Process-Constrained Data Analytics for Sensor Assignment and Calibration

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ABSTRACT:

The proposed research will develop and demonstrate data-analytic methods to address the problem of how to assign a sensor set in a nuclear facility such that 1) a requisite level of process monitoring capability is realized, and in turn, 2) the sensor set is sufficiently rich to allow analytics to determine the status of the individual sensors with respect to their need for calibration. The Electric Power Research Institute (EPRI) has identified the use of richer sensor sets in nuclear power plants and data analytics as a new means to improve operations and reduce costs.

The incentives to optimize a sensor set, as described above, are greater today that in the past. The assignment of sensor set has historically been approached as an alarm and control problem: for a given system, what sensor set ensures process condition can be monitored and controlled? In the past, the high cost of sensors and signal transmission with specialized nuclear-grade hardware confined the sensor set to a bare minimum. Recent increase in communication bandwidth and sensor connectivity in hard to read places due to advances in RF wireless and fiber-optical signal transmission, and sensor price decreases, have lowered the barrier to a richer sensor set at a facility. One can now take advantage of the available hardware options to enhance process and equipment diagnosis capabilities.

In principle one might approach the calibration problem as a pure data-driven black-box problem. Indeed, several methods have been developed using this approach. But practical experience gained by utilities over the past ten years with these methods has shown that the purely data-driven approach is not reliable. The problems with data-driven methods arise from complicating factors, such as the inherent variability of operation (both equipment alignment and operating condition), which can confound a data-driven approach, and the absence of theoretical guidelines for determining what constitutes an adequate sensor set that will deliver on the two objectives above.

The solution we propose to overcome these shortcomings is to supplement the data analytic approach with process information in a so-called *process-constrained data-analytic* approach. Briefly, simple balance equations are written for generic components (e.g., mechanical pump, valve, and heat exchanger). These do not require *a priori* knowledge of process parameters, such as heat transfer coefficients or friction factors. All that is needed on the part of the utility user is to identify the components and how they are connected together. Through the data analytic approach to be developed in this work, the inverse sensor set problem can be solved. The goal will be to determine the minimum sensor set to permit diagnosing and localizing an equipment fault given a stated level of fault severity. Another problem of more immediate interest to a nuclear facility is identification of the minimum sensor set needed to determine the calibration status of all the sensors. With this solution, the required sensor set can be identified to provide for automated calibration status, thereby avoiding the time consuming O&M resources for calibrating sensors that are not in need of calibration. This approach is cross-cutting, i.e., it is equally applicable to advanced reactors as it is to currently operating light water reactors.