Model Based Sensing & Controls for Power Generation

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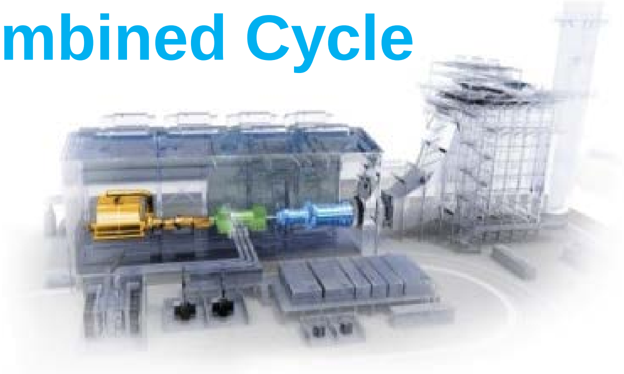
imagination at work

Government contract acknowledgement on slides 5, 6 and 10.

Advanced Controls for Power

Combined Cycle

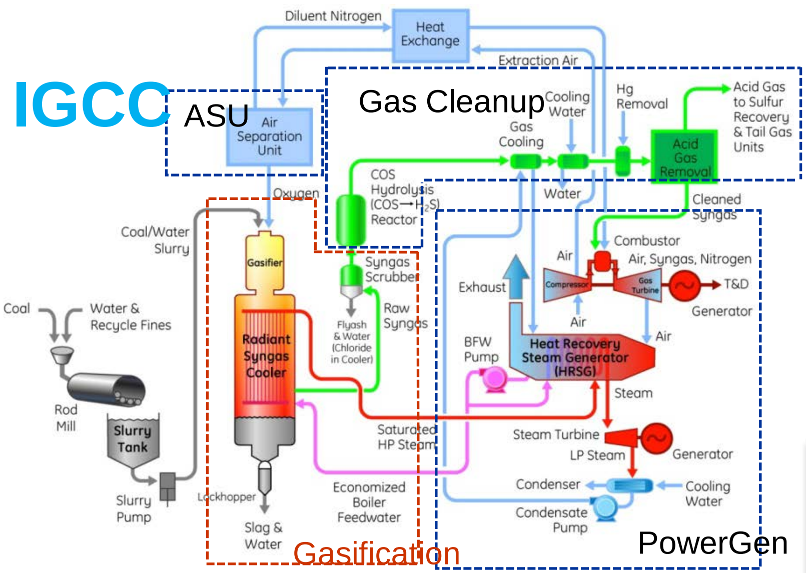


- More cyclic operation – starts, turndown
- Demand for increased flexibility and efficiency

Wind

- Controls for efficient operation
- Load mitigation through active controls – reduced CoE

IGCC

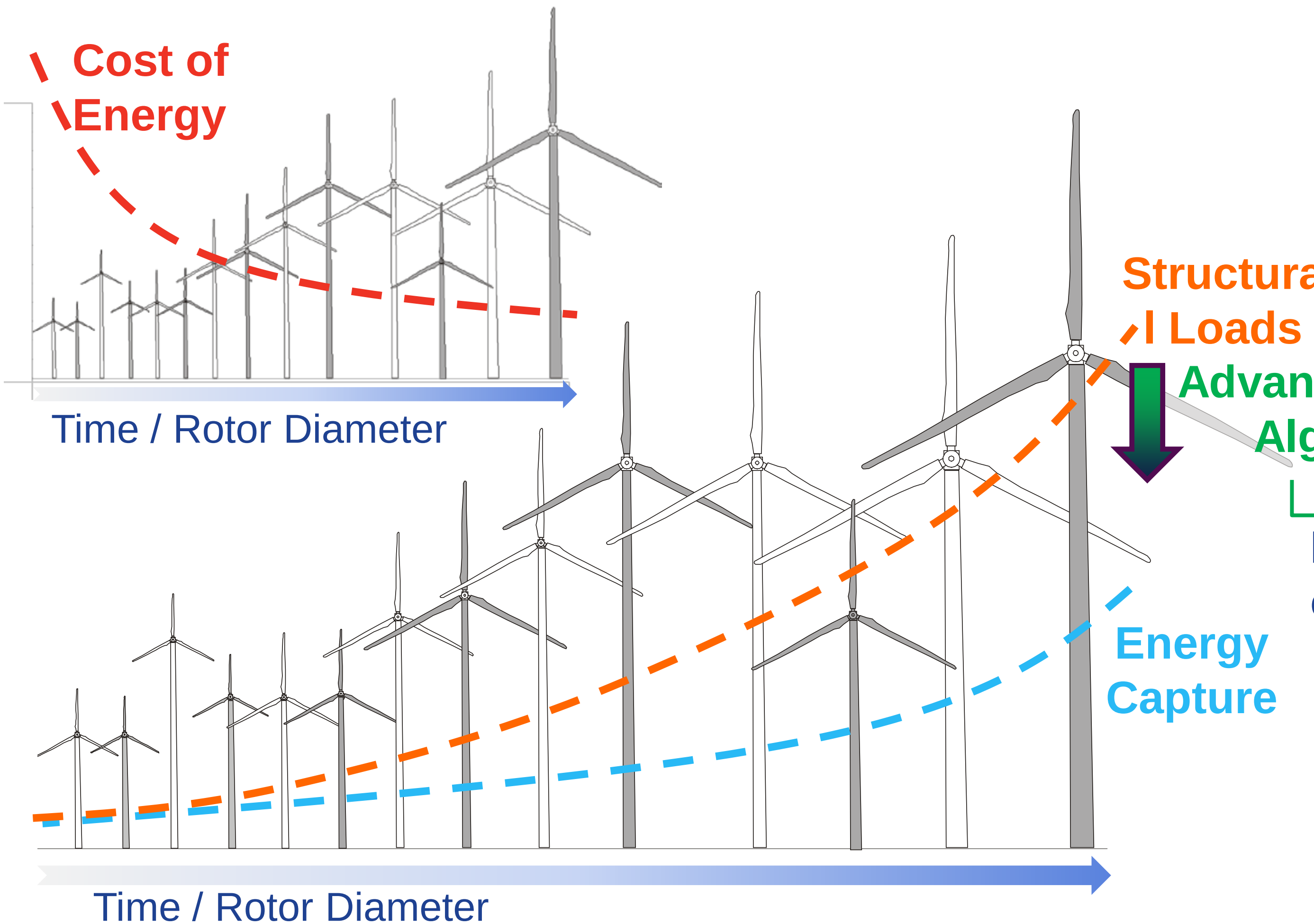


- Complex chemical plant coupled to power gen
- High demands on plant availability, efficiency
- Limited sensing in core gasification section – extremely harsh environment

Advanced Controls for Enhanced Operati
- efficiency, availability, flexibility

Model-Based Controls for Wind Turbine

Wind Energy Evolution: Challenges due to rotor growth



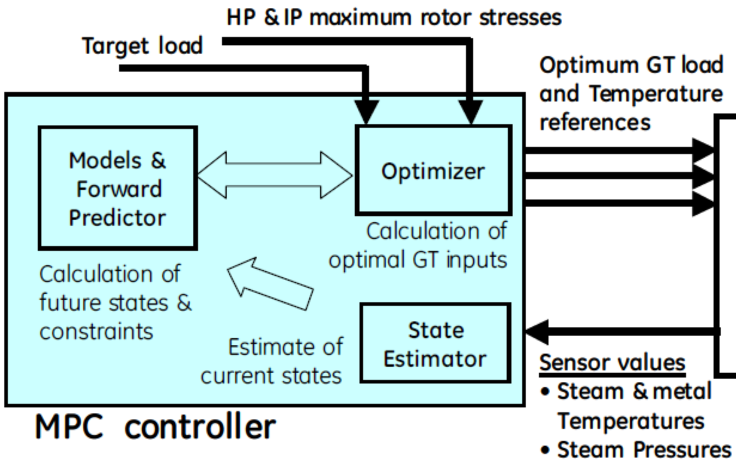
Model-based controls

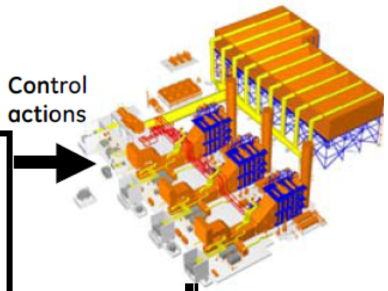
- reduce structural loads
- increase capacity factor and annual energy output

Model Predictive Control - CC Plants

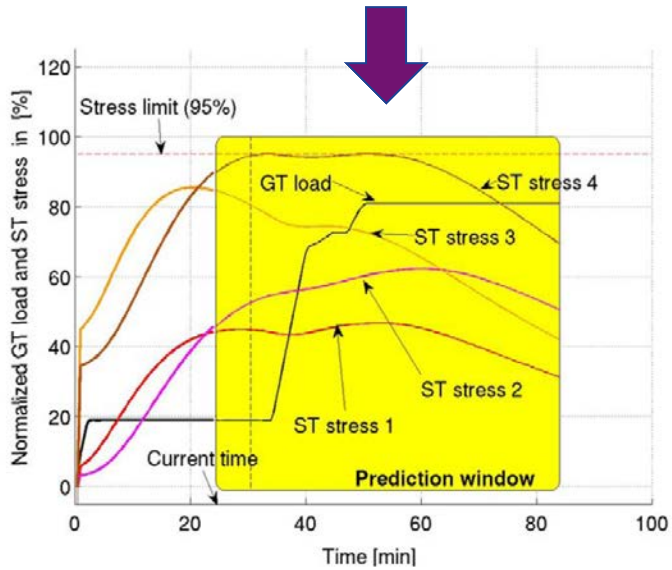
MPC

Computes optimal GT load and temp. references every few seconds



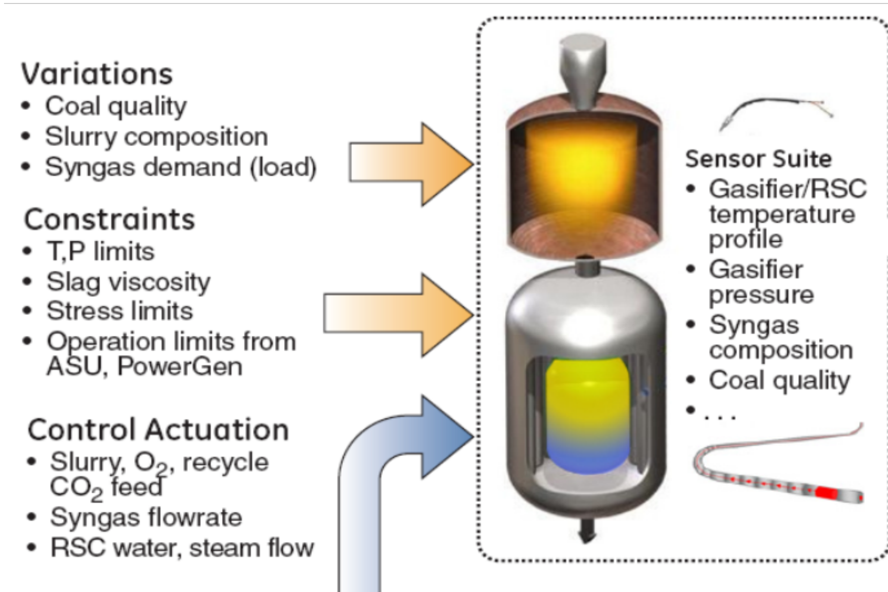


Explicitly addresses future ST stresses



Optimized CC Plant startup
- system level operation optimization

Model Predictive Control - IGCC Plant



Complement online sensors with model-based estimation

Advanced Sensing System
- Harsh-environment sensing

+

- Model-based virtual sensing

Advanced Control System (MPC)
- Model-based online dynamic constrained optimization

Supervisory level model-based optimization for coordinated operation

DoE Contract: DE-FC26-07NT43094

- Faster startup - 20% less pre-heating time
- Faster load transient – 20% faster turndown
- Optimized steady state performance – efficiency and carbon conversion
- Optimized performance for coal & coal + pet-coke blends

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Modeling for Advanced Controls

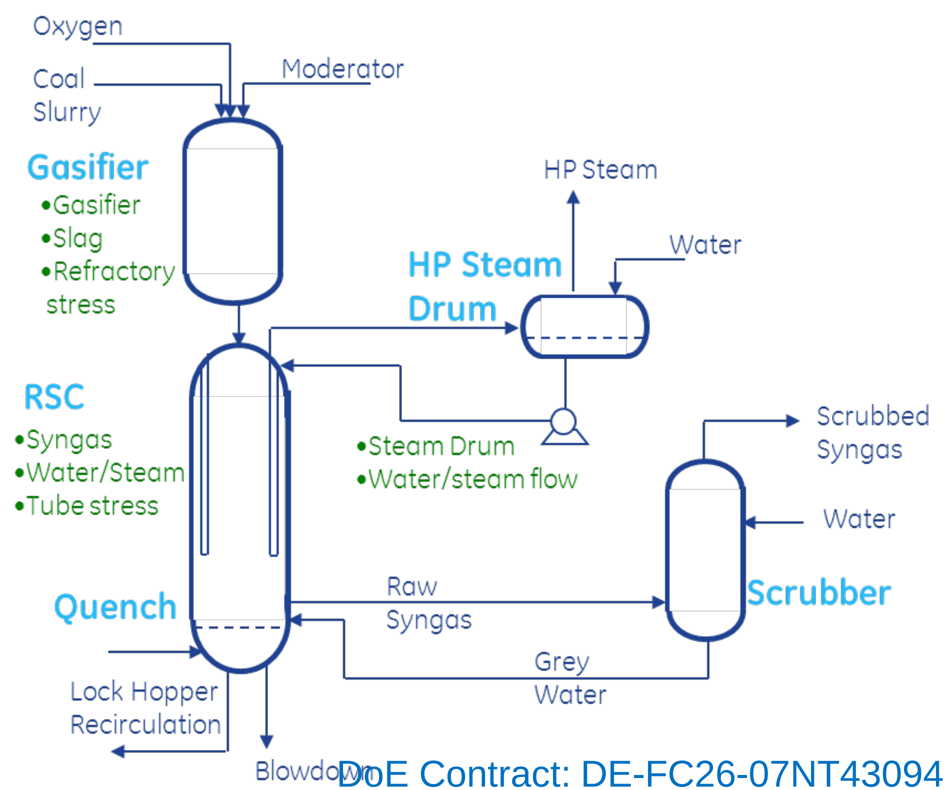
Need good transient models consistent with monitoring & control requirements

- Physics-based models – domain knowledge, valid over entire operation envelope, capture nonlinearities
- Speed for real-time controls & optimization – model reduction
- Flexibility for plant configurations, variations – parameterized models
- Accuracy – online adaptation

Operation modes

Start Up		Nominal Operation (high P)
Pre-heating	Pressure Ramp-Up	
• NG burners for gasifier refractory • Steam for RSC	• Syngas Pressure ramp • Steam Pressure ramp	•Turndown (50-100%) •Fuel changes (coal + PC blend)

Gasification section model for IGCC plant



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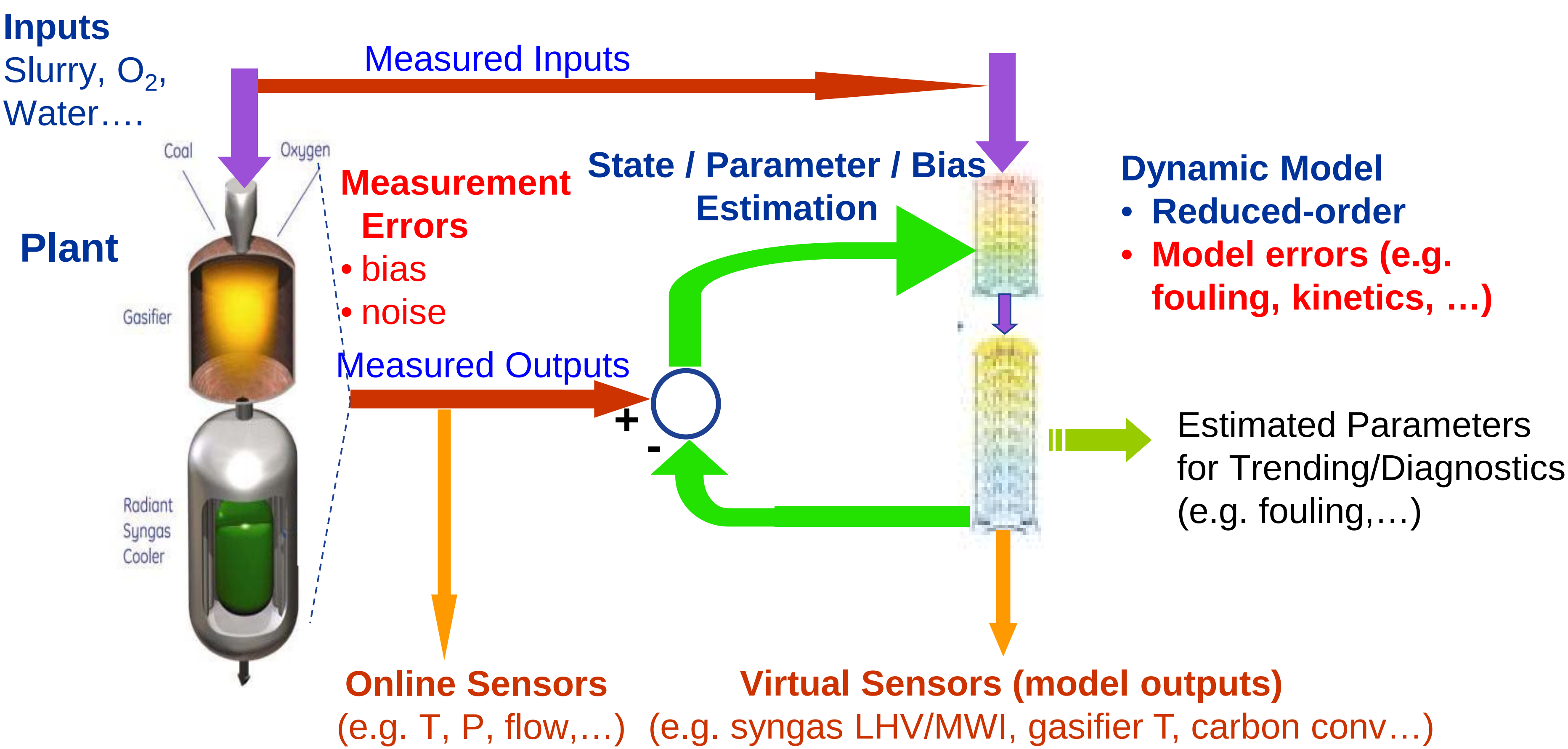
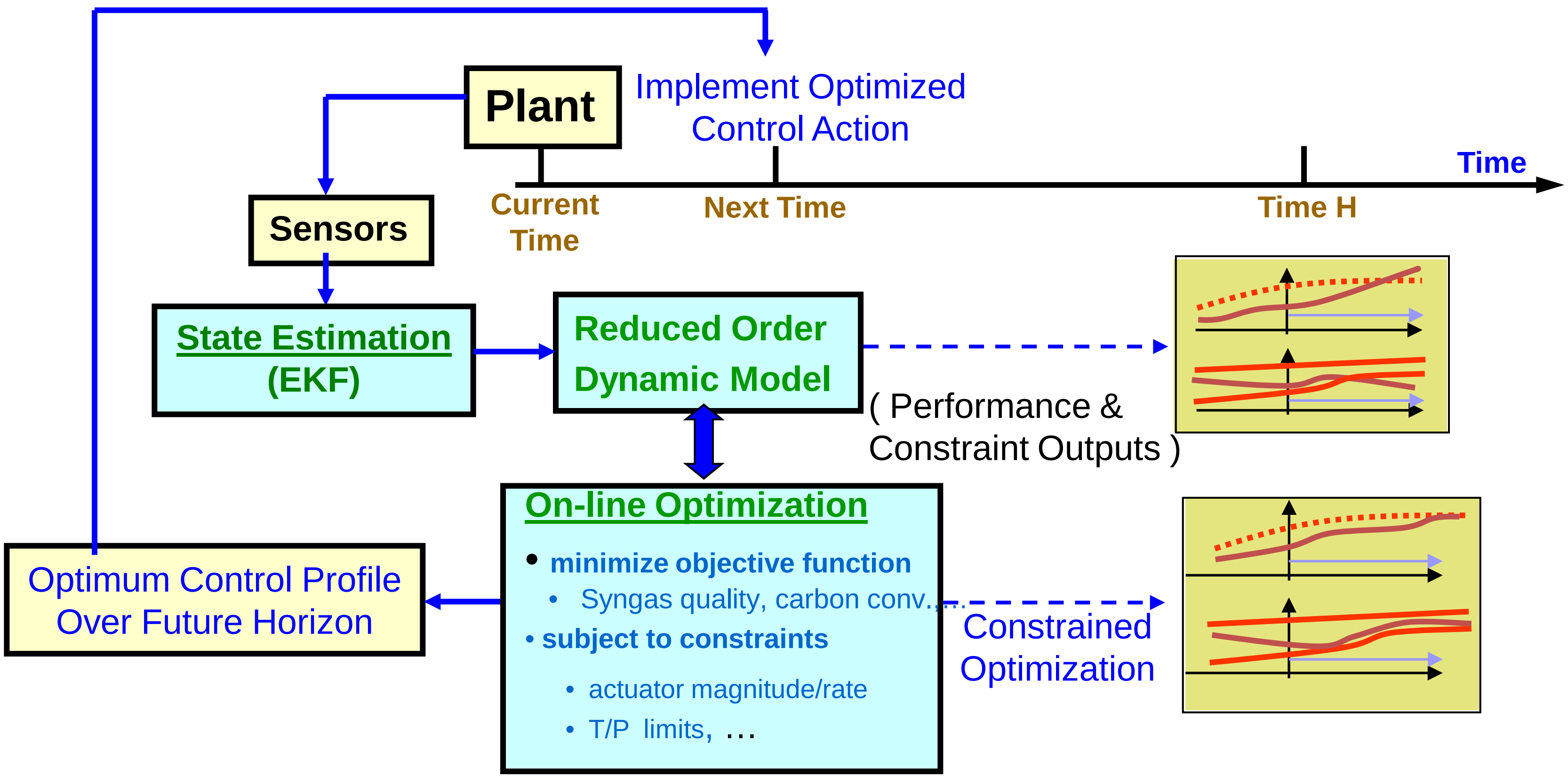
Sensing for Advanced Control



Model-based estimation (virtual sensors) to complement online sensors – robust to modeling & sensor errors

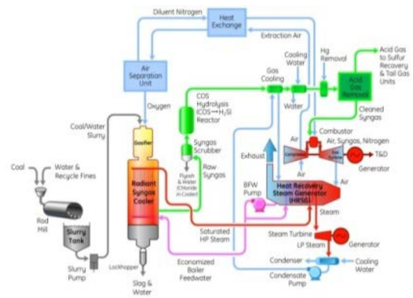
Model Predictive Control (MPC)



Flexible & optimized operation via online model-based prediction & optimization

- System-level optimization – coordinate operation of components/subsystems
- Optimize for performance objective – flexible objectives for varying operation modes
- Explicit handling of safety and operability constraints – run to direct boundaries
- Anticipation of transients over future prediction horizon – operation prediction

Sensing System Design



Combined Cycle
- Firing temperature
- Stresses

IGCC
- Gasifier T
- Carbon conversion
- Refractory wear

Wind Turbine
- Stresses
- Thrust

Performance, Safety

Advanced controls –
- Operation boundaries

Advanced sensing -
- Online monitoring

Digital Computer -
- Cheap, fast computing

Model Based Sensors (Virtual/soft Sensors)

Resource, Operation

"Lean" sensor set-
- Harsh environment
- Sensing technology
- Cost/weight/complexity

Model-based design of robust sensing system to meet growing operation/control requirements

Optimal Sensor Placement

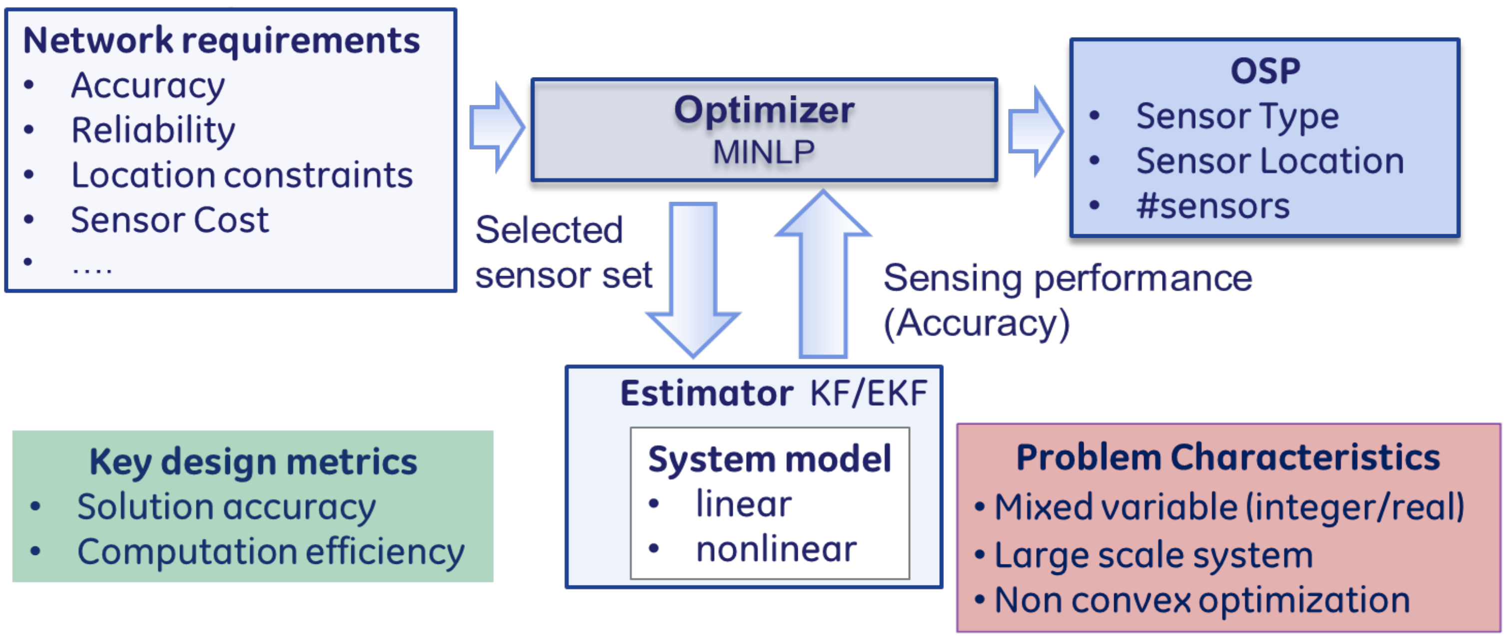
Common Sensing System Design Questions and Requirements

- **Design Questions**: Sensor type, location, number
- **Design Requirements**: Precision, reliability, time constants

Systematic Model Based Design – Optimal Sensor Network & Estimation

- Application to IGCC gasifier refractory health monitoring

DoE Contract # DE-FE0005712



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Model Based Controls - Summary

On-going focus on model-based sensing, controls & optimizat

- Physics based models – domain knowledge, operation envelope, nonlinea
- Model-based estimation – complement online sensing
- Model-based sensing system design – robust sensing system
- Model-based advanced controls – improved unit operation & safety
- Model predictive controls – flexible & optimized system level operation

Expansion to integrated diagnostics, prognostics & controls

- Online model-based diagnostics of sensor/actuator/system faults
- Prognostics for equipment health/life
- Integrated diagnostics, prognostics & controls
  - Fault tolerant operation – avoid trips/shutdowns
  - Improved power generation asset utilization