Technology Attributes for Successful Unit Optimization

By Peter Spinney

Successfully optimizing a power plant requires employing technology best practices. Applying these elements varies by solution, plant, and by unit. Each customer has unique needs and goals. But all of the issues need to be addressed in considering comprehensive optimization, i.e. deployment of the full range of solutions needed to best achieve the three overriding objectives of availability, efficiency, and emissions control for a generating unit, plant, or fleet. These technology attributes are listed below.

- **Scalability and Integration**. Power producers are acquiring assets with a variety of legacy control systems. An optimization system must simultaneously integrate with legacy control systems and new IT applications as they become available. Emissions, efficiency, and availability for fossil-fired steam generating units depend on a complex set of highly interdependent subsystems. Optimization solutions must not only address each of the subsystems and processes affecting their performance individually (i.e. sootblowing, combustion, steam temperature control, turbine efficiency, post-combustion emissions control systems, etc.); they must also account for interactions across systems and coordinate their optimization toward common higher-level objectives.
- **Accommodate Changing Objectives and Constraints**. Due to the large number of systems, subsystems, associated system states and control variables, the effects of all the involved interactions cannot be known in advance. Many older optimization applications provide great initial benefits, but fall by the wayside when new objectives or unforeseen events arise. The ability to quickly add trained models that provide the optimization system with the ability to address such developments is crucial to achieving sustained maximum benefits and ensuring safe, prudent unit operations.

  For example, new or stricter emissions limits can come into play; or the addition of post-combustion control technology such as an SCR can dictate the need to move from NOx reduction to minimizing ammonia usage. The optimization technology must be flexible enough to accommodate such changing and constraints and objectives without undue effort or disruption. Where possible, tradeoffs between objectives that can be monetized should be managed in a way that minimizes total variable costs and/or maximizes profit.
- **Integrate Optimization and Advanced Controls.** Until recently, available optimization offerings have entailed choosing between neural network-based optimization and multivariate predictive control (MPC). In fact, some combustion processes are better suited to one methodology than the other. For example, the rapid response times required for steam temperature control are best addressed with MPC technology, while the constantly changing relationships between air dampers, mill outlet temperatures, and NOx are best addressed through adaptive neural modeling and optimization. Maximum benefits are achieved by employing both methodologies coordinated through a common underlying platform.
- **Go Beyond On-line Retuning**. A key challenge for an optimization system is to maintain optimal performance in the face of changing fuel quality, boiler states (furnace cleanliness, pulverizer charge, slagging, etc.) and ambient conditions. On-line retuning captures and responds to the effects of such changes on the relationships between controllable parameters and unit

performance. Direct search methods inform neural models of the relevant causal relationships otherwise masked by correlations as multiple control loops move in unison as a function of load. These methods also automate parametric testing, which supports short non-intrusive installation, as well as responding to major changes in operations that inevitably occur after the initial installation. Only by combining the direct search exploration and neural network adaptive learning can systems benefit from true on-line learning.

- **Validate Models**. Neural network models are unique in their ability to address the highly non-linear, multivariate, constantly changing nature of combustion. They also involve non-unique solutions that are susceptible to issues such as local minima (or maxima), over-generalization, "learning bad data," etc. As the early experience with older combustion optimization systems made clear, even a neural network that tunes itself on-line is susceptible to being "confused" by disturbance variables (such as changing coal quality) or discrete process changes (such as different burners or mills in-service), thereby becoming inaccurate, and losing the confidence of operators. Only by using "committees" of multiple models can models be validated to ensure against these potential problems. Approaches without such capabilities will perform unreliably in the face of bad data, sensor drift, and conditions changes not directly reflected by model inputs.

- **Apply First Principles**. While combustion and NOx formation require inductive modeling, unit efficiency and capacity are best modeled and optimized by exploiting the laws of thermodynamics. Combining a detailed first-principles model of the unit with a real-time solver, trigger variables and simulation capabilities supports continuous identification of gaps between actual and achievable efficiency and capacity, prioritized on the basis of their economic impact.

  Neural network optimization can also be combined with first principles to provide a better solution than separate neural optimizers and performance monitors. A rigorous on-line solving thermodynamic model can also inform optimizers using inductive and/or rules-based methodologies with valuable knowledge. Examples include providing real-time knowledge of back-calculated coal quality information for combustion optimization; local heat transfer efficiency for sootblowing; and equipment degradation or mechanical problems for predictive maintenance.

- **Embed Knowledge with Heuristics**. There are hundreds of person-years of experience and operating knowledge in the minds of the operators and engineers running power plants. Unfortunately, this knowledge is being lost through down-sizing, early retirements, and the difficulty finding experienced well-trained personnel to replace those being lost.

  Optimization technologies – whether based o inductive models or first principles – can be powerfully augmented through the use of rules-based expert systems methods whereby human knowledge is embedded in software to perform such problems as anomaly detection, root cause analysis, or to identify ways of better using closed-loop optimizers.

- **Impart Visibility and Insight**. Combustion optimization entails using manipulated variables to achieve multiple objectives, managing the tradeoffs between them, and doing so in a manner that avoids violating emissions and operating constraints. The complexity is beyond the ability of a human operator to comprehend, and there will be moves made that seem counterintuitive.

  Full realization of benefits requires providing users with real-time knowledge of what the optimizer is doing, the reasons for its actions, the benefits provided by allowing these actions, and the additional benefits that could be achieved by keeping MVs in-service, relaxing unnecessarily tight constraint ranges, tuning control curves, etc.

- **Provide Engineering and Analysis Tools.** There's a wealth of information and operating knowledge that can be extracted from the models underlying a properly designed optimization system. Applications and support engineers can help customers identify problems through this knowledge that might have gone undiscovered for days or weeks.

  Providing tools to help customers proactively exploit this knowledge substantially enhances the value provided and supports broader buy-in on behalf of the engineering, maintenance, environmental compliance, and management personnel at the plant and throughout the organization. Access to these and the administrative tools needs to be accessible when and where they are needed – from the desktops of appropriate plant and corporate personnel who require them.