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Knowledge³TM

A Platform for Process Modeling,
Optimization, and Control

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imagination at work

Knowledge³TM

A Platform for Process Modeling, Optimization, and Control

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Introduction

GE Energy has a long history and deep expertise in both condition monitoring and machinery/process control. As tools for analyzing asset condition, such as mechanical and thermodynamic performance, have evolved and proven their value, it was natural for customers and GE to look for ways to expand existing technology to new applications. Some of these tools, such as the Closed Loop Optimization and Control (CLOC™) System discussed in the last issue of ORBIT, represent the marriage of modeling and condition monitoring (in this case, thermodynamic performance) with closed-loop control, allowing an entirely new level of optimization effectiveness. Other technologies, such as the

RuleDesk™ utility in System 1® software, focus on allowing users to embed rules-based diagnostics to automate labor-intensive processes (in this case, tedious review of condition monitoring data).

Here, we are pleased to introduce ORBIT readers to an entirely new platform that blends these capabilities, while adding many others, and extends well beyond traditional asset management applications to the broader scope of generalized process modeling, optimization, and control. We call this platform Knowledge³™ (Kn³), because it blends three distinct knowledge-capturing capabilities into a single tool: modeling, optimization, and control.

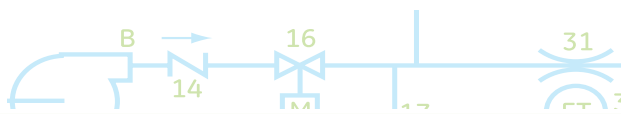


A New Platform for New Applications

Kn³ embeds portions of the proven technologies used in several of our other purpose-built tools. For example, the multi-variable control module used in our CLOC System and the rule-building environment of System 1 software can both be found in the Kn³ platform. Kn³ also allows users to consider a much broader range of optimization, modeling, and control opportunities that complement the optimization tools already available from GE. As a result, Kn³ has

emerged as an extremely powerful, yet generically applicable tool, able to address virtually any industrial process or application. For example, a Virginia power generation facility is presently using Kn³ to optimize a coal boiler. There are numerous other applications, and later in this article, several of these potential applications will be discussed. First, however, an overview of Kn³'s capabilities is in order.

Kn¹ Process Modeling



Process engineers have long understood that “first principles” models are not always practical for particularly complex processes or those with extreme sensitivity to initial conditions. This makes modeling and controlling such processes a significant challenge, particularly when trying to optimize.

To deal with highly complex processes that don't easily lend themselves to first-principles modeling, the process engineering community has increasingly harnessed neural network technology. There are proponents for both sides — some who adamantly oppose anything except first principles, and others who believe the heuristic approach made practical by high-speed computers and neural nets renders a first-principles approach obsolete. In truth, however, both approaches have merit. Tools that can blend the best of both approaches generally demonstrate the broadest applicability and effectiveness.

Recognizing this, the Kn³ platform allows users to implement a purely rules-based approach, a purely neural-net approach, or any combination of the two.

1. Rules

Detailed, easily configurable rules can be written on any combination of data entering or leaving the Kn³ platform.

Rules include mathematical and logical operations, allowing the user to combine data for better and more detailed results. Rules can also be used to visually alert users that an improper operating condition has occurred (or is developing), allowing proactive intervention.

2. Neural Nets

The Kn³ platform allows the development of predictive models, using neural networks, for key outcomes resulting from a process. Neural networks computationally mimic the nervous system of the human body. The system uses inputs (stimuli) to predict outputs (responses) based on the patterns “learned” by the system. Training the system to develop a corresponding model is done by using historical and/or measured data. The goal of the model is to properly characterize outputs given inputs. Here, inputs consist of data that are known to impact the process. The success of neural networks in a wide variety of applications — even those with complex behavior such as weather forecasting — is outstanding. Accuracy is generally greater than 95% and often higher than 99%. In addition, Kn³ is designed to automatically retrain neural networks based on data acquired on-line, when their predictive performance has become inaccurate. In this way, the models never grow static and accuracy is maintained even as conditions change.

Kn² Optimization



The Kn³ platform provides sophisticated, multi-objective optimization, allowing several different goals to be addressed simultaneously. The optimization uses the modeling described above to provide predicted results for a specified set of inputs. The optimization iteratively updates inputs, progressively driving the calculation efficiently and accurately towards the best set. The determination of “best inputs” is based on those that achieve the goals in the optimal way while observing all constraints. For example, inputs for the model would generally be all the *possible* setpoints

for the underlying basic process control system. Outputs would be the *best* combination of setpoints that influence the process to result in optimal efficiency, emissions, product quality, throughput, or whatever else was the goal of your optimization.

The optimization technology used for this purpose is Genetic Algorithms (GAs). GAs are renowned for consistently finding the true optimal solution and use a process that mimics those found in nature. It is a mature technology that has been used effectively in numerous processes.

Kn³ Control



When coupled with GE’s MVC® (Multi-Variable Control) system, users can effectively “close the loop” with the optimized setpoints found by Kn³. MVC implements the optimal setpoints calculated by Kn³ by sending them to the underlying regulatory control system. It does this in a manner that

ensures there are no abrupt process changes or upsets while observing all required control constraints. MVC is a mature, proven technology that GE Energy has applied in several other products including the CLOC system for combined-cycle plants.

Data Management Tools

Kn³ is designed to address all relevant data and information about the process you are modeling, optimizing, and/or controlling. The platform has a powerful data management engine that allows it to acquire data from a variety of sources, validate it, and write custom rules combining data and results in useful and powerful ways. Unlike other environments in which application flexibility

comes at the price of a complex and unwieldy platform, Kn³ is very easy to use and configure. It incorporates the configuration engine and highly intuitive RuleDesk™ technology of System 1 software, allowing graphical development of algorithms rather than requiring fluency in a complex programming language.

User Interface

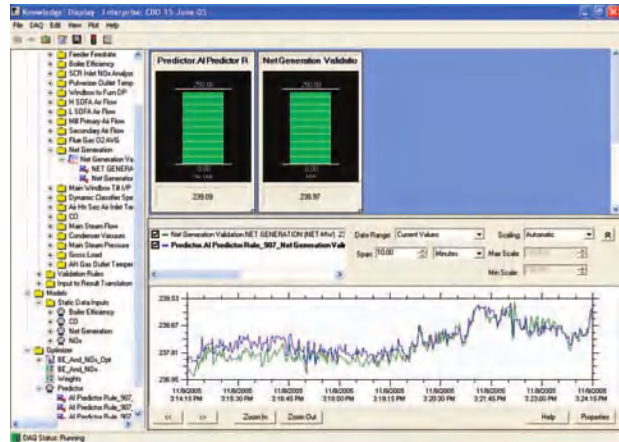
Kn³'s Graphical User Interface (GUI) allows the product to be used off-line or on-line, permitting users to test and validate results, build models, and perform diagnostics in both real time and archived environments. The GUI is also highly configurable, allowing users to customize the look and feel of individual screens according to their needs.

Principal functionality within the GUI includes:

- display of data, rules, model configurations, and operating statistics;
- display of data used in the models including current values and predicted values;
- display of optimization results including current and optimal values;
- visual alarms to alert users of an operating condition requiring action;
- and, historical trending of all relevant data.

When applied online, Kn³ incorporates standard client-server architecture. The GUI software (client) can

be loaded on any machine on the network, accessing data from one or more servers. Off-line, the entire software program can fit on a desktop or laptop computer, providing a fully self-contained tool that can travel with you.



Kn³'s user interface is easily customizable, designed to address the diverse processes for which modeling, optimization, and control is required.

Potential Applications and Benefits

The possible applications of Kn³ are limited only by the user's imagination and the availability of good data that accurately characterizes the process. Here are some examples:



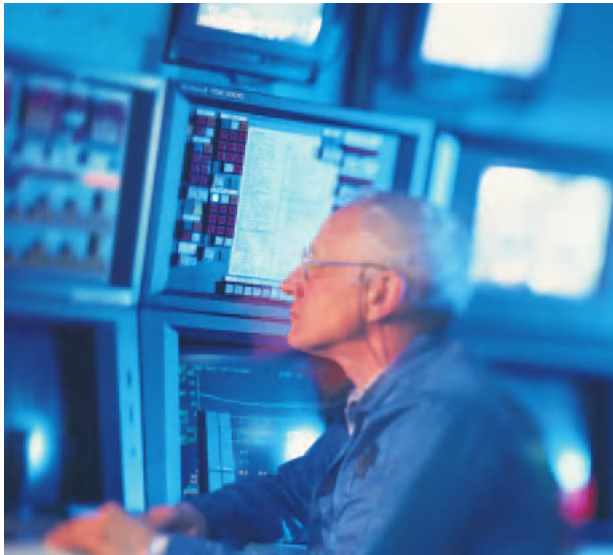
• Energy Optimization

Kn³ can be applied to a variety of energy-related processes such as power and steam production, pipeline optimization, and grid management. One example, is coal boiler optimization where the goals are to improve emissions, efficiency, and/or availability. For coal boilers, Kn³ can range from simply a scenario tool (modeling), to open-loop optimization (add optimization), to closed-loop optimization (add MVC). The product is currently in use on a 220-MW coal boiler in Virginia to reduce NO_x emissions while simultaneously improving boiler efficiency.



- **Improved Production Quality**

Kn³ can be applied to processes as diverse as steel and pharmaceuticals. The goals in these types of applications are to improve the quality and quantities produced, while reducing costs — without violating process constraints.



- **Diagnosis**

Kn³ is particularly useful for diagnosing problems or identifying anomalies in highly complex data that does not lend itself to rules-based analysis. Many times, conditions can change so slowly or give such subtle warning signs that conventional rules will simply not flag anything as abnormal. A particularly powerful capability of neural nets is their ability to spot anomalies. Knowing there is a problem — even when root cause has yet to be determined — allows users to be far more proactive than waiting for symptoms to progress to more “obvious” levels that can be detected by a rule. As one customer explained, “waiting until you know the solution to tell me there is a problem may be too late.” Combining both rules-based and neural net capabilities has particularly powerful applications in the condition monitoring realm.




- **Pattern Recognition**

With its neural net technology, Kn³ is an excellent tool for pattern recognition. Neural nets can be applied successfully to several processes related to pattern recognition, whether it is identifying a sequence of events that may have previously gone unnoticed yet always precedes a particular process upset, thermo-graphy images, or applications as diverse as MRI scans in health care, weapons identification in luggage for airport security, and face recognition for law enforcement. In all these examples, the more accurately and efficiently patterns can be recognized, the better and less costly the process. Kn³'s added advantages of being able to manage data and apply rules makes it uniquely powerful and applicable in this arena.

Summary

Kn³ expands the proven rules-based analysis technology used in GE Energy's condition monitoring applications by adding several state-of-the-art technologies and allowing users to model, optimize, or control virtually any process.

Because the tool can deliver any of these functions individually or in combination, it is uniquely flexible and powerful, equally relevant to process design engineers, process control engineers, and plant diagnostic engineers. 

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