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PRECISION DATA VALIDATION BOOSTS PROCESS OPTIMIZATION BENEFITS

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FUEL COSTS ARE RISING, EMISSION STANDARDS ARE TIGHTENING AND SKILLED MANPOWER IS ALWAYS IN short supply. To remain competitive, many power producers are turning to plant process optimization—a field that is so "in vogue" today that prospering without it seems doubtful. But as large fossil plants around the world employ expensive consultants to install sophisticated process optimization tools, plant managers are discovering (if they weren't already aware of it) that precise validation of the data going into these tools is the single most important prerequisite to success.

Precision data validation is the ability to recognize abnormalities in real-time power plant systems. Today, the usefulness of process optimization, as well as other automated systems and technologies for plant monitoring and control, is highly dependent on the reliability of plant instrumentation and the accuracy of the data it provides. But this fact really hits home when a power producer invites a data validation consultant into a plant. Invariably, the contractor identifies instrumentation problems with a variety of systems that supercede the results of various optimization analyses. These problems are reducing generation output, raising the heat rate, and increasing emissions of SO_2, NO_X, and CO_2—each of which increases operating costs.

Dairyland Power Cooperative's J.P. Madgett unit (photo courtesy of Dairyland Power Cooperative).

To make matters worse, instrumentation problems are insidious. For example, the typical drift of a new thermocouple installed in a 1,000 F environment (e.g., a main steam or hot reheat line) is 3-5 F in its first year of operation. Since thermocouples typically drift high, a measurement deviation of only 3 F in main steam temperature leads to an increase in unit heat rate of approximately 6.1 Btu/kWh. A similar deviation in hot reheat temperature leads to a 4.3 Btu/kWh increase. For a 400 MW unit with an 80 percent capacity factor and a fuel cost of $1.75/MMBtu, the direct annual increase in fuel cost resulting from these deviations alone is more than $50,000. Faced with this reality, one by one, plant managers and operators are becoming converts to the precision data validation movement.

TRI-STATE TRIAL

Lanny Lambrecht, Tri-State Generation & Transmission Association performance testing specialist, realized the need for precise validation of plant measurements before many power producers. In 1993, Lambrecht and Performance Consulting Services began installing a precision data validation system based on advanced pattern recognition (APR) technology at Tri-State's Craig Unit 3—a 428 MW pulverized coal-fired unit. During the initial data collection and model set-up at Craig, the APR-based tool identified a problem with the economizer oxygen level, a modulating valve on the steam coil air heater, a modulating high pressure feedwater heater level controller and an inaccurate main condenser pressure measurement. While these problems had apparently been undetected for some time, they were readily identified using APR technology.

FIGURE 1

PRECISION DATA VALIDATION BENEFITS

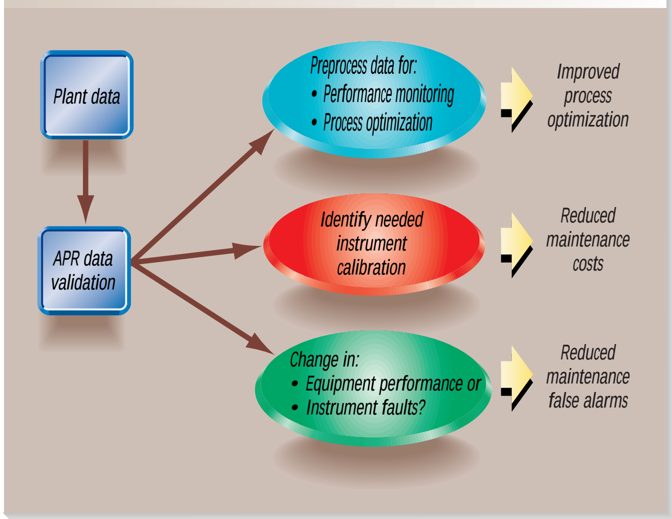
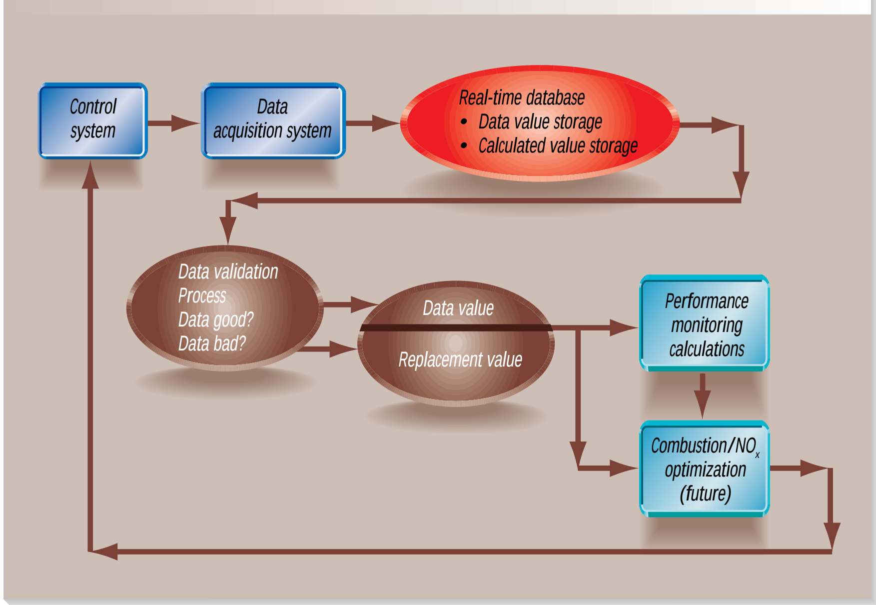


FIGURE 2

DATA VALIDATION IN A CLOSED-LOOP SYSTEM



After these early successes, Tri-State never looked back. To date, they've avoided wasted manpower recalibrating valid instruments, improved heat balance calculations and validated new equipment at Craig. They've since expanded the technique to their circulating fluidized-bed unit in Nucla, Colo.

Like Tri-State, power producers are typically motivated to apply precision data validation to achieve three benefits (Figure 1).

First, they want to use data validation to pre-process the plant data that is used by performance monitoring, combustion optimization and control systems. The idea here is to ensure that calculated results and operational recommendations are based on reliable information (Figure 2).

Second, power producers want data validation to accurately identify instruments that need calibration. They want calibration efforts to be focused on only those instruments that need attention, reducing total hours required for instrument maintenance.

Third, plant engineers want to be able to differentiate between changes in equipment performance and instrument faults. With the capability of effective data validation, engineers can reduce maintenance "false alarms."

NEW TECHNOLOGIES

Power producers know that validating the instrumentation data being fed to monitoring, control and optimization tools is no easy task, especially given shrinking plant staffs. Thousands of parameters are measured at a typical power plant today. Many of the aging instruments that measure these parameters are exposed to harsh operating environments that include extreme and widely fluctuating temperatures, vibration, and exposure to dust and dirt. Maintaining these devices with only a few skilled instrument technicians is often a challenge.

Plant operators are understandably skeptical when "new and improved" data validation methods are mentioned. In the past, such methods have involved expensive redundant instrumentation, difficult-to-maintain statistical correlations, and most recently, highly touted neural networks (that reportedly "work like the human brain" but, in fact, have limited capabilities).

Redundant measurement analysis is in common use today on some safety related parameters in nuclear power plants and critical control measurements in fossil plants (e.g., drum level) where multiple sensors measure the same parameter. Similarly, statistical correlations, in which measurements of related parameters can be used to check a nonredundant sensor, are frequently used to monitor instrument drift.

But power producers, eager to take best advantage of emerging monitoring, control and optimization strategies, have been clamoring for a better method of data validation for some time. Indications are that APR shows great promise to cost-effectively and efficiently meet precision data validation needs. The algorithms behind products offered by vendors of commercially available data validation tools today are quite similar, and each is based on a set of fundamental principles best illustrated by an example.

How APR Works

APR technology views a system as a set of numerical data values, such as main steam temperature, condenser pressure and plant heat rate. These values are grouped together in arrays called "data records." A data record is simply a snapshot of plant data values for a single instant in time. The individual items associated with a data record are called "points," and their related values are called "point values."

APR modeling and data validation capabilities are rooted in proprietary numerical pattern recognition methodology. A key aspect of this methodology involves quantifying the similarity between pairs of data records. Computed similarities are scalar values that typically range between zero and one. For example, a similarity value of one indicates the two different data records are identical (e.g., each temperature, pressure and flow value at one instant in time is the same as at a different instant in time). Conversely, a similarity value of zero indicates that two data records are completely different from each other (e.g., plant conditions at full power compared to plant conditions at zero power).

Prior to analyzing a system, a number of data records spanning a range of system operating conditions are collected and stored in a file. The purpose of these "reference data records" is to act as a knowledge base characterizing normal system behavior (Figure 3).

After the reference data records have been collected and stored, APR technology involves obtaining a new snapshot of system data called the "input data record." This record is first compared with each of the reference data records using the similarity operation. The APR technique includes selection of several data records from the reference set that have the greatest similarity to the input record—referred to here as "nearest neighbor" records.

Once the nearest neighbor records have been selected, the similarity between all pairs of nearest neighbor records is computed, forming a "recognition matrix" of similarity values. The recognition matrix and the input data record are then used to compute values for each of the monitored points. That is, a point value for each of the input points is computed, collectively resulting in an "output data record."

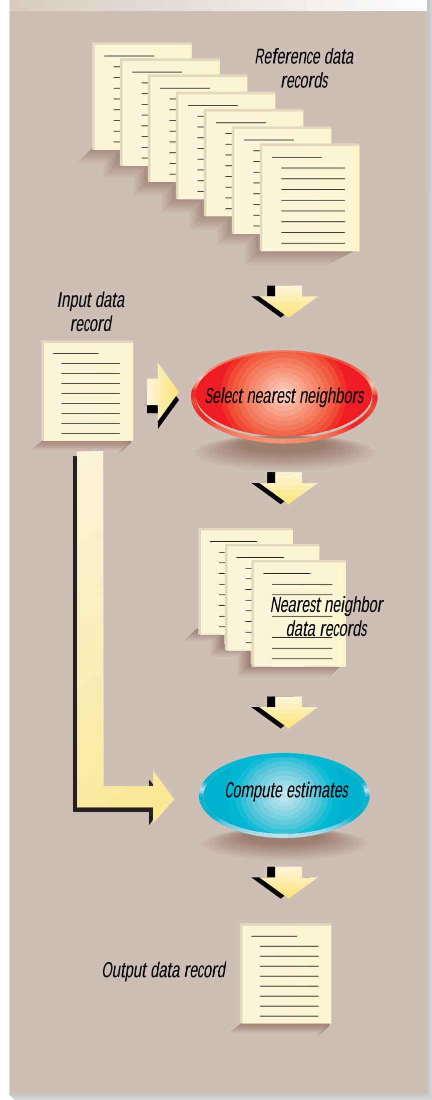
The computed output record is an accurate representation of how the system should be behaving based both on past performance and current operation. The calculated values are highly fault-tolerant because defective plant parameters in the input record do not markedly bias or affect the accuracy of the computations. When plant parameters are missing from the input record, the tool provides accurate predictions for these parameters as well.

Once computed, the output record is typically compared with the input record for further data manipulations. The significance of any differences between the input and output values is generally viewed in the context of the specific application (e.g., indication of a signal failure, calibration drift or abnormal system operation).

Advantages

This approach brings several advantages over earlier methods. For example, since APR technology treats all monitored parameters as interrelated, and hence models them simultaneously, the underlying algorithm is highly fault tolerant; the effects of incorrect or missing plant measurements are minimized. This interrelated modeling also helps to pinpoint specific parameters that are deviating from normal operating behavior. Conversely, most neural network techniques must separate system parameters into dependent and independent

FIGURE 3
APR DATA FLOWCHART



sets. To obtain results similar to what APR technology would provide requires multiple neural net models, assuming that all measurements could be accurately modeled using neural nets.

In addition, APR technology typically requires no iterative training phase—another downside of neural network approaches. As a result, input reference data can be modified as often as desired, allowing immediate adaptation to new information.

Another upside is the 100 percent repeatability of this approach. If the analysis is executed twice using the same reference data set, the results are identical. Conversely, the results of neural network modeling are highly dependent on the training process. Varying "seed" values, the training technique or convergence criteria can have a significant impact on neural net modeling results.

One reason for APR repeatability is its characteristic use of well-behaved deterministic algorithms. No iteration schemes requiring convergence criteria are used, guaranteeing that the algorithm has no failure modes and always produces an optimal solution given the available information.

Choose Wisely

While the underlying algorithms in APR products are quite similar, key software differences reside in the user interface, including ease of setup and use. Yet perhaps more important than the selection of a particular APR product is the experience of the people behind it. No plant manager wants raw software programmers with no plant experience explaining how to improve performance and reduce O&M costs based on some numbers on a chart. Identifying an APR product backed by professionals with experience in power plant performance, plant simulation, and management consulting is likely to be beneficial.

APR technology is well proven and established. At Dairyland Power Cooperative, four units are running with a real-time performance monitoring package, and the co-op wanted to make sure the data coming into those packages was valid. Dairyland installed an APR product on a JP Madgett unit, which consists of a coal-fired Riley Stoker boiler and 360-MW turbogenerator. Placed on line in 1979, Madgett is a load following, sliding pressure unit burning Powder River Basin coal (see photo).

In one year of APR operation, Dairyland is realizing benefits. For example, the APR system indicated an abnormal drain temperature on the high-pressure feedwater heater at low load. Since this was happening at night at low loads, the condition might have been difficult to uncover. The controller was set improperly, so that the drain was opening when it was supposed to be closed. Correcting the problem allowed the heater to perform much more effectively, improving overall unit efficiency.

Dairyland uses APR technology to monitor various time increments. For example, over a six to 12 month period, the software watches for instrument drift and other long-term trends. Every one to three months, the software follows up on any potential problems identified over the previous 12 months. The system also scans data every 24 hours to identify acute impending failures.

Reducing the load on instrument technicians was another primary motivation for Dairyland's decision to install APR technology. The three technicians at Madgett were overloaded, and the APR has enabled them to operate more efficiently. Like its contemporaries, Dairyland seeks to implement an optimization program at Madgett. The co-op's odds of success at this endeavor are greatly improved with the use of APR.

Conclusion

Most popular and beneficial optimization programs, advanced controls and other emerging power plant technologies incorporate some sort of limited data validation capability. APR further improves the accuracy, reliability and confidence of data validation in these programs. Precise data validation may also help accelerate the practical use of advanced methods of plant automation, including closed loop optimization. High accuracy, fault tolerant data validation could be integrated with computerized maintenance management systems to automate work order generation for troubleshooting, repair and calibration. PE

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