“Engineering-Grade Simulators are a Valuable Aid-To-Design and Control-Analysis Tool”

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Agenda

• Need for Dynamic Model Simulators
• B&W Dynamic Modeling History
• Engineering-Grade Full-Plant Simulators
• Dynamic Modeling Results
• Future Dynamic Modeling Applications (2017 on)
• Next steps
Why Does a Boiler OEM Use Dynamic Model Simulators?

• The design process often uses steady-state loads
• Must evaluate how the boiler (and plant) reacts when moving from one load to another
• New customer requirements are being placed on load ramping capability
• Location sometimes requires planning for frequent grid problems; must engineer controls around problems
• Can be used for design optimization
• Verify and validate (V&V) controls
• Future uses may generate new revenue streams
2007-2016 B&W Dynamic Modeling Projects

- Once Through simulator
- Nuclear balance of plant
- Nuclear full-plant simulator (nuclear)
- Carbon Capture (special modeling needs)
- New fossil designs
- Flue gas recirculation control
- Advanced boiler module development (B&W in-house)
- Boiler implosion studies
- Once-through controls (OTC) project
- Consultants controls course
- Package boilers
- Double reheat
- Component testing
Engineering-Grade Full-Plant Simulators (EGFP Simulator)

• For many (most) applications, the focus is on operator training — simulators are made to be an operator trainer simulator

• For a boiler designer and manufacturer, the focus is on engineering design — simulators are built to be engineering-grade and the simulators are used as a tool to aid design and to evaluate controls

• Features of an EGFP simulator
  1) Contains boiler, BOP, and controls models
  2) Has modified Commercial-off-the-Shelf (COTS) components in some way
  3) Extensive, yet flexible, control system
EGFP Sim.; Modified COTS Components

- Absorption in components (like PSH) is a function of load
- A given component is run with boundary conditions corresponding to B&W design codes
- Then, component behaves as if parameterized by our design codes
Advanced OT Module

Furnace Module
- Computes combustion
- Can set M=0 to take metal out of COTS equations

Metal:
- Compute heat transfer on ID from metal to water using B&W correlations
- Compute metal temperatures
- Compute \( \frac{dQ}{dt} \)_{OD} = \sum \{(dQ/dt)_{OD}\}_i
- Correct K(4) by factor: \( \frac{(dQ/dt)_{OD}}{(dQ/dt)_{OTRFDF}} \)

Waterwall:
- Solve mass, momentum, & energy equations

COTS Furnace Module

\( (dQ/dt)_{OTRFDF} \) on OD
Gas to water

\( (dQ/dt)_{Waterwall; 1} \)

\( (dQ/dt)_{Waterwall; 5} \)

\( (dQ/dt)_{Waterwall; 9} \)
**EGFP Sim; Controls Model**

- **Full-plant control model**
  - Extensive model
  - Enables V&V of entire control system
  - Must be linked to high fidelity process model
OTC Initial Fast Load Change; 5%/min
Fast Load Change; Fix for low $O_2$

Rate change limiter added on air flow keeps $O_2$ levels up on ramp down

Air Flow Master
OTC Fast Load Change; 5%/min
Loss-of-Grid Runback to House-Load (boiler-follow + MW_e)

- Developing optimized procedure and standard
- Perform transition from 100% to 40% MCR as smooth as possible.
  - Minimize RH and SH temperature dips below set point
  - Good coal flow control for FEGT
- Want to avoid:
  1) Excessive steam pressure
  2) Water in collection tank
  3) Low O_2 levels
- Key procedural items
  1) Trip three pulverizers sequentially
  2) Ramp boiler demand down fast
  3) TTV used to control boiler pressure
Loss-of-Grid Runback to House-Load (boiler-follow + MW_e)

- Optimization in progress
- Performance may be limited by physical characteristics such as damper closing times, fan response times, etc.
Transient after MFT to Provide Gland Steam

Demonstrated that 2 hours of gland steam can be provided

Steam Pressure
Steam Temperature
Reheat Delay Time for IEEE Standard Governor Model
Model of FM Boiler
Goal; Controls V&V Before Shipment

FM Boiler and PLC Controls Hardware

FM Boiler Model linked with PLC Controls Hardware

Communication via OPC
Future Dynamic Modeling Possibilities

• Could include full-plant performance evaluation regarding faster start-ups, upgrades, and cycling.

• Linked TRAX/RELAP/High-fidelity-furnace would provide high-fidelity lower and upper furnace temperatures for FEA structural damage models.

• If the trend continues in IC&E where B&W does more of the total DCS system, it is conceivable that B&W could provide a plant the exact DCS logic via a DCS simulator (like our DeltaV simulator). Control logic ports 1-1 from DCS simulator to actual system. This requires linking DCS simulator to a high-fidelity TRAX process model.
Using Simulator Results as Input for FEA Boundary Conditions

Engineering-Grade Full-Plant Simulator

Transient Boundary Conditions
- Temperature
- Pressure
- Flow Rate

Finite Element Analysis (FEA) (Abaqus®, ANSYS®, etc.)

Automatic Generation Control (AGC)
- Mode of power generation
- Very frequent load changes
- Results in thermal cycling
- Hard on Boilers

Stresses, Strains, Etc.

Structural Damage Model and Life Assessment

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ANSYS is a trademark of ANSYS, Inc.
EGFP Simulator Fidelity Needed for FEA

• Full Plant
  - If a component has adequate internal fidelity, then the temperature and pressure change through that component will be accurate.
  - If all components have adequate fidelity, then the “loop” in the plant will be accurate (analogous to Kirchhoff’s law in circuits). Thus, inlet/outlet temperatures/pressures of any component will be accurate and suitable for incorporation into FEA.
  - A well-tuned model to field data will increase accuracy of boundary conditions (not possible on new boiler designs).

• Components
  - Multi-node capability within components allows internal temperatures and pressures to be ascertained. This is important when only a portion of a component will be analyzed by FEA.
  - Target components might include headers, fluid junction locations (i.e., attemperators), and heat exchangers.
B&W CFB Unique Features Requiring Specialized Modeling
Simulator Results Can Aid in Patents

United States Patent
Sakadjian et al.

Patent No.: US 9,200,622 B2
Date of Patent: Dec. 1, 2015

SOLAR-NUCLEAR HYBRID POWER PLANT

Applicant: Babcock & Wilcox Power Generation Group, Inc., Barberton, OH (US)

Inventors: Bartev B Sakadjian, North Canton, OH (US); William A Arnold, Akron, OH (US); David L Kraft, Massillon, OH (US)

G21D 5/12; G21D 5/14; G21D 5/16; Y02E 10/46; F03G 6/003; F03G 6/005; F03G 6/065; F03G 6/067; F24J 2/42; F22B 1/023; F22B 1/006; F22B 1/123; F22B 1/162; F22B 1/1823; F22B 1/063; F22B 1/143; F01K 13/00
USPC ............................................. 60/641.8–641.15
See application file for complete search history.
Discussion and Take-Aways

• Value and Need
  - Dynamic modeling has solved, and will continue to solve, difficult transient engineering problems in boilers
  - Use (# of projects) and applications (# of product lines) are increasing

• Status
  - Have several up-to-date licenses
  - Have some ability to customize the code for our needs

• 2017 and Beyond
  - Dynamic modeling is a unique tool in B&W’s toolbox
  - Proposed additional training for B&W personnel
Thank you !!

Questions?

Questions Evolve → Into Ideas