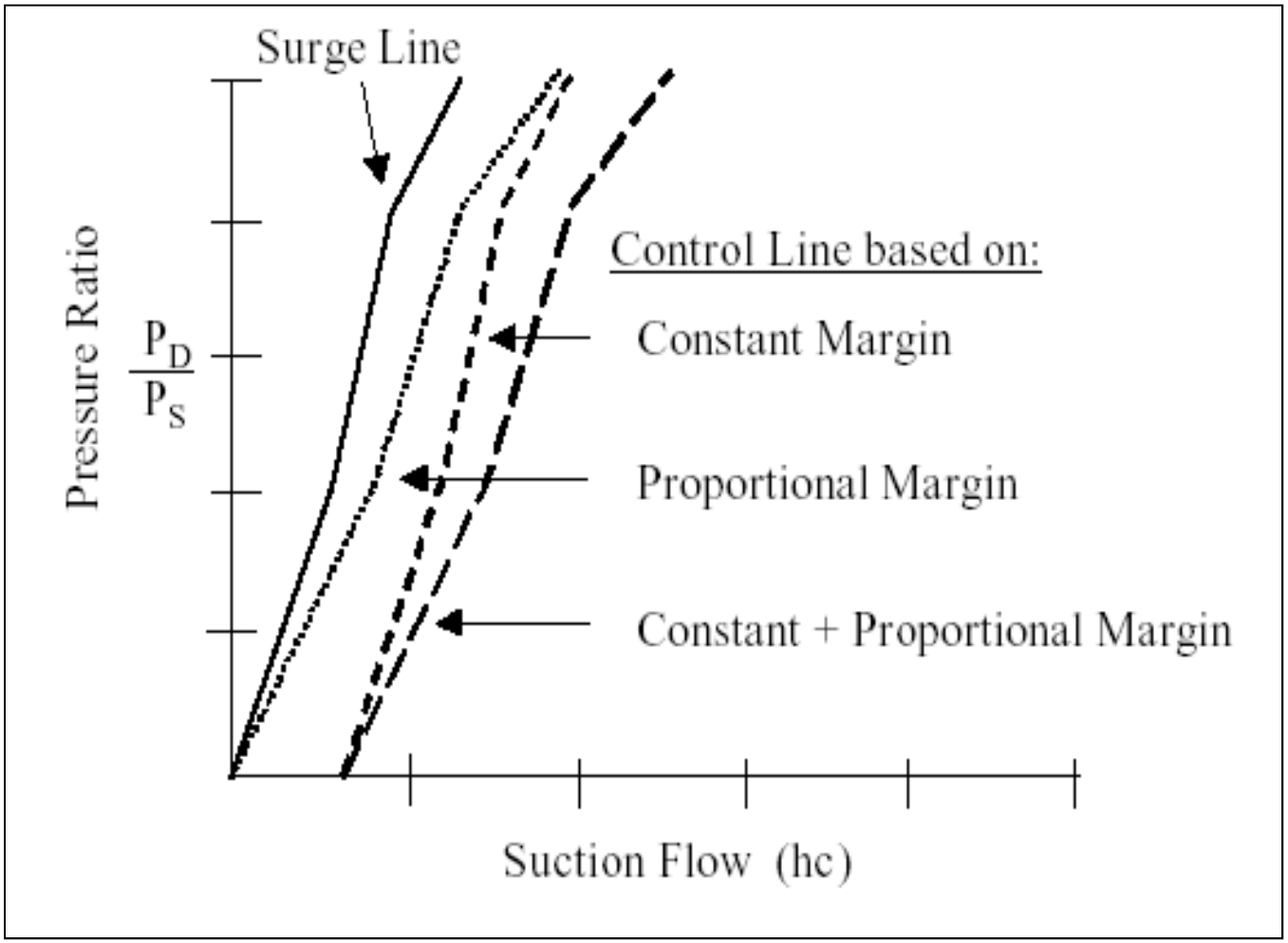
Universal Surge Line



Surge Margin



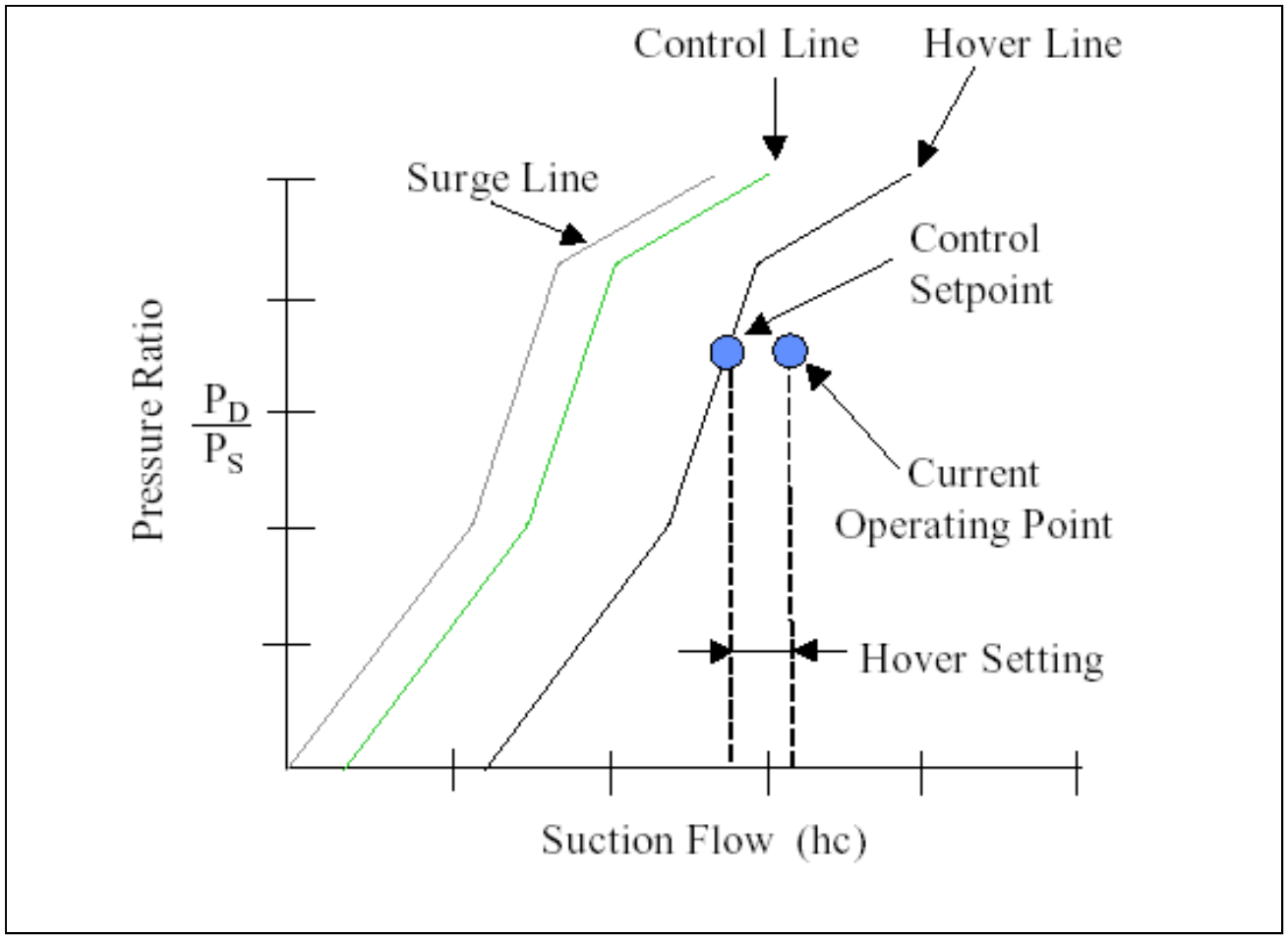
Safety Margin



Surge Control Features

- Universal Surge Line
- **Surge Controller Setpoint Hover**
- Automatic Adjustment of Safety Margin
- Independent Proportional Term
- Adaptive Tuning
- Fast Opening/Slow Closing of Recycle Valve
- Manual Recycle Valve Control Options

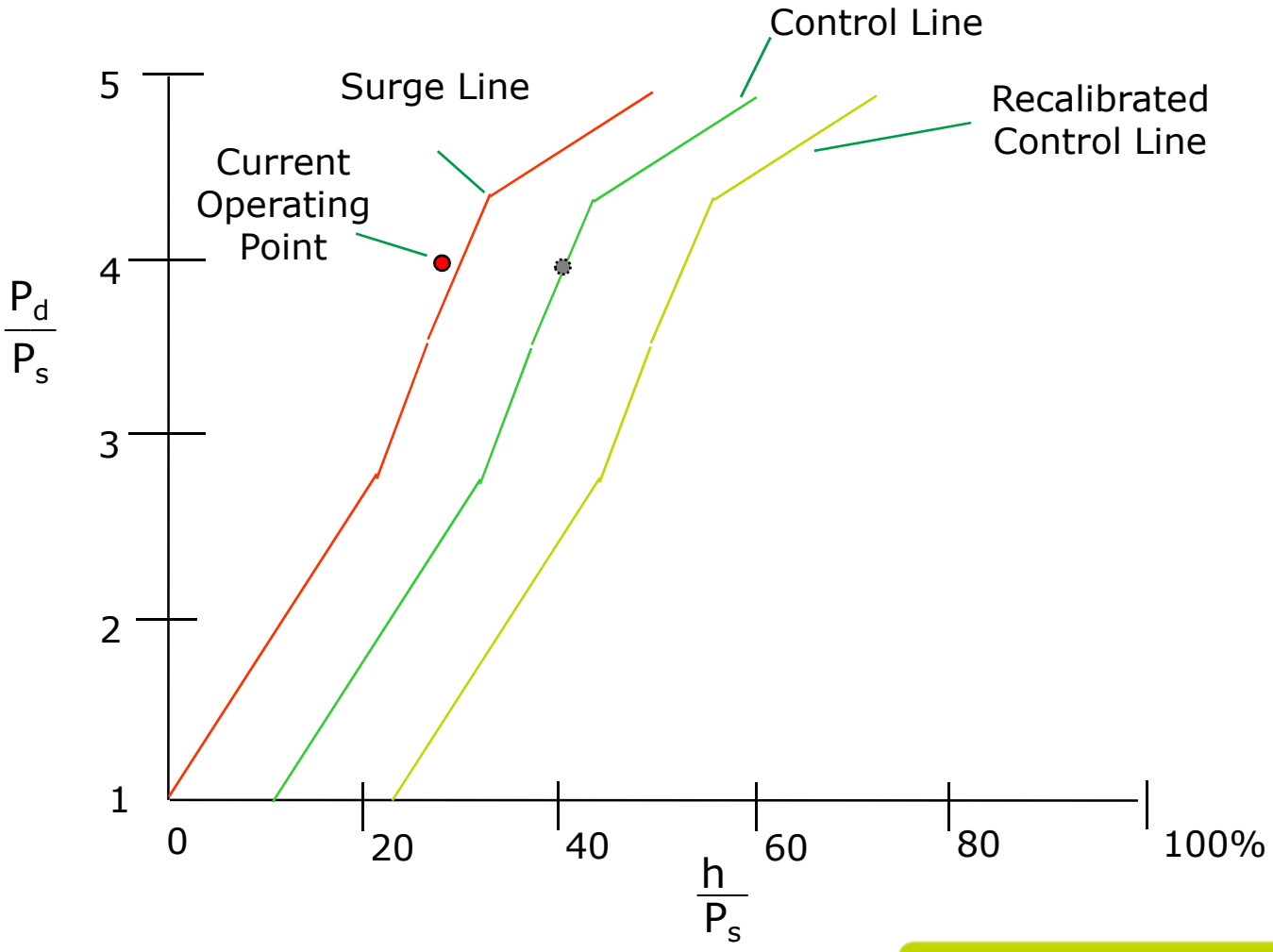
Setpoint Hover Feature



Surge Control Features

- Universal Surge Line
- Surge Controller Setpoint Hover
- **Automatic Adjustment of Safety Margin**
- Independent Proportional Term
- Adaptive Tuning
- Fast Opening/Slow Closing of Recycle Valve
- Manual Recycle Valve Control Options

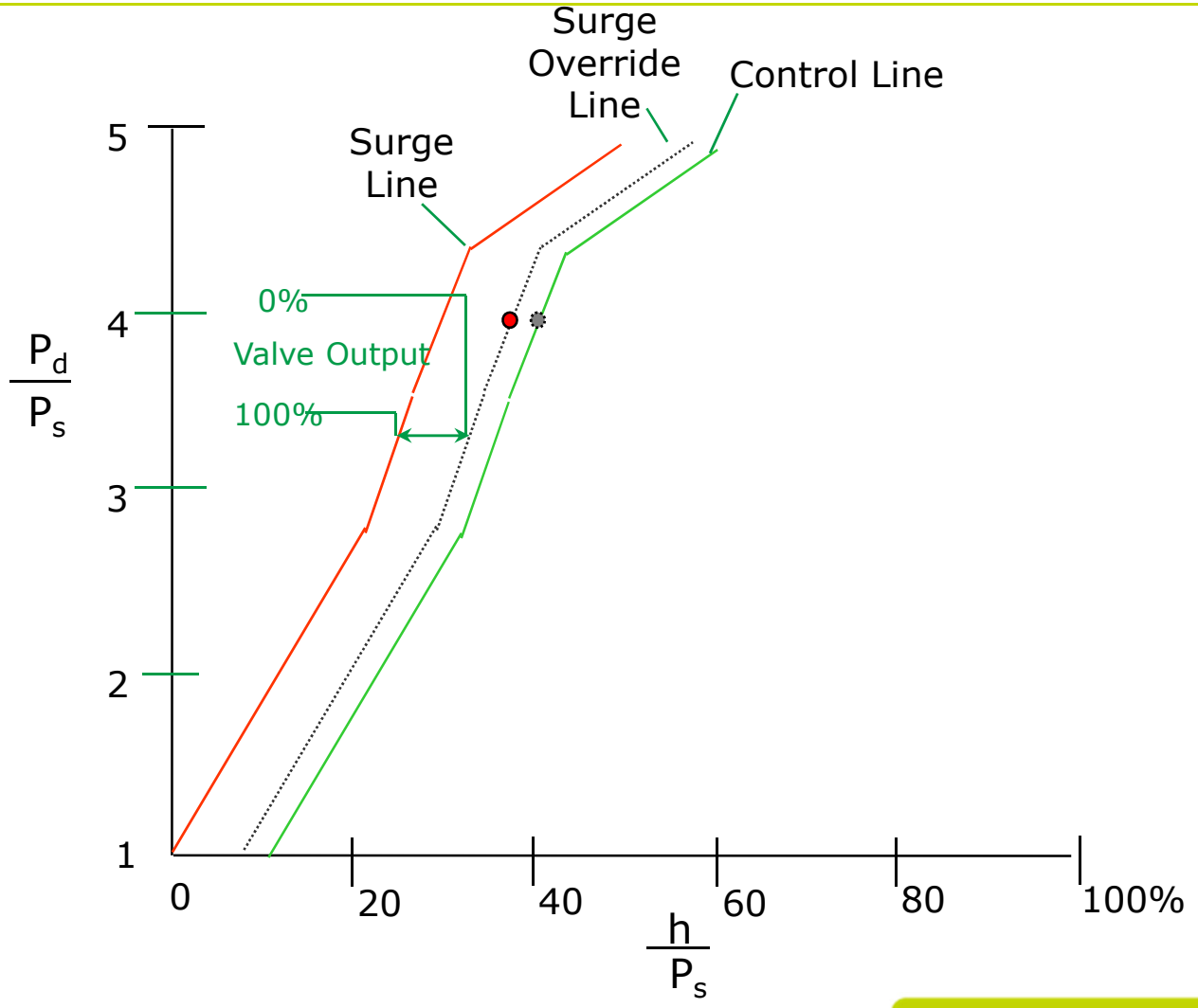
Control Line Recalibration



Surge Control Features

- Universal Surge Line
- Surge Controller Setpoint Hover
- Automatic Adjustment of Safety Margin
- **Independent Surge Override**
- Adaptive Tuning
- Fast Opening/Slow Closing of Recycle Valve
- Manual Recycle Valve Control Options

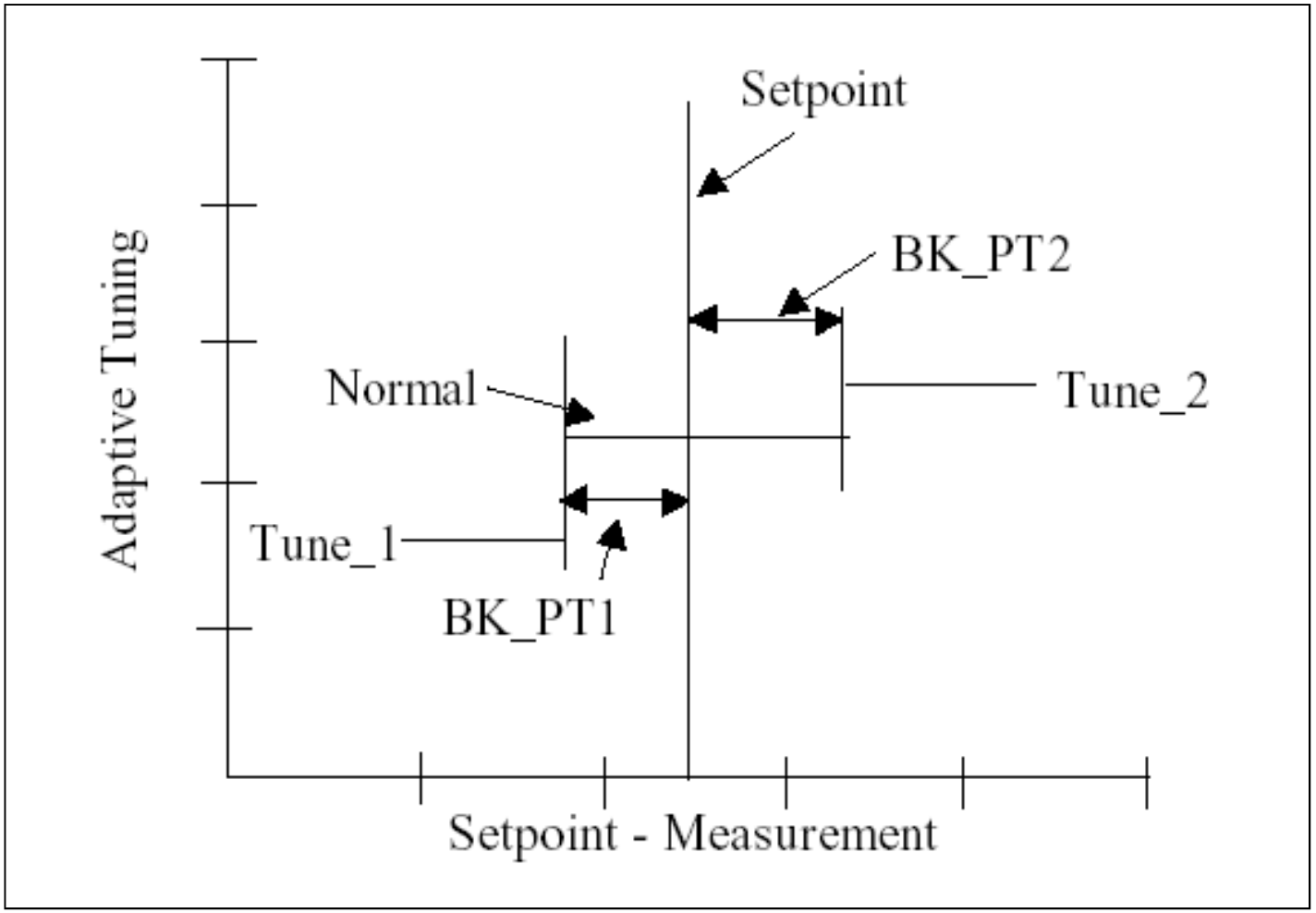
Surge Override



Surge Control Features

- Universal Surge Line
- Surge Controller Setpoint Hover
- Automatic Adjustment of Safety Margin
- Independent Surge Override
- **Adaptive Tuning**
- Fast Opening/Slow Closing of Recycle Valve
- Manual Recycle Valve Control Options

Adaptive Tuning



Surge Control Features

- Universal Surge Line
- Surge Controller Setpoint Hover
- Automatic Adjustment of Safety Margin
- Independent Surge Override
- Adaptive Tuning
- **Fast Opening/Slow Closing of Recycle Valve**
- Manual Recycle Valve Control Options

Recycle Valve Opening/Closing

- Fast Opening

  Quickly responds to surge condition, but does not exceed response time of system

- Slow Closing

  Allows turbine speed controller/process cascade controller to smoothly adjust to new process operating conditions

Surge Control Features

- Universal Surge Line
- Surge Controller Setpoint Hover
- Automatic Adjustment of Safety Margin
- Independent Surge Override
- Adaptive Tuning
- Fast Opening/Slow Closing of Recycle Valve
- **Manual Recycle Valve Control Options**

Manual Recycle Valve Control

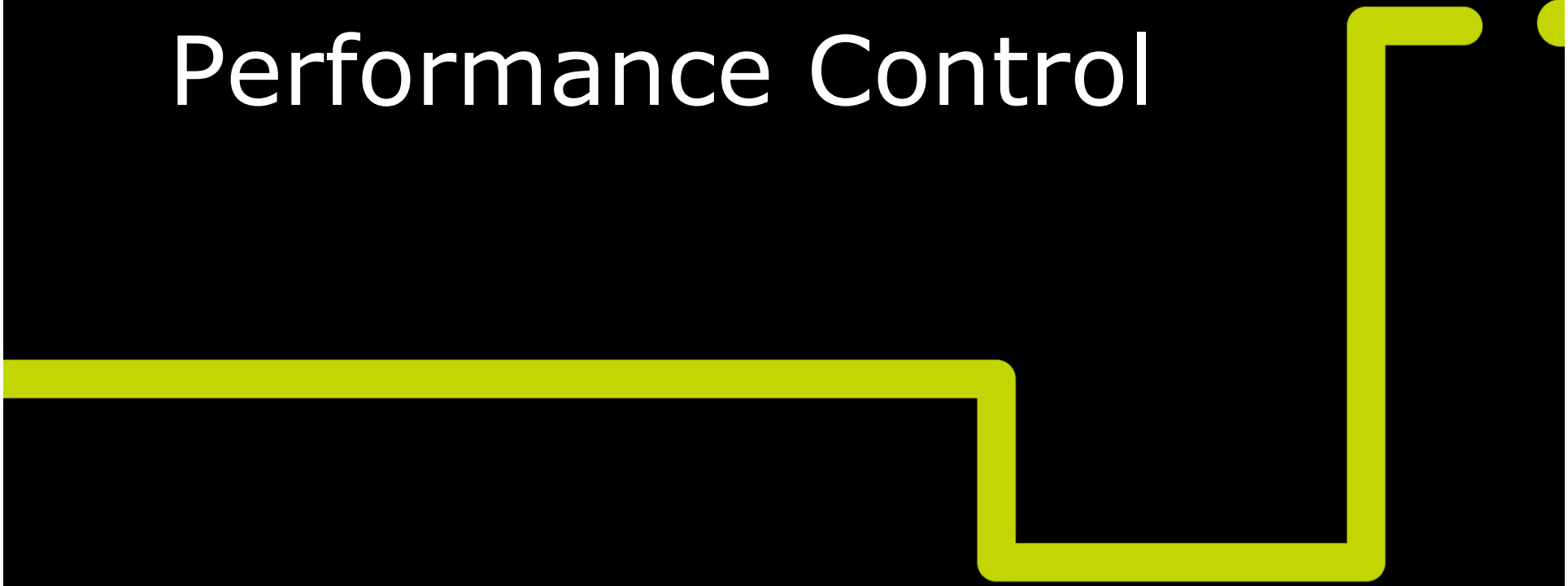
Partial Authority

- Operator is allowed to open the recycle valve only when his/her command is higher than the surge controller demand
- Operator cannot close the recycle valve below the surge controller demand

Full Authority

- Operator is allowed to close and open the recycle valve with no surge protection
- Used to stroke test recycle valve prior to start-up
- Used in some fallback scenarios

Performance Control



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Performance Control

The objective of a control loop is to operate a process:

- Within the operating zone
- In safe and stable manner with minimum human interaction
- In a way that achieves operational design objectives with optimum efficiency

Performance Control

How can we manipulate the capacity through the compressor to influence the process?

Performance control can be accomplished in three ways:

1. By varying compressor speed via turbine or variable frequency drive (VFD)
2. By using an inlet throttling valve for a constant speed machine
3. By opening and closing the anti-surge valve (not very efficient)

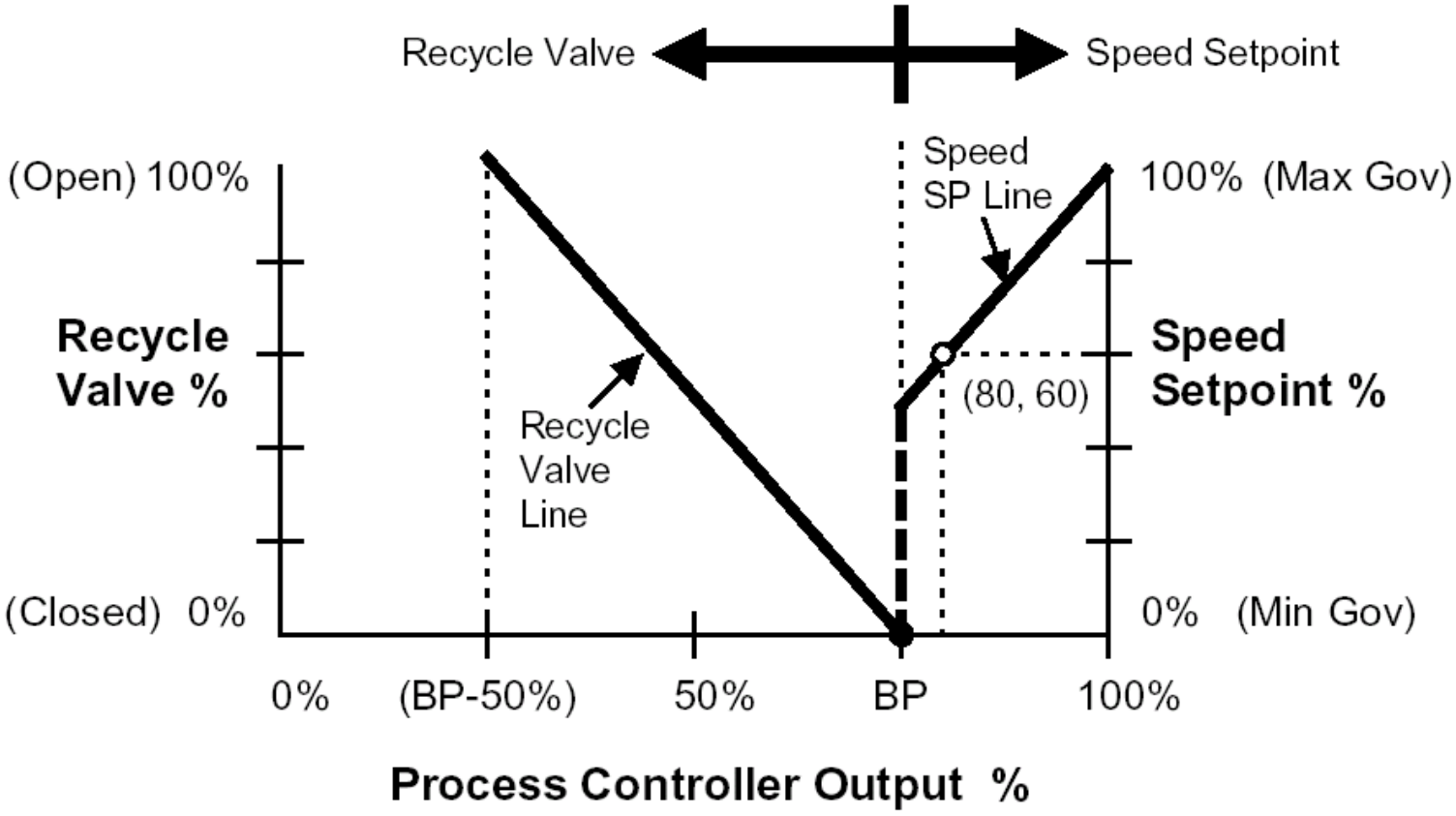
Decoupling Capacity Control

Decoupling Capacity Control

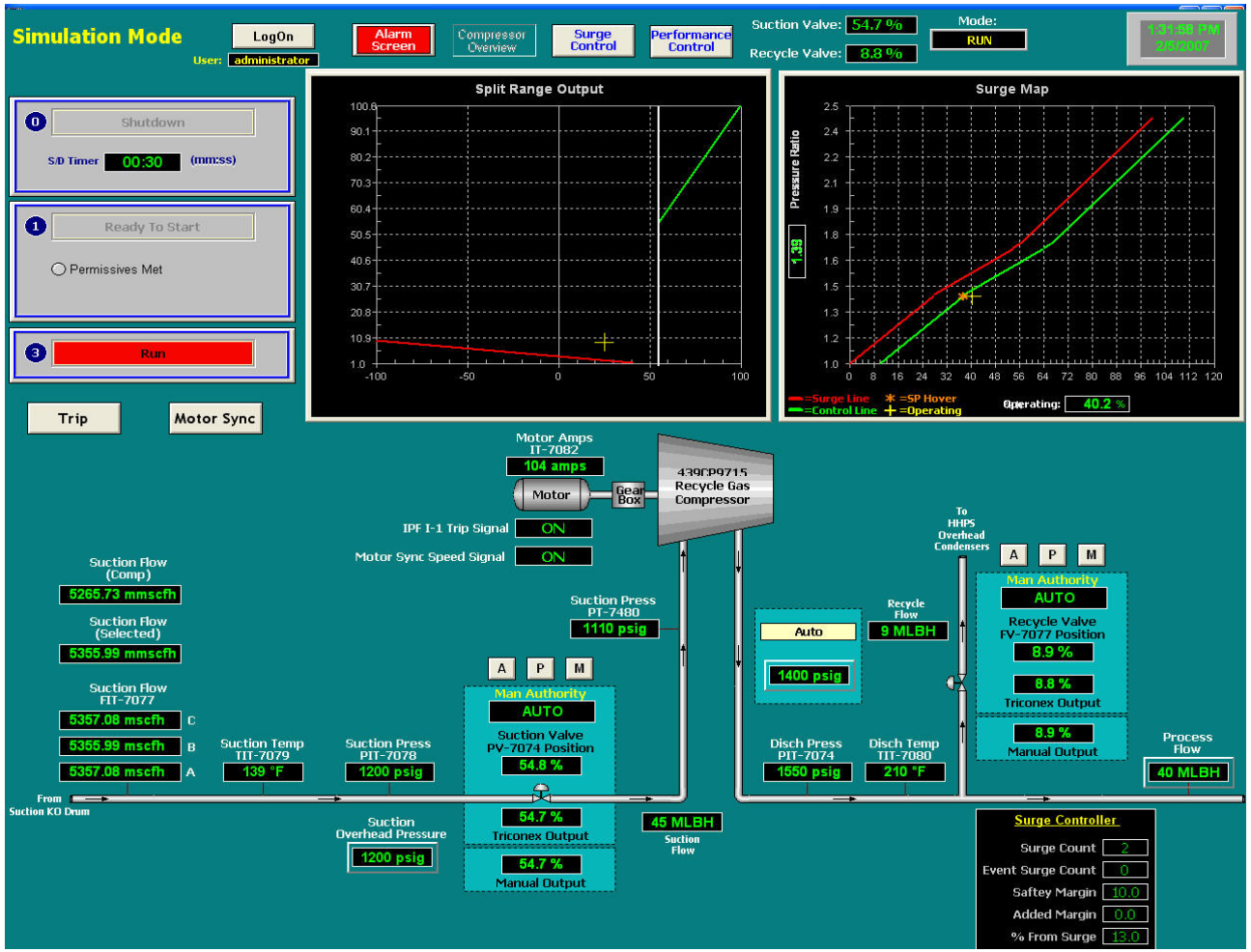
The decoupling algorithm does the following:

- Absorbs fast load changes until compressor speed/process valve can respond
- Prevents capacity control from driving compressor into surge
- Decouples performance controller and surge controller to prevent undesired interaction at low rates

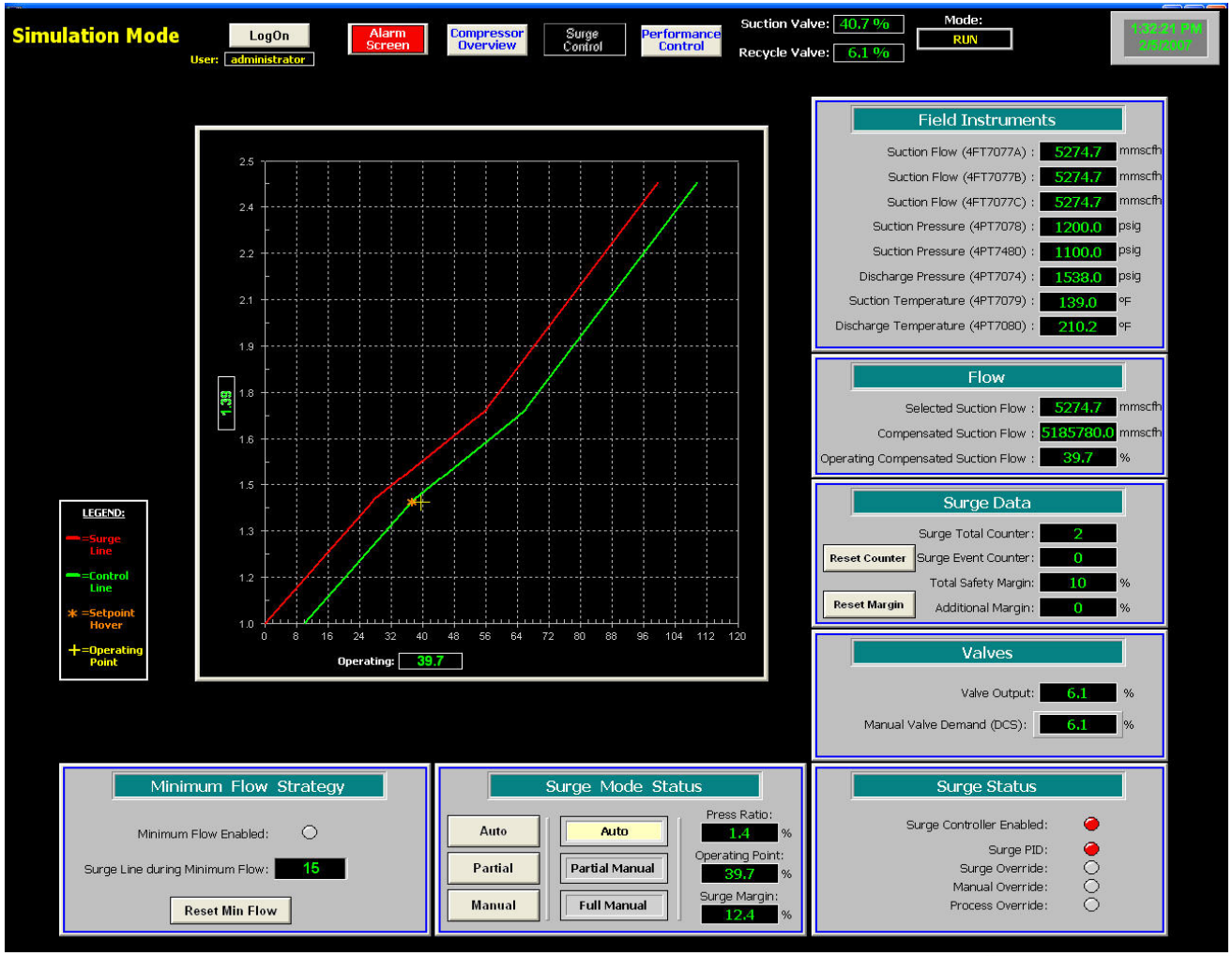
Decoupling Capacity Control



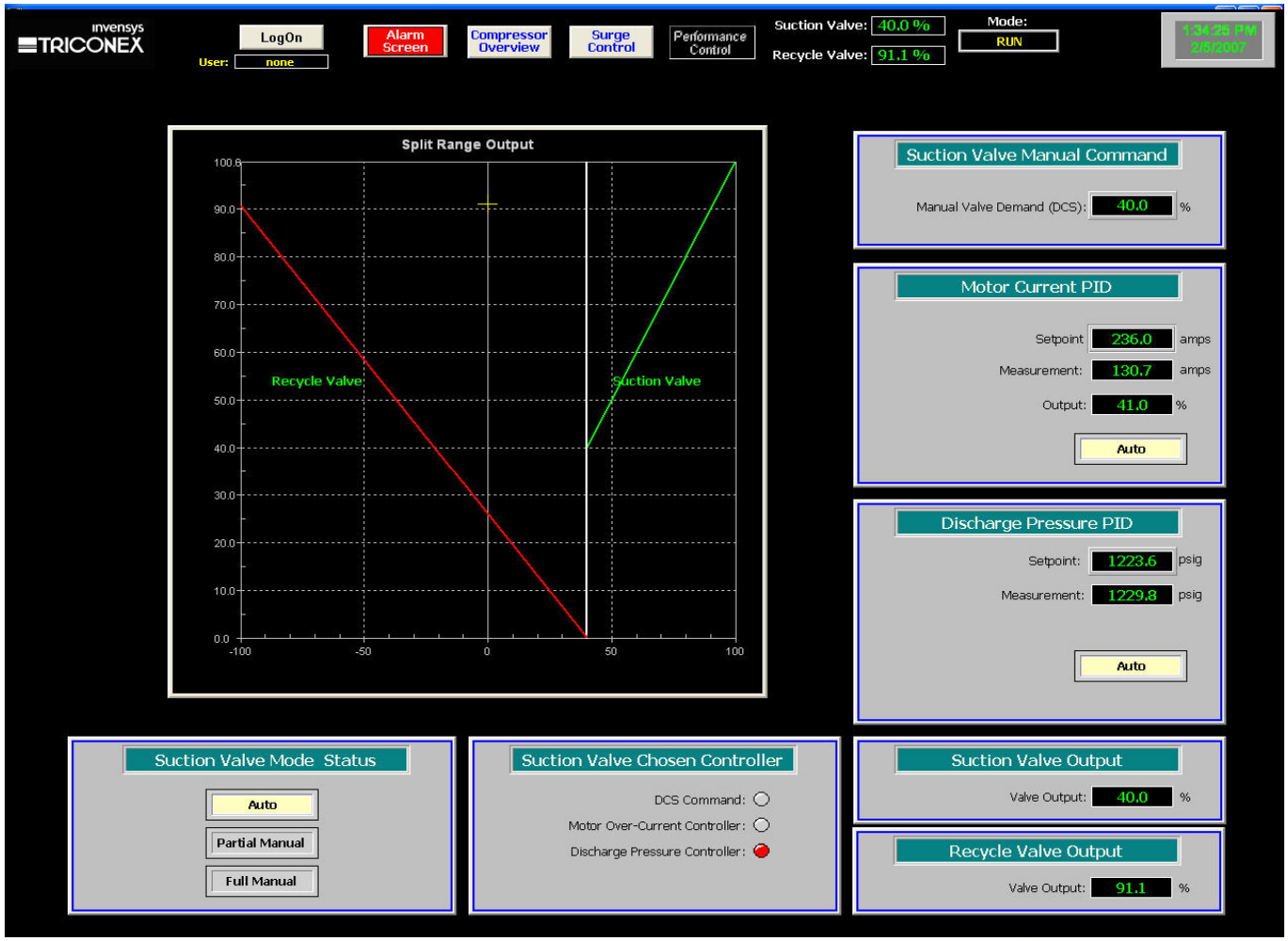
Surge Control and Capacity Control



Surge Control



Capacity/Decouple Control



Mechanical Retrofit

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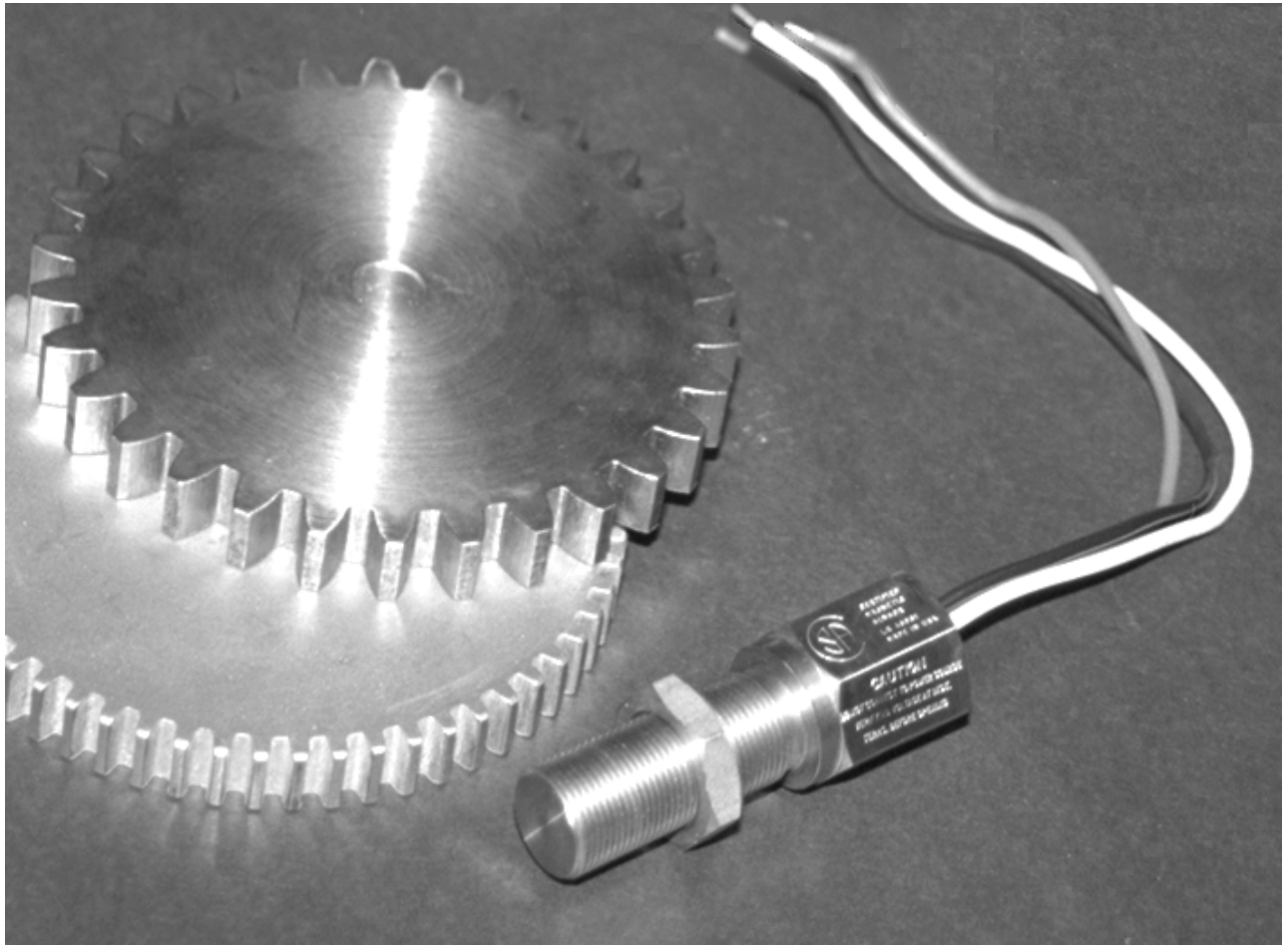
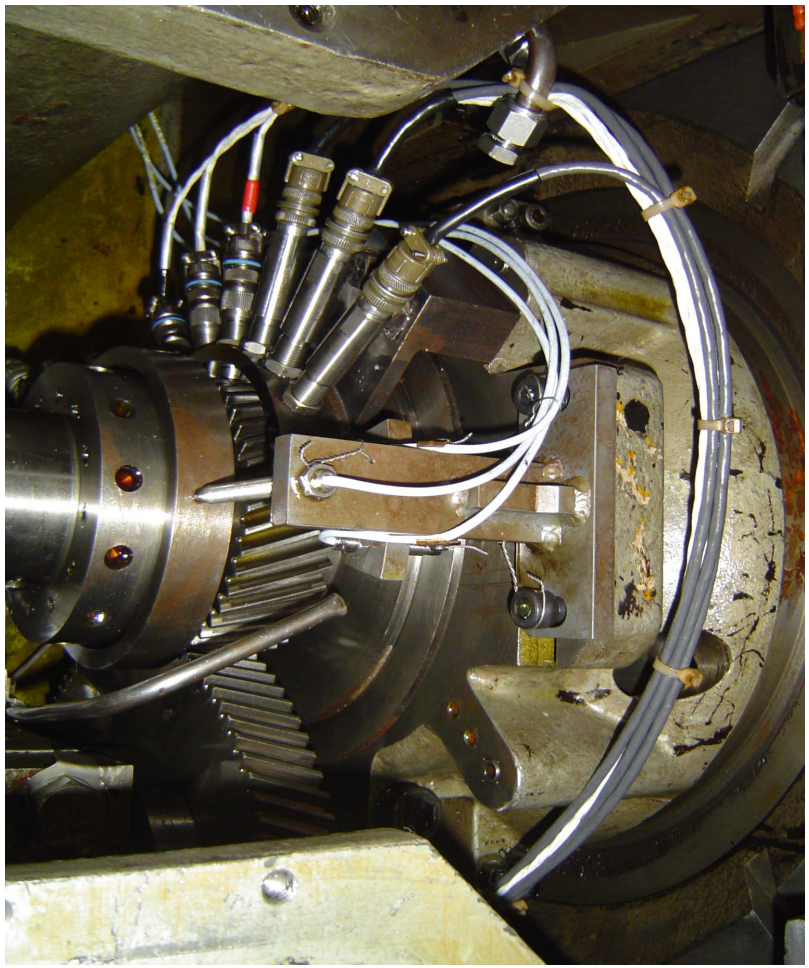
Magnetic Pickups



Speed Gear



- Speed Gear
- Speed Probe Mounting Bracket
- Speed Probes

Linear Variable Differential Transformer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