Smart Management Strategies for Smart Manufacturing Plants

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Introduction

This paper reviews the evaluation, management, and implementation aspects of Smart Plants, as elucidated by a "Smart Distillation" survey performed by Dr. Jimmy Humphrey in the fall of 2007. It asked the following questions:

Suppose all key distillation columns within a company were equipped so that accurate real time material and heat balances could be determined around each column, and further suppose that data may be shared locally and globally with the enterprise in real time -- what advantages do you see, and what are the challenges?

Why a "Smart Distillation" Survey?

"Smart Distillation" is one of many design and operational innovations that fall under the general category of "Smart Plants." The purpose of moving to "Smart Plant" technologies is to improve a facility's ability to predict problems and act proactively to prevent problems before they occur.

Globalization, availability of feedstocks and fuels, and the retirements of an aging workforce, are some of the challenges facing process industries today. It is an opportune time for the process industries, universities and government to collaborate on new programs to upgrade existing plants or build new plants based on to "Smart Plant" design principles.

Why choose distillation to explore this topic? Because even though extensive amounts of research have been done over the past 30 years on alternative processes, there is no replacement in sight for distillation. About 80,000 distillation columns are in operation in existing chemical plants and petroleum refineries worldwide, about one-half of which are in the U.S. These columns, with a thermodynamic efficiency of only 3%-5%, consume the energy equivalent of 2.5 to 3.0 million BPD of crude oil worldwide. Distillation is critical to process industries, contributing directly to revenues of about $6 trillion per year.

Why Evaluate "Smart Plant" Alternatives?

The issues that "Smart Plants" are intended to address are numerous and costly to U.S. process industries. The authors estimate that reductions in excessive energy consumption through "Smart Plant" innovations, for example, could save industries $20 billion per year. Avoidance of unplanned plant shutdowns could save an additional $20 billion per year. Improved targeting of maintenance, which would avoid both “too much too soon” and “too little too late,” could save $5 billion per year. Because a single environmental or safety incident can cost a company as much as $2 billion, the cost savings from avoiding or reducing incidents is potentially larger than all of the other projected savings combined.

What We Learned

Approximately fifty individuals responded to the "Smart Distillation" survey. One-half of these responses came from individuals in process industries, and the other half came from individuals in universities, suppliers, government, and consulting firms. Responses included both direct answers to the questions and more general feedback and suggestions, as well as examples of pertinent industry initiatives. As a whole, the respondents confirmed that there is interest in "Smart Distillation" and "Smart Manufacturing" by process industries, operating companies, universities, and government agencies.

Many of the "Smart Distillation" advantages identified by respondents go beyond distillation to include unit operations, such as heat transfer, and other industries, such as telemedicine. Similarly, the key challenges identified by respondents covered a broad range of topics, such as processing large volumes of data in a timely manner. Both the advantages and key challenges are discussed in the next two sections.

Main Advantages of "Smart Distillation”

Respondents to this survey identified 70 different types of advantages that could result from the proposed instrumentation and data utilization that would results from "Smart Distillation." The principal "Smart Distillation” benefits identified by respondents included the following:

- Monitor, diagnose, and troubleshoot distillation columns (heat exchangers, furnaces, reactors, etc.) via broadband using centrally located, highly skilled technical staffs.
- Constantly compare performance of similar columns (globally) to identify and improve those that are underperforming.
- Perform process diagnostics on individual columns and compare actual with theoretical performance.
- Detect unexpected leaks earlier and save money by maintaining safe operations.
- Continuously operate columns at tighter product specifications to reduce off-spec products and increase energy efficiency.
- Having the energy requirements of each column, an online version of the Total Site Analysis could be determined (using Site Utility Curve).
- Constantly update distillation models and use them for accurate optimization.
- Optimize capital equipment to reduce carbon footprint of the global enterprise.
- Operate columns closer to their flood points to maximize production.

- Enable R&D and Process Improvement groups to mine data for validating process simulation theories and control strategies.
- Improve MHB awareness of operators and others to prevent safety incidents such as occurred recently in U.S.
- Compare performance of plants versus commercially available technology to make better capital investment decisions.
- Coordinate and schedule production from information that is available globally to maximize overall profits.
- Foster relationships among industry, university, and government to sponsor student interns to develop predictive models using accurate real time MHB.

Key Challenges to Implementing "Smart Distillation"

Respondents to this survey also identified several potential drawbacks and concerns about "Smart Distillation." The key challenges cited most often are:

- Is there such a thing as an accurate material and heat balance? Are compositions and flow rates based on inaccurate measurements? Can compositions be measured in real time? Distillation does not always operate as a steady state process;
- More emphasis needs to be placed on applying wired and wireless sensors as well as soft sensors. Getting accurate real time measurements, and applying accurate predictive models, are critical to taking proactive actions that prevent plant problems before they occur;
- How do we handle the volumes of data that will be generated? These data may cause confusion and delays without considerable supporting software and graphics. Can we develop intelligent data analyses to quickly process the amount of data generated and pinpoint the problems?
- How can benefits outweigh the costs for small plants? and
- Will we have enough people with the expertise to intelligently mine the data?

Where Industry Is Today

Some process industry companies are sharing plant data globally via the Internet to enable in-house "experts" access to this information. One respondent described an application that he is using to track the extent to which some unit operations vary from a theoretical optimum state, and receive financial reports that show dollars lost in real time. We also learned about a major chemical company that implemented a centralized monitoring system to achieve environmental management, which includes a dozen plants located in multiple states.

Some respondents reported that they are in the early stages of developing and sharing the benefits of real time data utilization. They are currently using:

- Broadband to access data historians to get real time plant data. These data are used for monitoring, diagnosing, troubleshooting, and modeling.
- Real time optimizers that use third-party software (e.g., AspenTech's RTOPT) on individual distillation units.

- Advanced control systems that preferentially feed the most efficient distillation columns first, to the extent demand permits.
- Systems to track how far off optimum some unit operations are and translating the difference into dollars lost in real time.
- Centralized monitoring system with web access for Title V Compliance and process historian data collection and evaluation via broadband

Wireless instrumentation has not made significant inroads in the process industries sector because most plants have not yet installed wireless networks outside of administrative offices and control rooms. However, wireless technology offers significant cost, versatility, and other advantages to manufacturing plants, which will enable it to dominate the instrumentation market in the coming years. When those conditions prevail, more instrumentation will be installed in operating units, opening the door to a number of “Smart Plant” innovations.

Knowledge Management Considerations

In a published work entitled “Position Paper on Knowledge Asset Management,” Professor Ann Macintosh of the Artificial Intelligence Applications Institute (U. of Edinburgh) explained the importance of information “assets” to an organization and suggested four criteria for assessing Knowledge Management (KM). These criteria are explained below (items in italics were added by the authors):

1. Identify the knowledge assets a company possesses
    - Where is the knowledge asset?
    - What does it contain?
    - What is its use and what form is it in?
    - How accessible is it?

2. Analyze how the knowledge can add value (“Create Added Value”)
    - What are the opportunities for using the knowledge asset?
    - What would be the effect of its use?
    - What are the current obstacles to its use?
    - What would be its increased value to the company?

3. Specify what actions are necessary to achieve better usability and benefit (“Make Knowledge Usable”)
    - How to plan the actions to use the knowledge asset?
    - How to enact actions?
    - How to monitor actions?

4. Review the use of the knowledge to ensure added value (“Ensure Value is Added”)
    - Did the use of it produce the desired added value?
    - How can the knowledge asset be maintained for this use?

- Did the use create new opportunities?

The chart below assesses each of identified Smart Distillation advantages against the last three Professor Macintosh KM criteria, A subjective rating scale of Smart Distillation advantages, from 1 (no effect) to 5 (high impact), was used to rank order the advantages based on how well KM criteria would be supported.

Smart Distillation Advantages (summarized)	Create Added Value	Make Know-ledge Usable	Ensure Value is Added	Total Score
Constantly update distillation models for accurate optimization.	4	4	3	11
Detect unexpected leaks earlier and save money by maintaining safe operations.	5	3	3	11
Improve coordination and scheduling of production to maximize profits.	3	4	4	11
Validate process simulation theories and control strategies.	3	4	4	11
Operate columns at tighter specs to reduce off-spec products & increase efficiency.	5	4	2	11
Compare performance to available technology to improve capital investments	3	4	3	10
Operate columns closer to their flood points to maximize production.	4	4	2	10
Optimize capital equipment to reduce carbon footprint	3	4	3	10
Compare performance of similar columns to improve underperforming. assets	4	3	2	9
Determine energy requirements of each column using Site Utility Curve	3	3	2	8
Perform process diagnostics to compare actual vs. theoretical performance.	3	3	2	8
Centrally Monitor, diagnose, and troubleshoot equipment via broadband	3	3	1	7
Improve operator awareness of MHB to prevent safety incidents	3	1	1	5
Sponsor student interns to develop predictive models using real time MHB.	2	1	1	4

KM is sufficiently important to warrant careful analysis of the potential advantages of various design and operation approaches on criteria such as the ones proposed by Dr. Macintosh. After ranking the potential advantages of a technological innovation, or comparing the KM impacts among competing ideas, planners and designers can move toward adopting approaches that are most likely to achieve optimal project results from a KM perspective.

Evaluation

In addition to assessing the advantages of “Smart Distillation” (and other Smart Plant technologies) against standard knowledge management (KM) criteria, planners must also consider life cycle cost, technical feasibility, work force acceptance, regulatory approvals, competing priorities, and numerous other factors. At the same time, one reason why plants have not always been designed or operated as “smart” as possible is that decision makers have often overlooked KM considerations.

How can KM be assured of playing a role in the design and operation of process industry plants? One way is to focus on the value-added component. Authors of process improvement books often advise readers to look at other fields of endeavor for insights into solving their problems. In this context, the Ohio Department of Education may offer a valuable perspective into assessing value-added considerations. The case in point involves measuring student progress.

The Ohio Accountability Task Force was created in House Bill 3 to guide the implementation of 'value-added' progress measures into the accountability system of the department. House Bill 3 mandated that the previously used “Performance Index Growth” method be abandoned in favor of a new value-added approach to be developed by the Task Force.

Task Force members soon realized that “Value-Added Measures” were needed to establish metrics for assessing progress because previous methods relied on metrics unrelated to the core values of the department. House Bill 3 demanded that the evaluations be based on metrics that took into account and accurately reflected the core values of the department related to student progress. Even relatively objective measures, such as achievement test scores, did not meet this test, because the results were not scaled to a core department value. Test scores were therefore scaled based on factors tied to the goals of each school and district, and so-called Composite Scores were then used to evaluate added value.

There are three lessons to be learned from this example. First, metrics are essential to measuring the value added from innovation; in other words, “value” must ultimately be quantifiable. Second, just because there are performance indicators that can be measured and compared to historical data, does not mean that they will properly evaluate value added. Third, and perhaps most importantly, metrics that reflect the core values and goals of an organization are of greatest benefit to decision-makers when evaluating alternatives based on value added.

Implementation

“Smart Distillation” will require the installation of new sensors, computer network components, and other improvements, in addition to the capacity to process a large amount of information. The challenges in meeting these requirements were pointed out by several respondents to the survey. This raises an implementation issue that is especially germane to “Smart Plants,” namely, should decision makers wait until every part of an innovation is supported by proven and available infrastructure before proceeding? Or, should implementation be commenced even with some uncertainty and “leaps of faith?”

One of the author’s experiences with technology for detecting changes to a company’s applicable environmental rules may provide some insights into this question. About ten years ago, industries began to comply with new federal permitting requirements for air emissions. All regulations to which a facility was subject were required to be listed in these federal permits, and if any of the regulations were amended, compliance with the new/changed requirements was necessary with thirty days of the effective date of the change.

Process industries realized that continuous reconnaissance of applicable state and federal rules would be needed to ensure continuous compliance with their new federal permits. To meet this challenge, a regulatory management of change (“RMOC”) subscription service was launched. It included reconnaissance of state and federal citations on agency websites, capabilities to conveniently update subscriber databases, and a quarterly notification to each subscriber summarizing the changes and their potential impacts. The historical text of changed rules was automatically stored in each subscriber’s database, an especially useful feature due to lengthy lag times that are common in most agencies’ enforcement of environmental rules.

Although efficient procedures and computer systems were implemented to achieve these results, manual labor was involved in downloading citation text from the web and in parsing the rule text into a “Before” and “After” snapshot of each change. Performance of the reconnaissance elements of the RMOC system became an issue after the number of scanned citations exceeded 10,000 rules. In response, the computer system was reengineered to scan and extract data from federal and state websites more efficiently. This eliminated much of the manual labor that was involved and boosted performance back to acceptable levels.

When the number of scanned citations reached 30,000, it became clear that more efficient data processing would be needed to meet future increases. A project was launched to devise a new technology for performing RMOC services at much higher loads. This research led to the development of a new web service, soon to be announced, that will not only meet foreseeable demands but can also fully automate the service.

Of special note in this example is that the new technology is not simply a refinement of the prior system tools. It is a completely different and much faster way to scan information from websites using tools and techniques that did not exist when the original RMOC service was launched. This quantum leap in capabilities enables the new system to handle all of a subscriber’s applicable rules, not just environmental ones, and to notify key personnel when changes were detected. Moreover, regulations written in multiple languages may be scanned by the new system to detect possible changes on a daily, or even hourly, basis.

The point of this example is to emphasize that “necessity is the mother of invention.” The decision to initiate a service using available technology and system tools, and not wait for better ones before taking action, has led to an RMOC solution that supports even “ultimate” capacity usage of the system with relative ease. Though load-limited and known to be so from the start, the initiating technologies served a purpose critical to the chain of innovation.

Similarly, the implementation of Smart Plant technologies will occur more than once in future cycles of reinvention and reengineering. Pursuing the adoption of Smart Plant alternatives now, even though future cycles may not be fully supported by technology, may be a successful strategy.