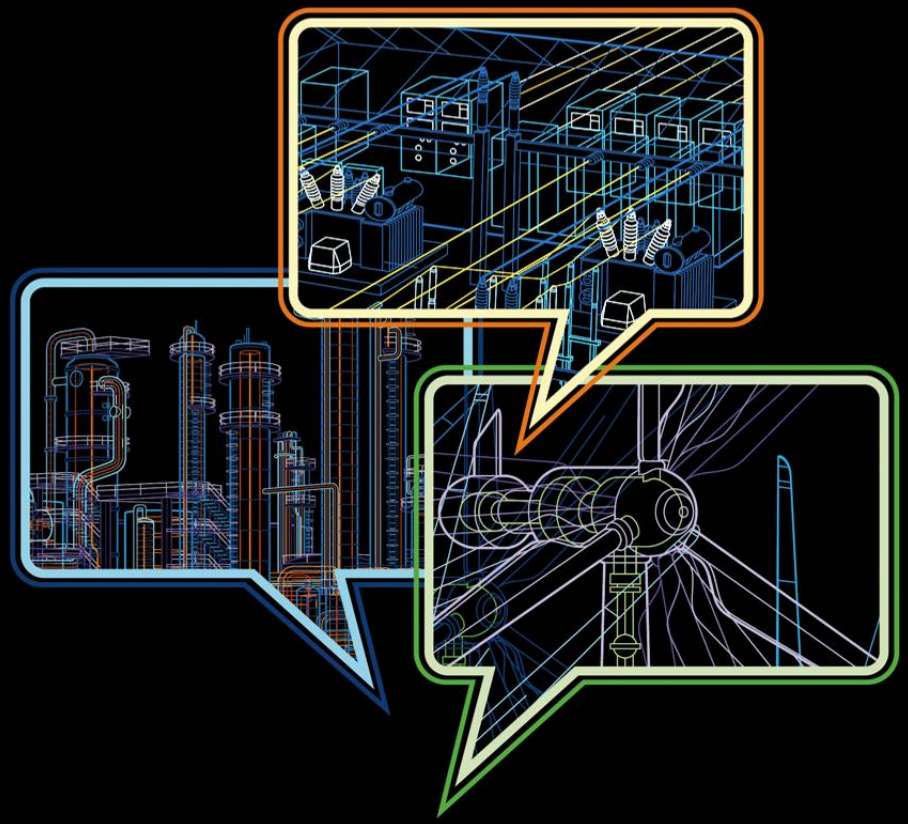


EBoP for Energy Efficiency – ICE Services & Global Power Generation
EE Assessment Training - February, 2012

Energy Efficiency Improvements
for Fossil-Fired Power & Cogen Plants

Plant Losses:
Thermal Process Losses + Auxiliary Plant Loads

- Conventional fossil-fired boiler power plants
  60-70% Thermal loss plus 7 - 15% Auxiliary loss

- CCGT: Combined cycle gas turbine power plants
  45-50% Thermal loss plus 3 - 4% Auxiliary loss

==========

Inefficiency loses money via higher heat rates* and reduced net capacity

==========

- Reduced power sales revenue / Excess fuel cost expenditures

- For North American Coal-fired plants:

Best HR: 9300 Btu/KWh (Eff = 37%)

Worst HR: 14000 Btu/KWh (Eff = 24%)

* Heat rate is thermal input divided by electrical output, the inverse of efficiency

Plant Efficiency Improvement Goals

- Revenue Improvement: Enable a utility to sell & deliver more megawatts

- Reduce Operating Costs:
  - Improve plant net & gross heat rates (thermal → electric conversion efficiency)
  - Reduction in process variabilities improves reliability & uptime
  - Reduce upcoming CO2 emission costs

- Reduce Generator MVAR while maintaining robust power factor response

- Much more cost effective than new plant construction & life costs
  - Increases output and lifetime of existing sites
  - Costs are a mere fraction of the $1.5M / MW for new plant construction

Plant Efficiency Improvement Solutions

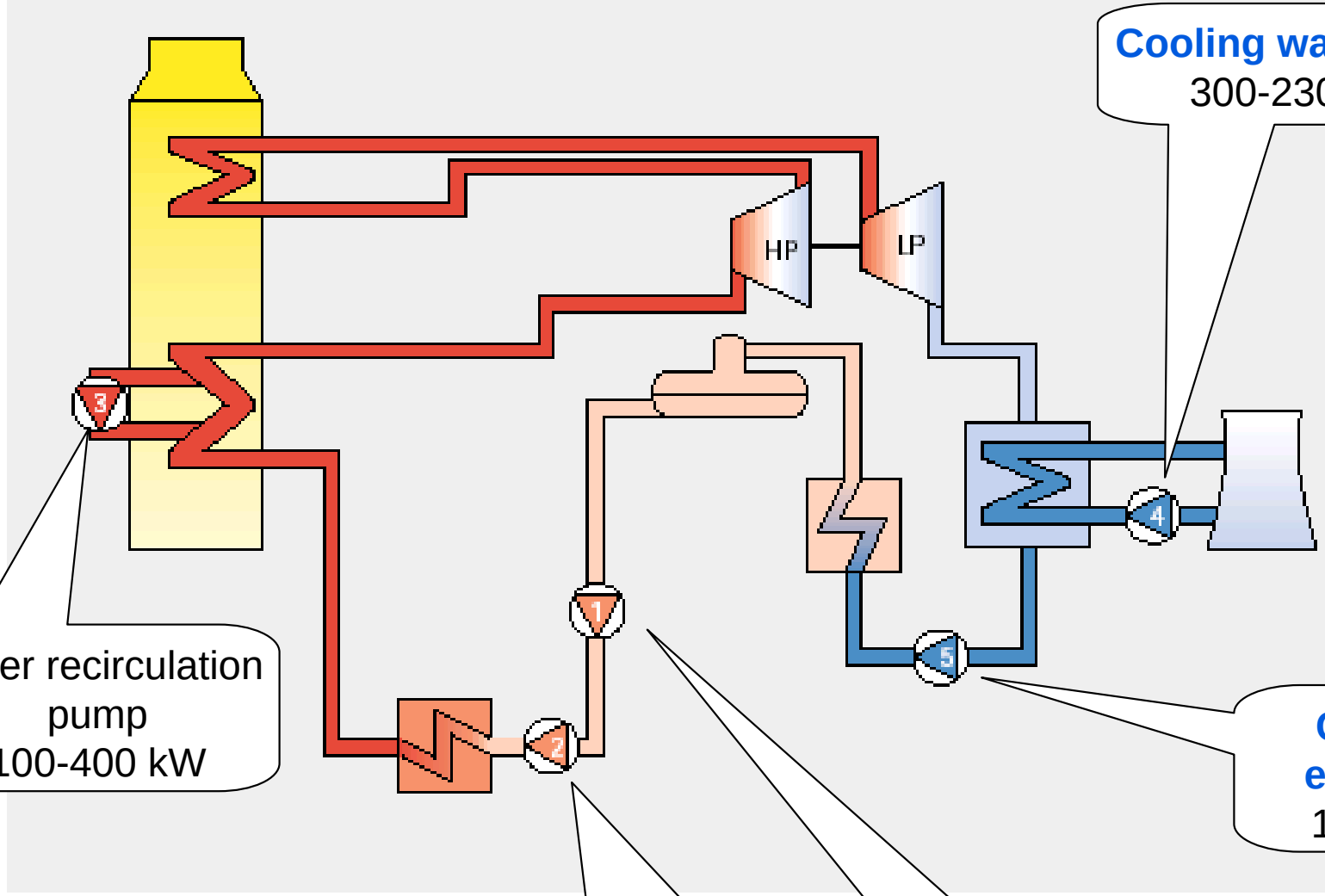
- “Drive Power” equipment – Motors & Drives for large pump & fan systems
- Advanced Variable Frequency Drive (VFD) solutions for auxiliary loads
- Application of VAR Compensation (FACTS) equipment at the generation site: SVC, STATCOM, Capacitors & Reactors
- Updated Transformer technology and sizing
- Advanced Process Control – Multivariable model-predictive controls

MV & LV Motors – Available New Efficiencies

ABB & Baldor Products

- Induction motors
  - Older or rewound motor efficiencies ~85% or lower
  - New High Efficiency ~97%
  - Available up to 22 MW
  - Induction motors are usually the first choice for applications up to 10 MW
- Synchronous motors
  - Efficiencies of 98% or more
  - Typically considered for higher power ratings (e.g. above 8 MW to more than 100 MW)
- Permanent Magnet Motors
  - Low RPM applications
  - Can still be used with VFD's

Power plant large pump applications use ABB motors & drives



Cooling water pump
300-2300 kW

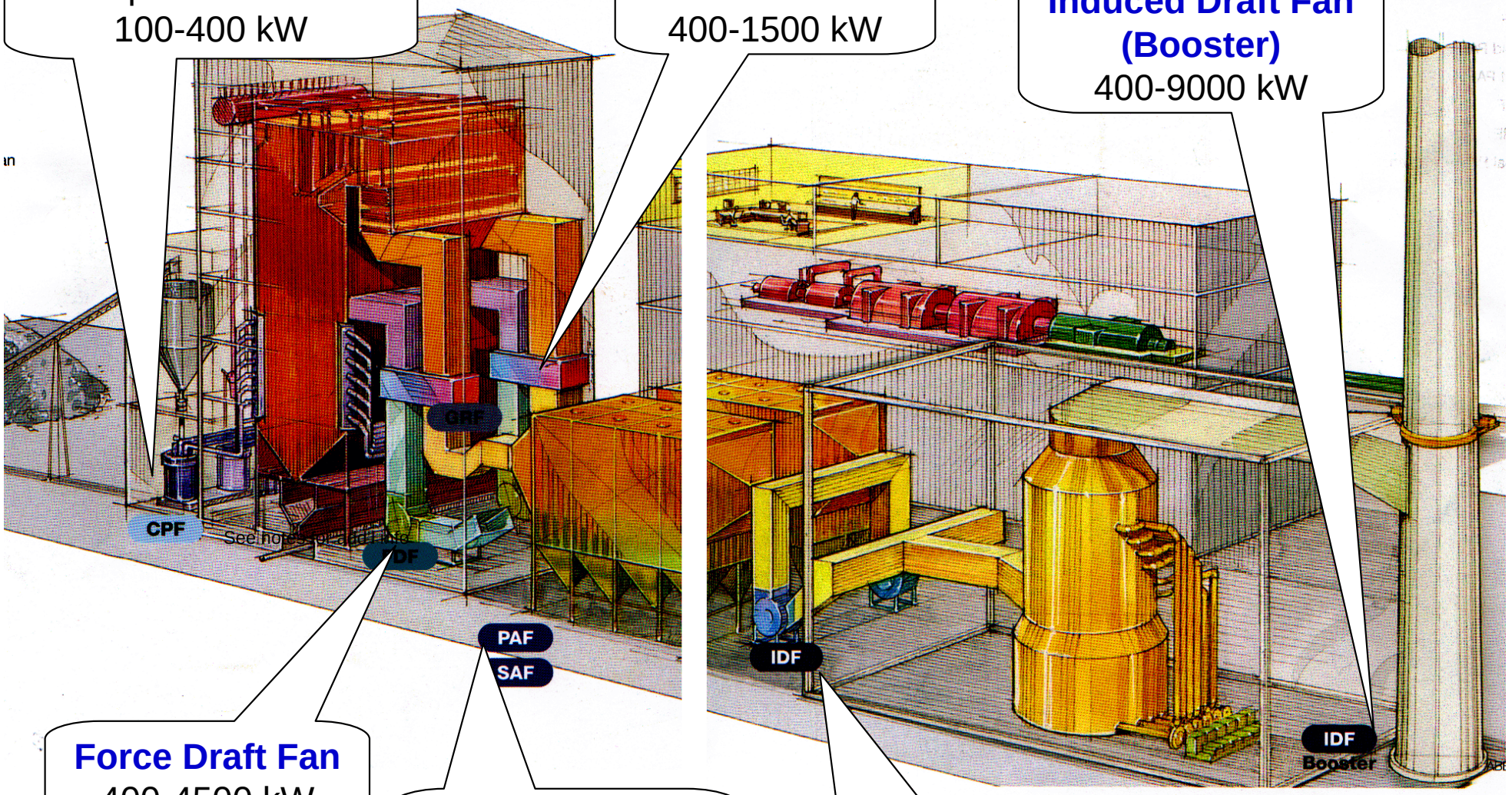
Boiler recirculation pump
100-400 kW

Condensate extract pump
100-1200 kW

Boiler feed pump
2000-9000 kW

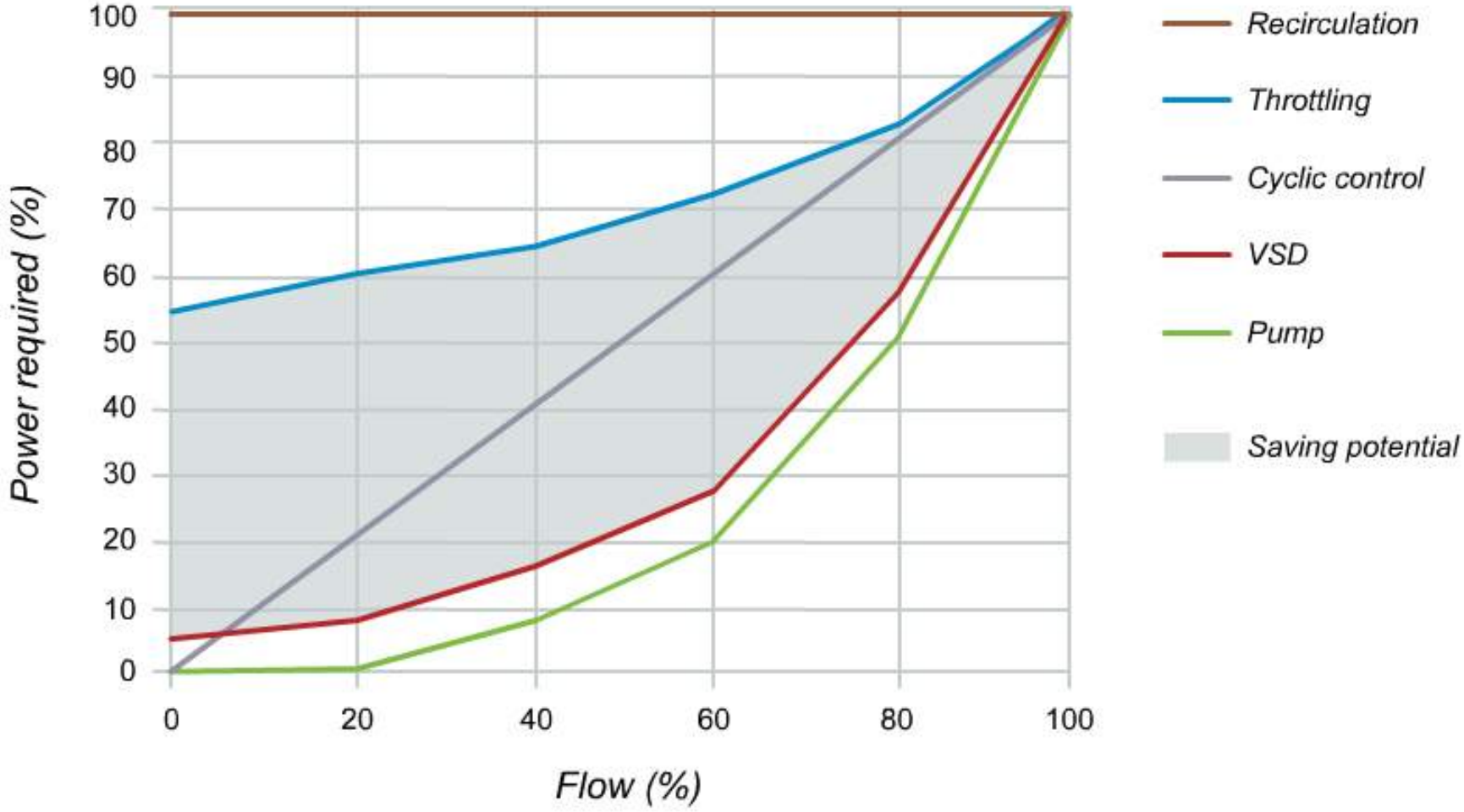
Feed-water booster pump

Power plant fan applications use ABB motors & drives



See speaker notes for add'l info

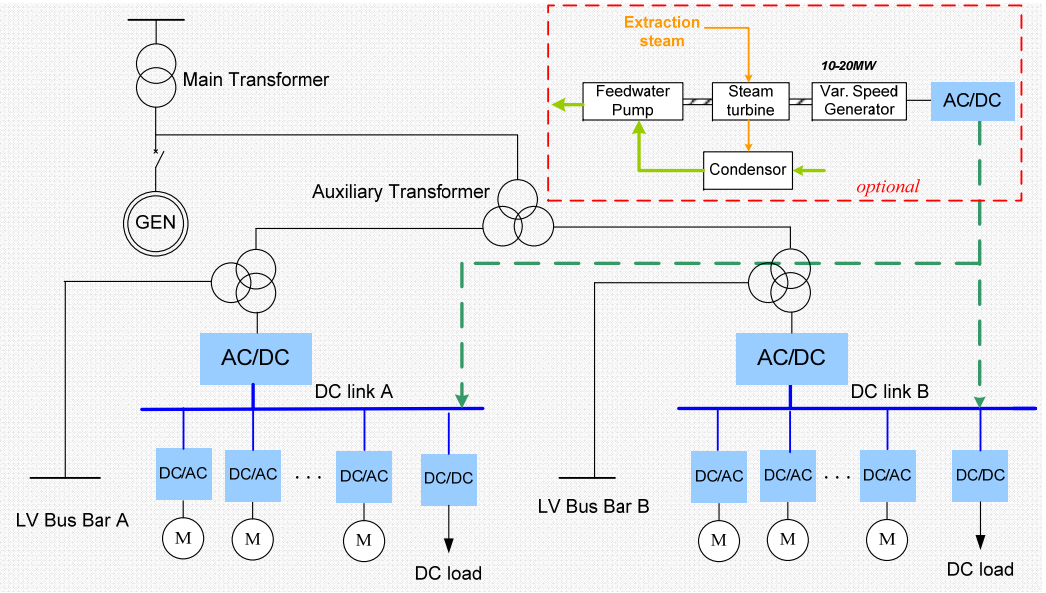
Flow Control Methods: Efficiency v. Load Range



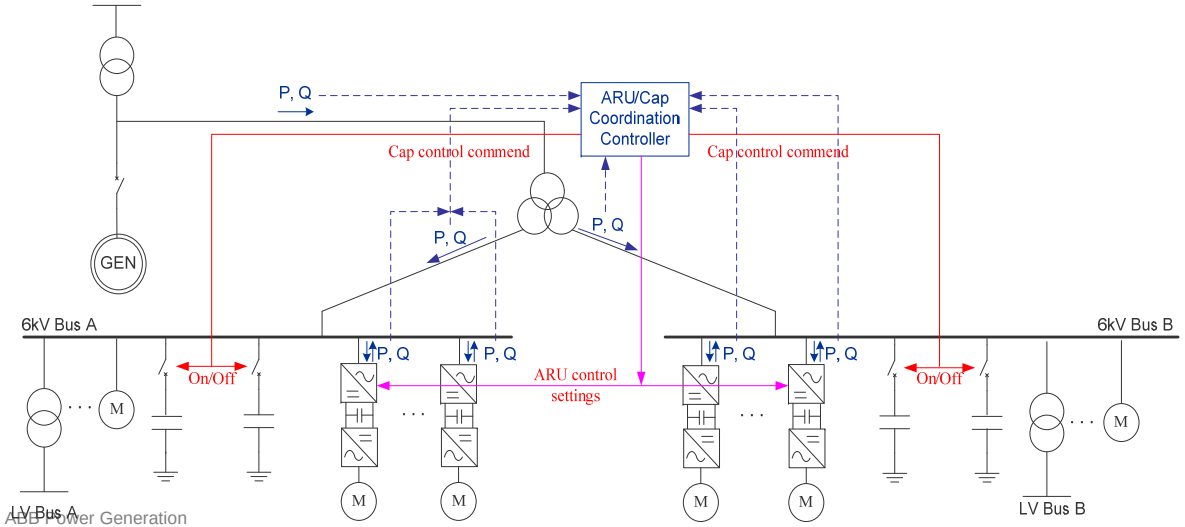
Optimizing Plant Auxiliary Power Configurations
Solutions for Power & Water Stations

- **Adapting APSO and DC-Bus solutions for both power and water stations**
  - APSO to be adapted to water pumping stations as well as generating stations.
  - Integrate both solution templates into ABB global plant engineering departments
  - Exclusive offerings from ABB
  - Targets: Fossil thermal, CCGT, Solar Thermal, and Water plant businesses

Common DC Bus Solution



APSO: Auxiliary Power System Optimizer



- **Benefits of APSO and DC-Bus**
  - Improved plant energy efficiency
  - Reduce the total power conversion capacity of drive system
  - Reduce size & number of transformers for MV drive systems
  - Minimize/eliminate reactive power for the overall plant
  - Implement coordinated controls for power plant performance improvement (APSO in 2011, DC-Bus 2012)
  - Improved ride through of aux. system under external disturbances
  - DC-Bus can directly integrate local energy storage for ride-thru and black start

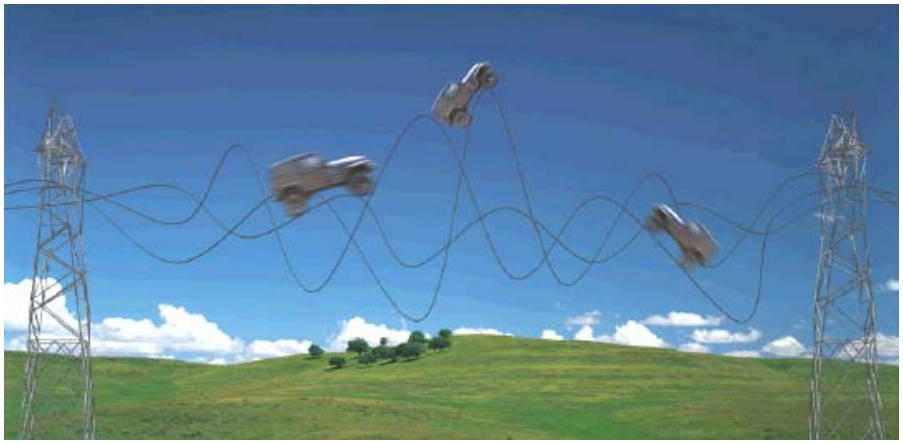
ABB Transformers: Right-Sized and Efficient

- Aging unit step-up transformers
  - This item “touches” every bit of electrical power exiting the plant - rebuild or replace with new efficient designs
  - Up to 0.35% efficiency improvement
  - Improved reliability avoids outages!

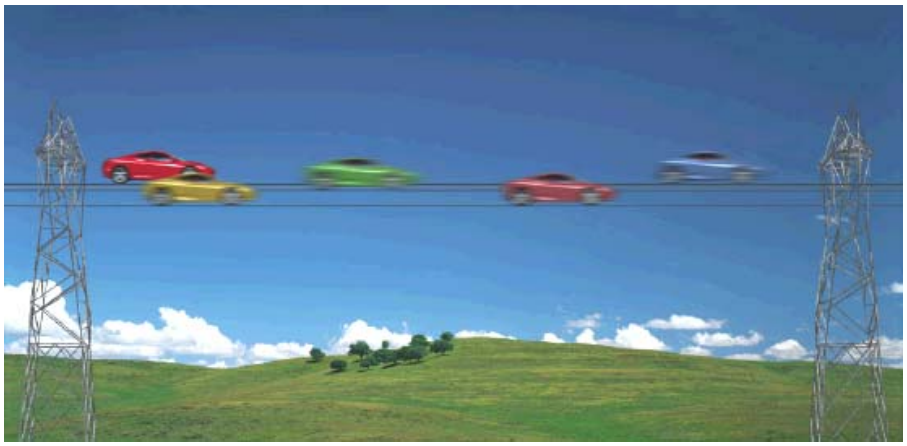
- Unit Auxiliary Transformer
  - Should be “right sized” with current needs for best efficiency
  - Rebuild or replace aged UAT’s with new efficient design

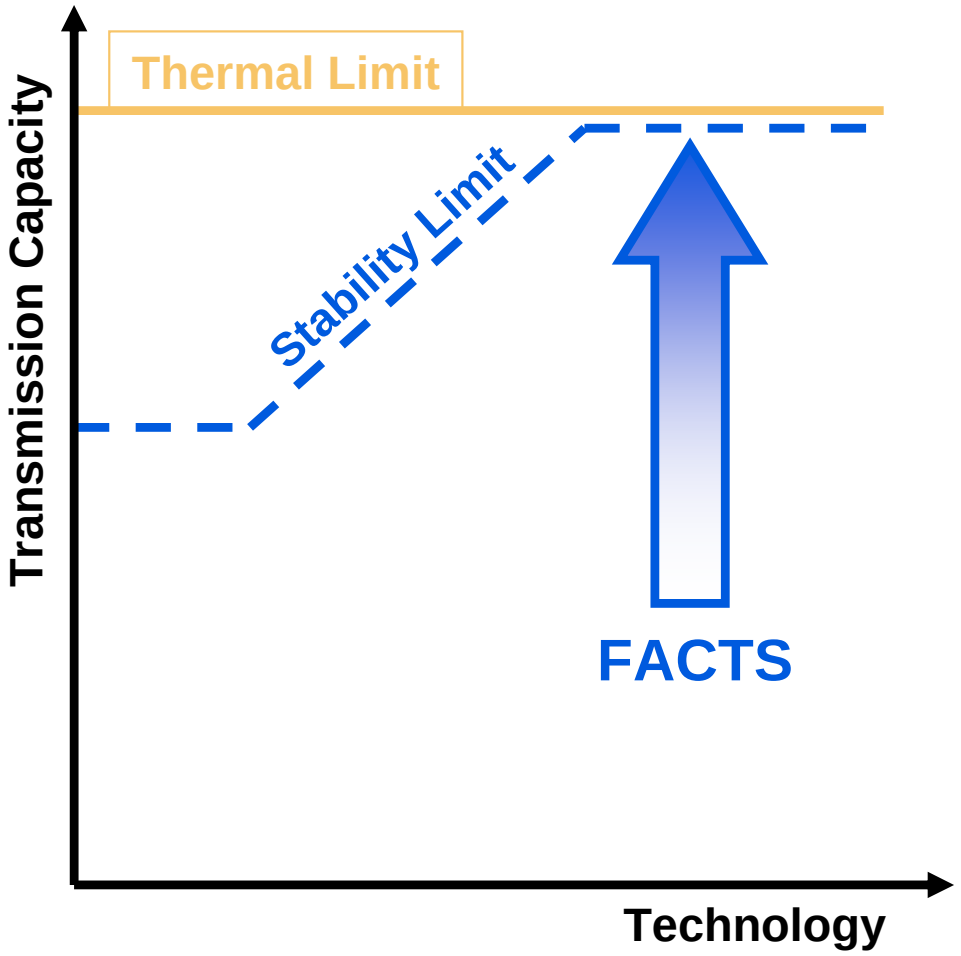
Power Factor (Q) Control: FACTS in the Power Grid

Without FACTS



With FACTS

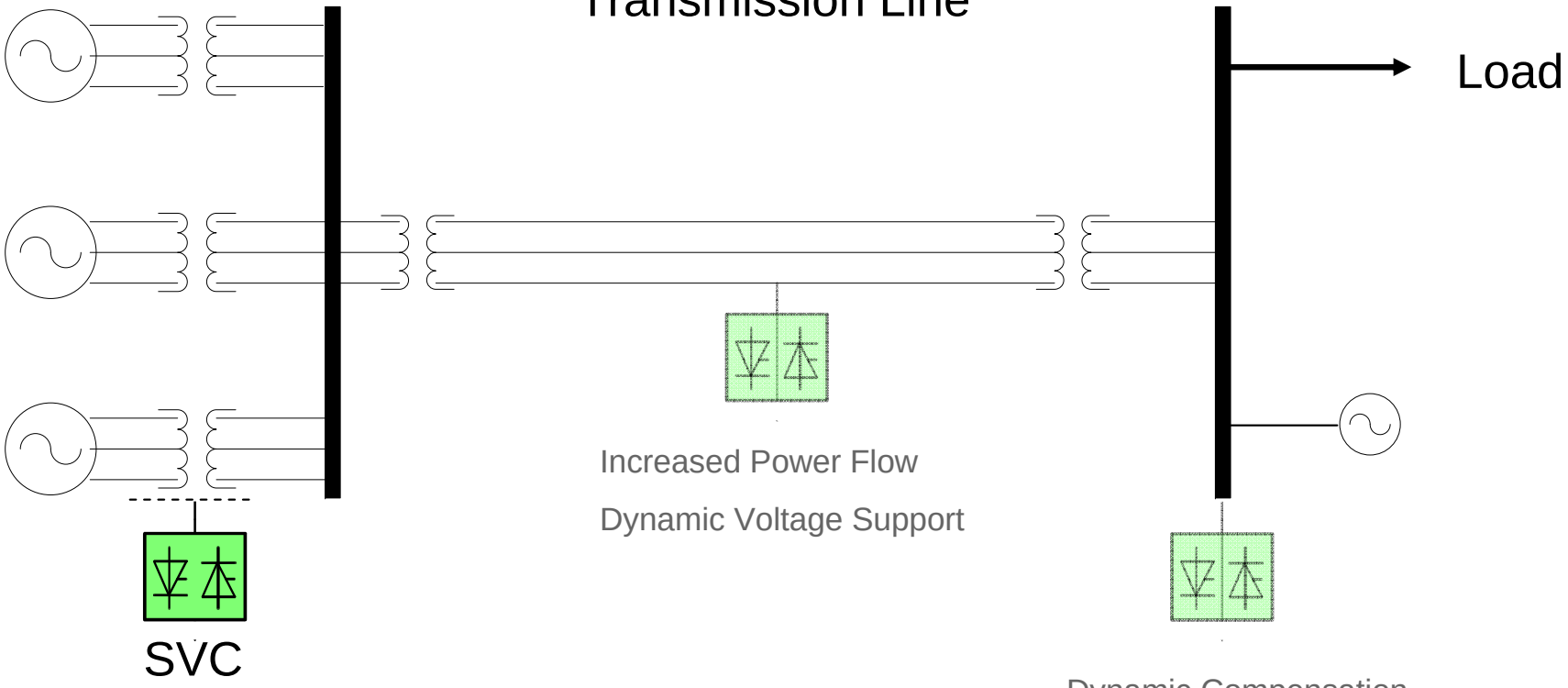




>>> FACTS increases real power flow in existing lines >>>

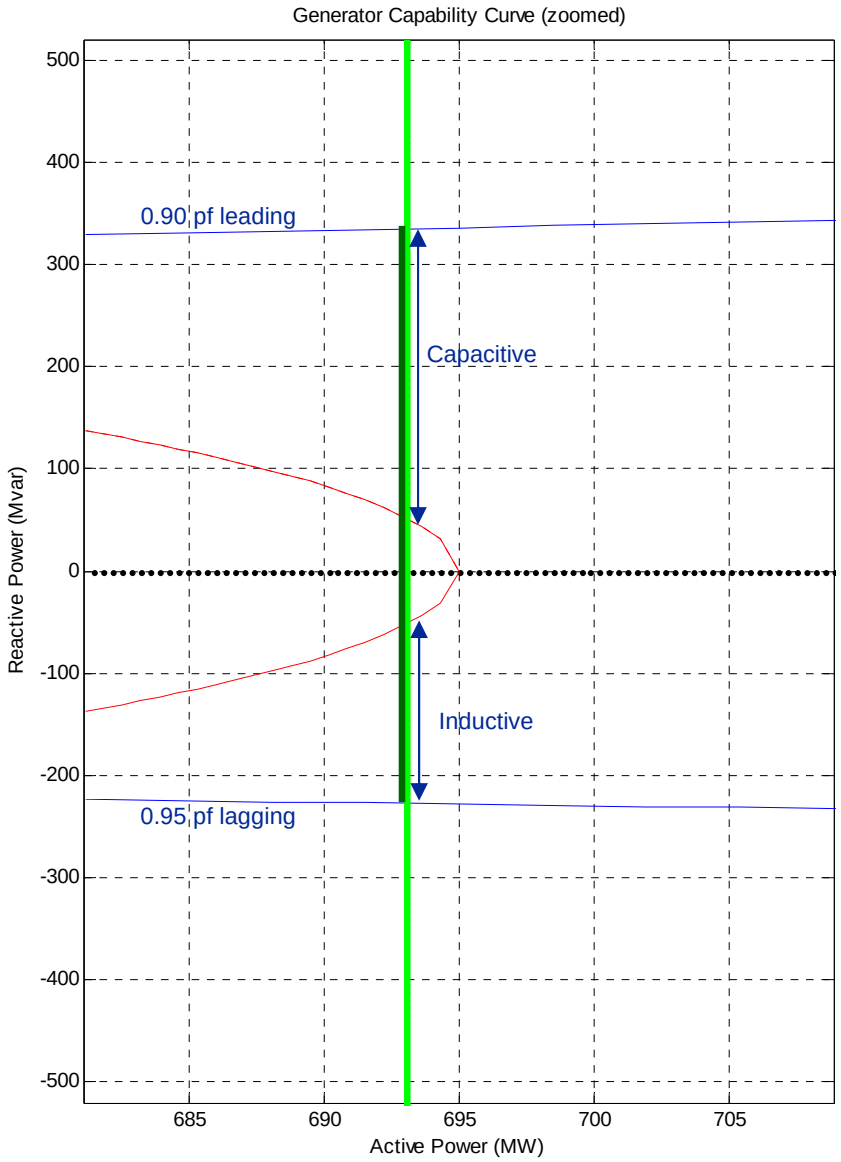
Dynamic Reactive Power Compensation in the Grid

Where can FACTS-SVC go?

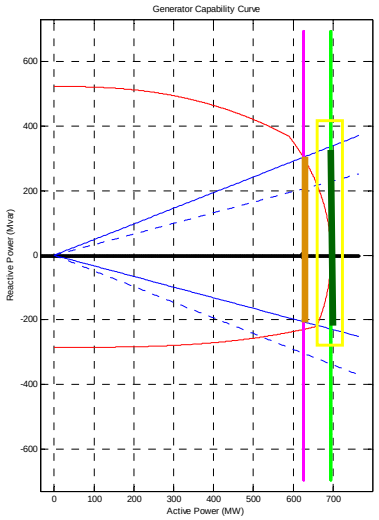


Increased Generator Output and Increased Generator Performance

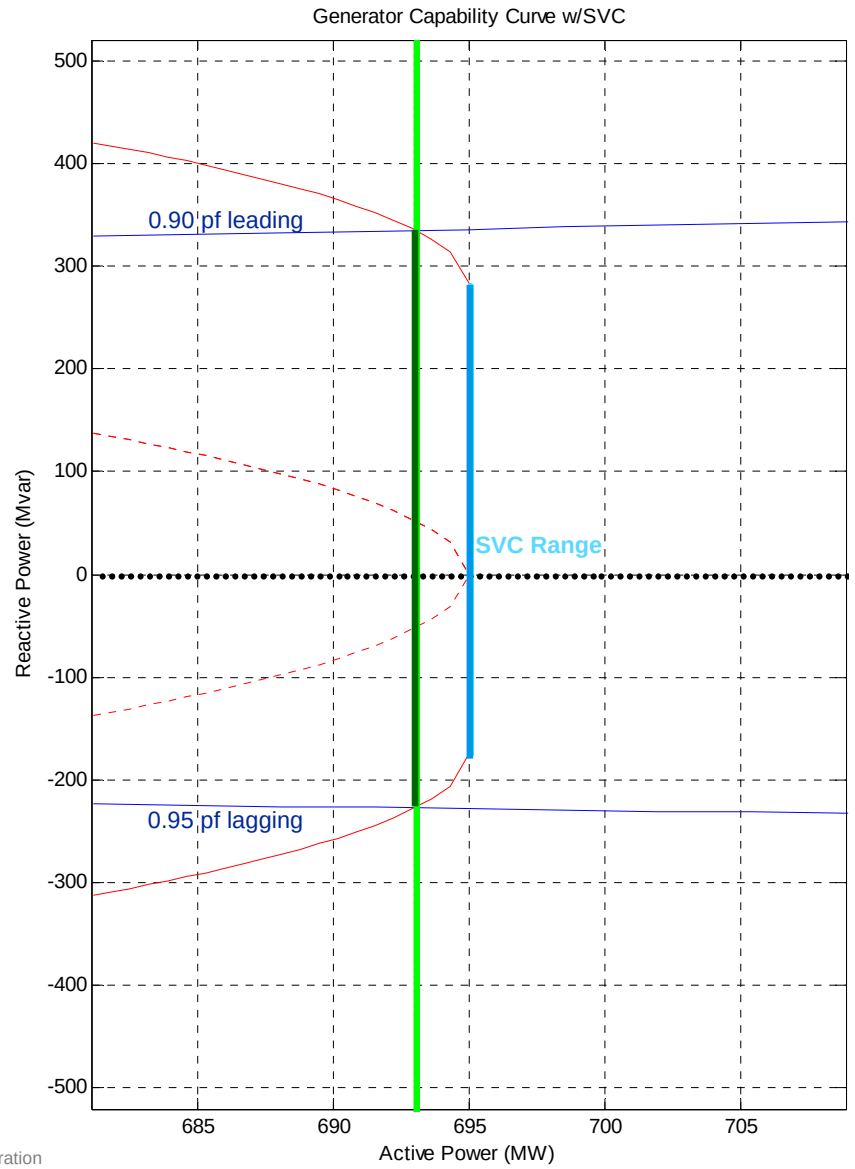
Generator Capability Curve



- **Power Factor Requirements:**
  - 0.90 pf leading (capacitive)
  - 0.95 pf lagging (inductive)
- **Reactive Compensation:**
  - -/+ 52 Mvar (from gen)
  - + 283 Mvar (capacitive)
  - - 175 Mvar (inductive)
- **Rated Output:** 695 MW
- **Current Operation:** 625.5 MW
- **Desired Output:** 693 MW



Generator Capability Curve
With Large Continuous Controlled SVC



- **Continuous Control SVC Solution**
  - + 283 Mvar (capacitive)
  - - 175 Mvar (inductive)

- **Rated Output:** 695 MW
- **Current Operation:** 625.5 MW
- **Desired Output:** 693 MW

- No switching elements required
- No limitations for operation

Evaluation Data Required

- Voltage Levels (Generator Bus & Transmission Bus)
- Interconnection Requirements (power factor)
- Reactive Compensation Trends of Generator

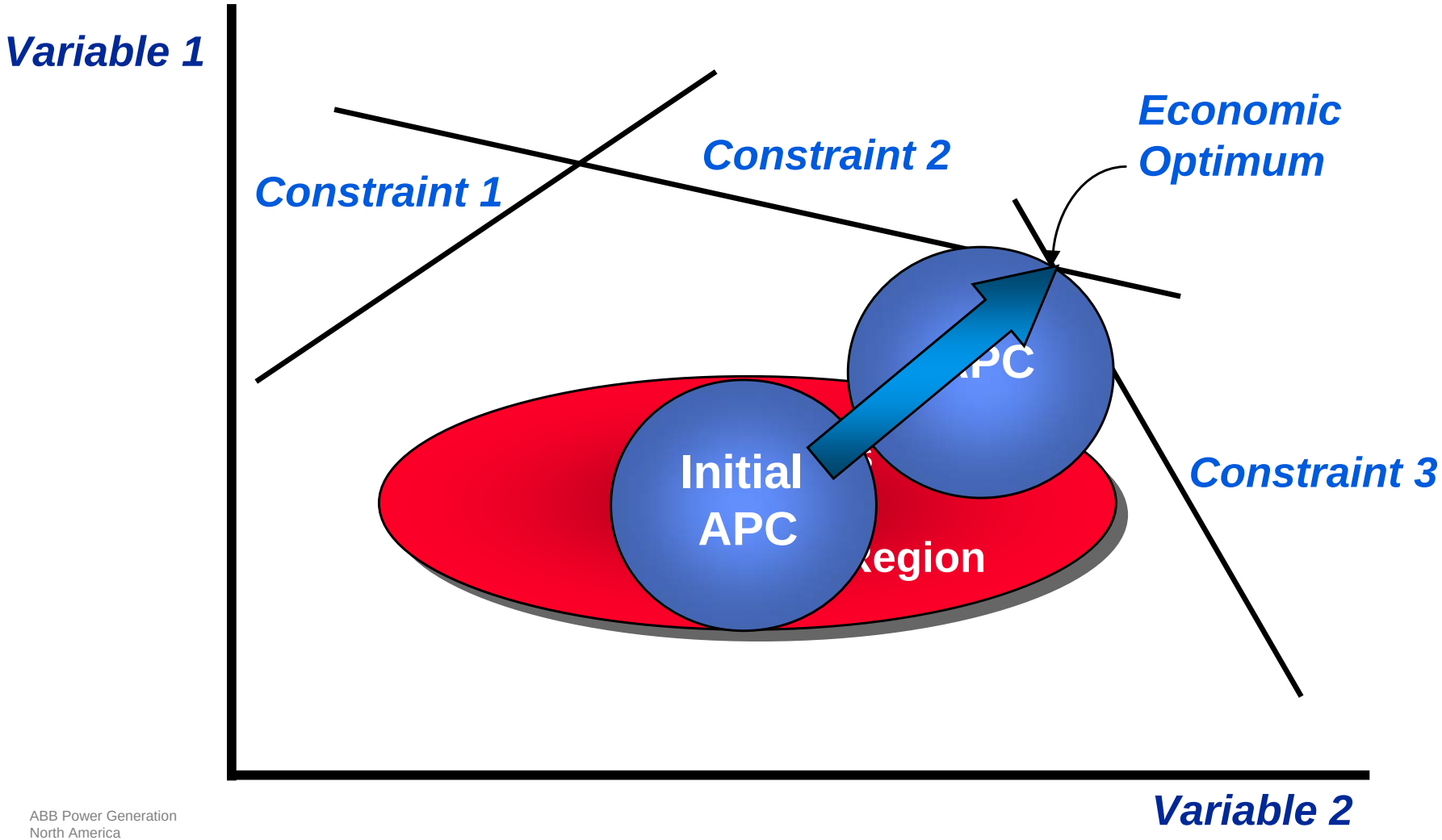
- **Generator Data:**

Plant / Unit	Generator Rating	Turbine Rating	Current Active Power Output	Desired Active Power Output
Plant 1:				
Plant 2:				

Advanced Control and Optimization of Power Plants

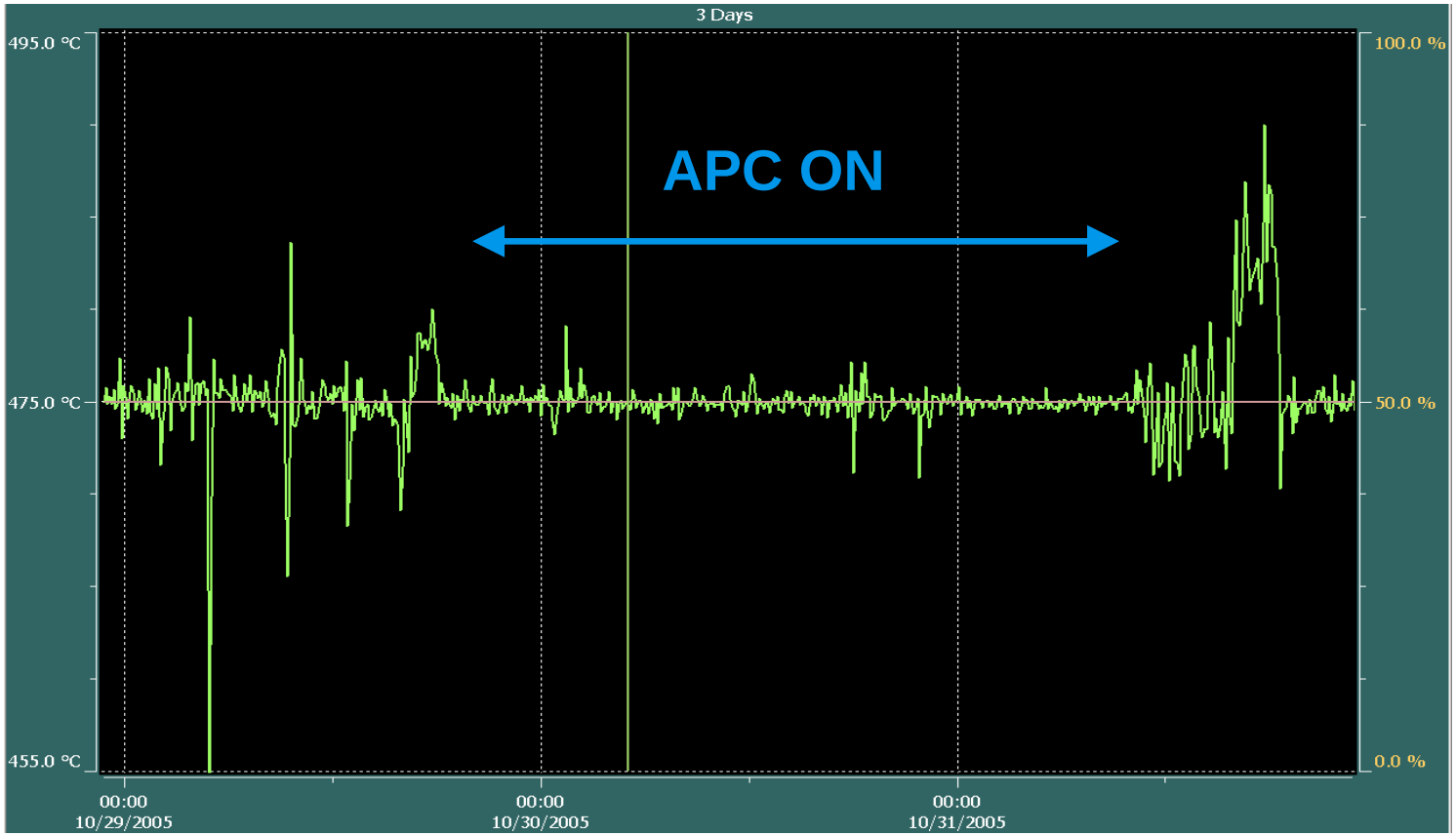
How APC Improves Performance

- Handling simultaneous constraints and variables



Advanced Control and Optimization of Power Plants

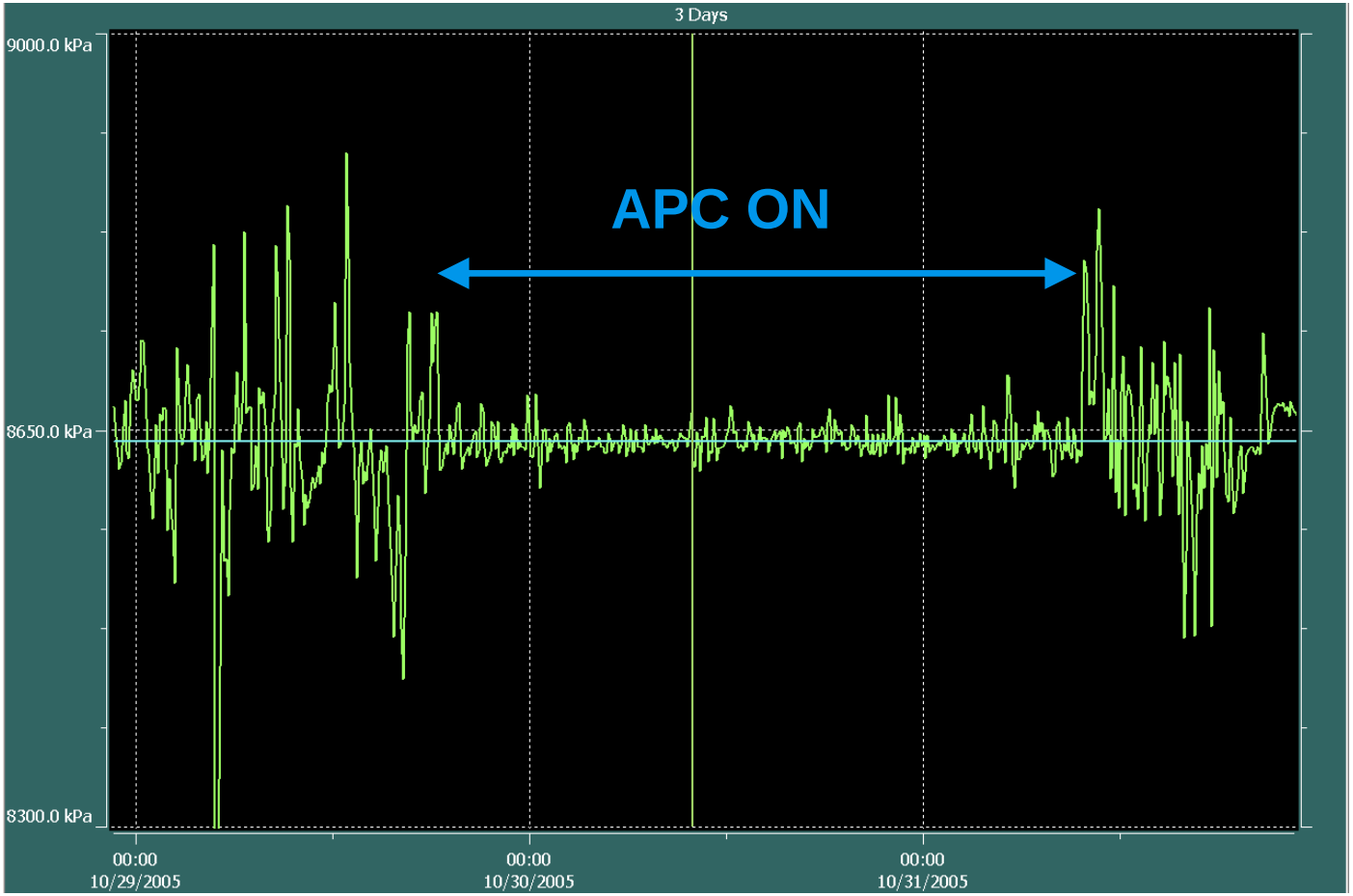
Improving Heat Rate – MS Temperature Maximization



- Reduce variability
- Shift target
- Higher steam temperature improves heat rate

Advanced Control and Optimization of Power Plants

Improving Capacity – Coordinated MS Pressure Control



- Reduce variability
- Shift target
- Higher steam pressure increases capacity

Some example numbers for crunching…

- **Opportunities in a "typical" 600MW coal-fired unit circa 1980's**
  - House load of 50MW (or more!)
  - New motors and VFD's applied to largest pumps & fans
    - 50MW of house load reduced to 38MW
    - Net heat rate improvement of 2%+ on average
    - Capacity improvement of 5-10MW+ at full output
  - SVC application – If feasible: 20-60MW output improvement
  - Analyze against unit load, cost & sale profiles using above improvements
    - Each Megawatt of utilized additional capacity is worth $500k/yr
  - Conservative project paybacks of 2-5 years

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for a better world™