Continuous Operations Performance Improvement using an Integrated Model Guidance system

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DCS and Historians capture volumes of data on a daily basis in process manufacturing facilities. This data has to be converted to *information* and beyond to actionable *Knowledge*, to enable Performance Improvement and improved profitability. An Analysis and Inference layer is required over the data collection for such *Knowledge* generation. "*Knowing*" current operations, how it interacts with economic conditions to affect profitability and being able to identify opportunities/threats for proactive actions, is key.

Process behavior is intrinsically non-intuitive with its complex non-linear parameter interactions. It is very difficult for the unaided human being to get his mind around predicting process behavior from experience alone. Rigorous model based process simulators when combined with Multivariable Statistical Analysis and an Intelligent Knowledge Management system form an essential and cutting edge tool that aids the "*Knowing*" process. Such an integrated system tied together into a unique analysis and inference process can serve as a "Bloomberg machine" for process manufacturing.

Such a system is being effectively incorporated to monitor daily operations, weed out errors in data, study operational inefficiencies, aid in root cause analysis, optimize operating conditions and sequences, improve energy efficiencies, optimize cleaning cycles, optimize capacity utilization and in general drive towards Continuous Operations Performance Improvement.

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Managing Continuous Process Manufacturing – A Challenge

Manufacturing: The directly controllable factor

Fluctuating market prices put severe pressure on margins in the continuous process industry. Fluctuation in product prices may not be in sync with the raw material prices, impacting margins. The manufacturer typically has very little control on the market. The only real control that a manufacturer therefore has, is the cost of conversion of the product. Managing the manufacturing efficiency and hence cost of conversion is a critical challenge. Increasingly stringent regulations and burgeoning liabilities associated with non-compliance further complicate the management of manufacturing operations.

The bi-directional interaction between supply chain and manufacturing

The interaction between the business case and the way products are manufactured pose unique challenges in the Continuous Process Industry (CPI). The consumer is too remote, supplies are subject to “take” or “pay” conditions, and process conditions are demand dependent and related to each other in a complex and nonlinear way for a given demand situation. Process manufacturers may have a large number of suppliers willing to sell feedstock differing in quality and price. The selection of suppliers may vary from week to week and may also depend on how the process is operated. The manufacturer may sell products of varying quality to a diverse market at various prices. The most profitable array of products impact the way in which products are manufactured. There is a great diversity in the way products can be manufactured in a given process plant. Greater interaction between the best mix of suppliers, the best mix of products and the conditions under which supplies are converted to products can result in more optimal performance.

The importance of knowledge of process behavior

Consider, for example, a change in the price of a couple of products, an alteration in the quality of raw materials, and a modified contract. They can have a drastic impact on the operations and profitability of the business. How should current operating conditions be changed? Answering this requires knowledge of process behavior and its interaction with the business case. How can I alter current operating strategy/configuration to improve efficiency under the changed conditions? Answering this requires deep knowledge of process behavior and predicting impact of alternate changes. How can I then continue to maintain stable operations under the new operating conditions? This requires continuous monitoring of the process and reacting to changes.

The complexity in managing data from the CPI

Unlike discrete manufacturing, process manufacturing involves changes at the atomic and molecular levels. The only sources from which to derive information about the changes taking place within the pipes are indirect descriptors of the state of the plant – raw measurements by instruments measuring temperature, pressure, composition, flow rate and so on. Unfortunately, raw measurements are inherently fraught with errors. Fortunately, the laws of nature permit precise modeling of complex interactions in these continuous plants. This when combined with raw measurements from the plant and expert inputs enable effective interpretation of the raw data/information to convert it into usable knowledge and actions.

Management of manufacturing in CPI

Processes

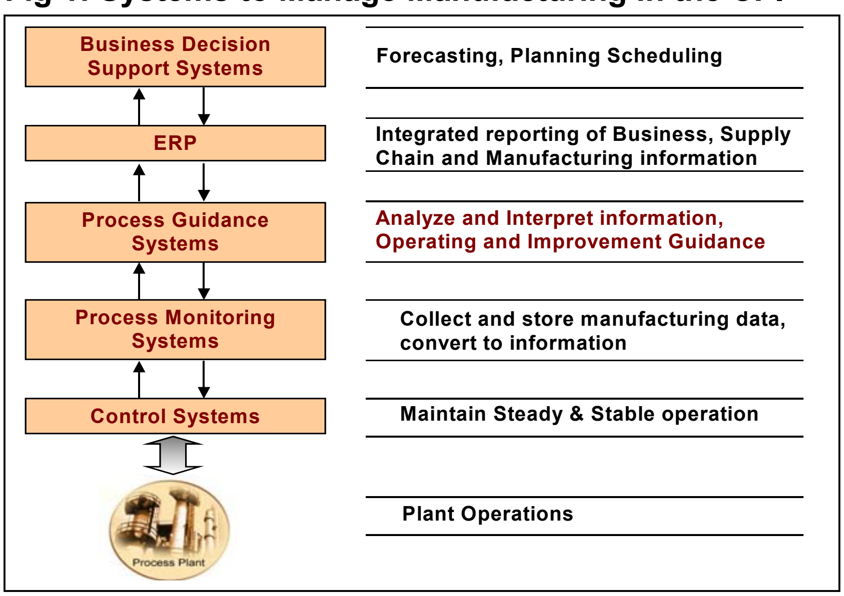
Management of process manufacturing broadly entails the following processes:

- Monitoring of the process
- Conversion of data to information
- Interpretation of the information to convert it to knowledge and actions
- Implementation of actions to maintain stable operations and meet cost and Supply Chain objectives

Systems

The systems typically found in the process manufacturing space to perform the above functions can be broadly classified as shown in Fig 1.

Fig 1: Systems to Manage Manufacturing in the CPI



The main function of the Control system is to maintain steady and stable operations, which is typically performed by the Process Control groups, within the organization, utilizing the DCS systems. The Controls group and systems also constantly monitors the plant data and provides relevant information to engineering, operations and business groups. Process Monitoring Systems mainly in the form of plant data Historians like IP21, PI and PHD systems collect, archive and enable visual trending and analysis of raw data from the control systems. Several companies are in now in the process of integrating their ERP systems and manufacturing systems in an attempt to more closely integrate the production, supply chain and planning activities, at least with the same information.

The Process Guidance System – key to utilizing information

In order for the information to be of any use, the data being collected has to be analyzed and interpreted. The results of this analysis and interpretation are:

- Proactive actions to resolve anomalous conditions
- Proactive actions to prevent unforeseen operational upsets
- Proactive actions to restore deteriorating equipment/process performance.
- Identify ways to continuously improve cost of production
- Identify ways to improve conversion efficiencies
- Identify ways to more efficiently comply with regulations

This is the key function of the Process Guidance System shown in Fig 1. Normally Technical Services Departments and/or Process Engineering groups perform this function in an organization. This requires a combination of experience, prior knowledge about the process, current operating data and analysis tools. This is a separate business process consisting of several process analysis tools and teams of functional experts.

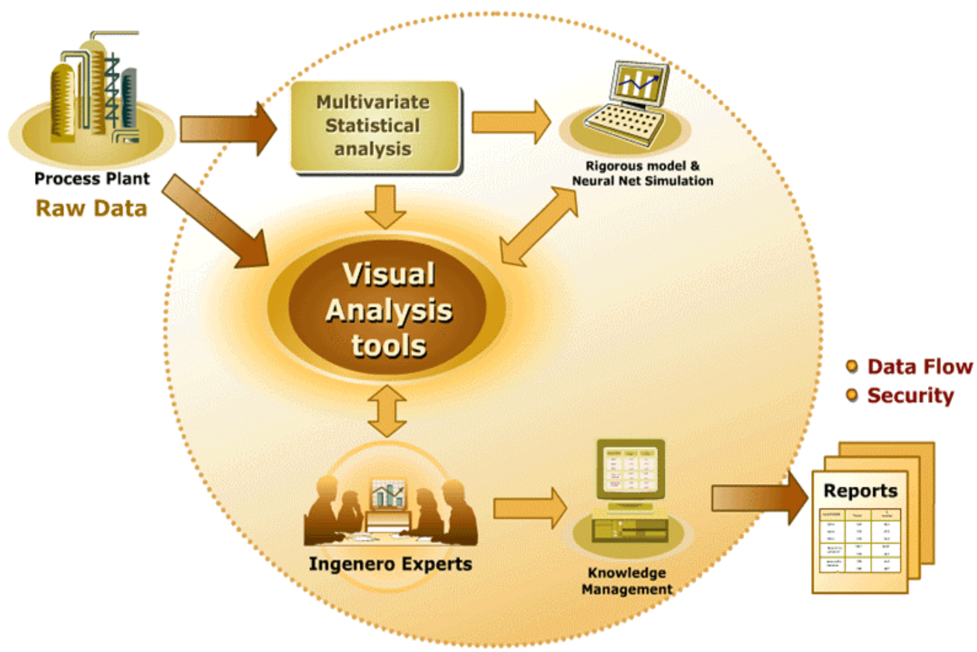
The Process Guidance systems may be de-linked from ERP and business systems. In this mode its serves solely as an information provider to the ERP and utilizes data from the ERP system to set its objectives for production and costs. In its ideally integrated form with the ERP and DSS, it can be used to arrive at optimal plans, factoring in process behavior into the business simulations.

The Process Guidance System

Structure

One such Guidance system has been developed and is being implemented at multiple operating facilities. Fig 2 shows the structure of the Guidance system. Several analysis tools like simulation, statistical tools, visual analysis tools are tied together into an integrated process. A team of experts and analysts form an integral part of the Guidance system. Each of these tools enable valuable analysis opportunities[1,2].

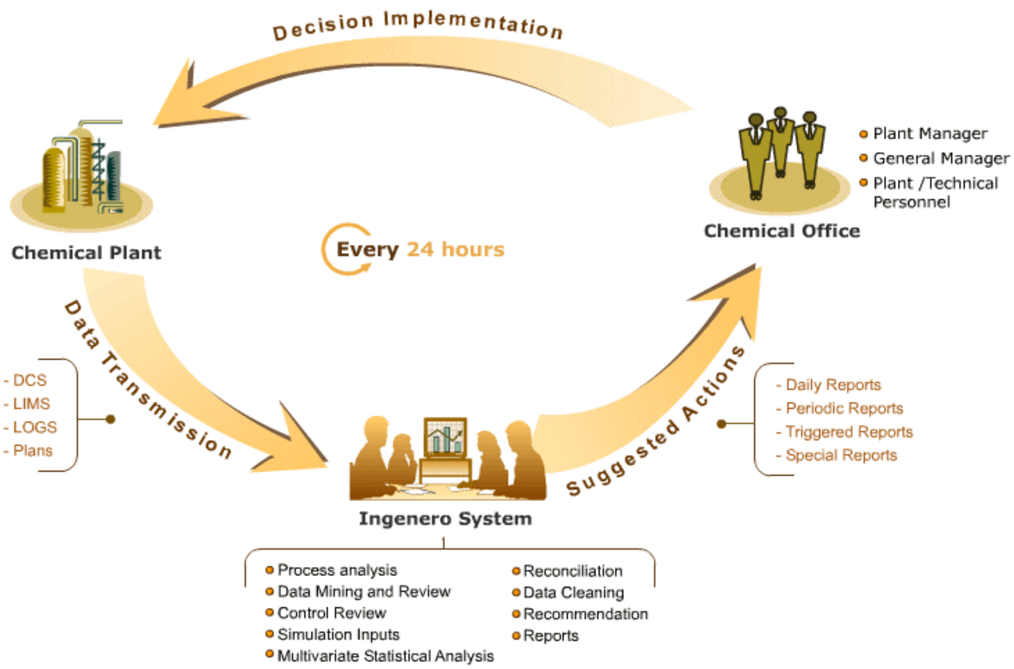
Fig 2: Structure of the Guidance system



Effective utilization of the Process Guidance System

The Guidance system is a necessary business process that combines analysis tools with human experts. It is most effective when it is utilized in a continuous manner as shown in Fig 3, where the global data network connectivity is leveraged to station the bulk of this business process at a remote central site and service multiple plant sites. Such remote support has been very successfully applied in equipment maintenance applications[3].

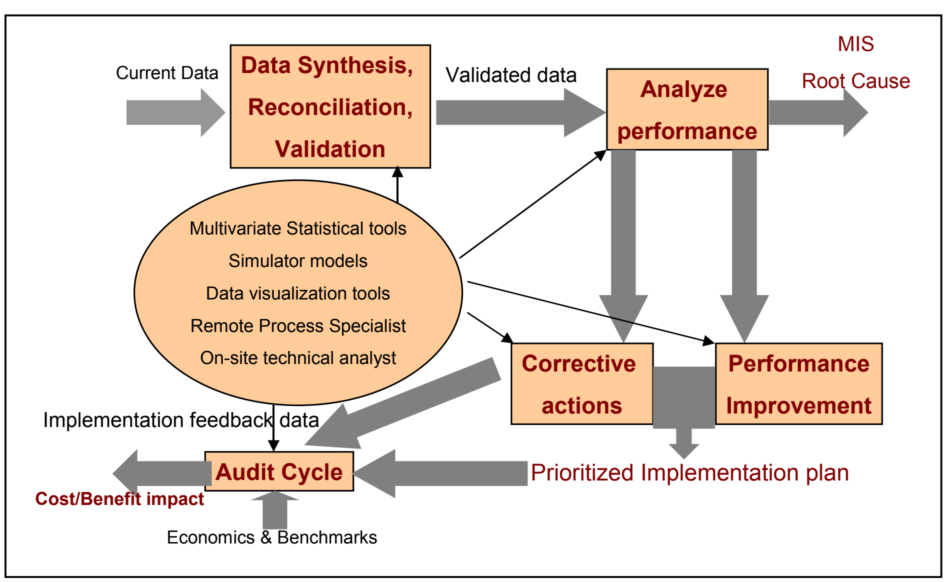
Fig 3: Effective utilization of the Guidance system



Functioning of the Process Guidance System

The typical functioning of the Guidance system is described in Fig 4. When utilized continuously, it serves as a "Bloomberg machine" for the process, serving operating insights to the Operations, Engineering and Control teams.

Fig 4: Typical Functioning of a Guidance system

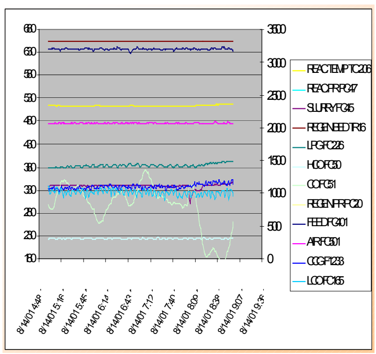


Reports are generated daily and automatically, which provides recommendations and a basis for the recommendations as illustrated in Fig 5.

Fig 5: Daily reporting and analysis

The Guidance system analyzes plant data using sophisticated tools, produces daily, weekly and monthly reports and analyses

Raw DCS Data



Raw Input

FCC expert

PCA Analysis

Daily Report

Parameter	Plan	Actual
Plant Load%	105	92
Production (Tons Per Day)	15,000	13,143
VGOHT	18,000	15,771
Steam	3920	4020

Daily Analysis

Problem Area	Causes	Recommendation
1800 ATF off spec	COT Disturbances	Reduce f / f gain in COT
2100 HSD off on pour point	10:35 HSD d/o temp high	Ensure APC is online
1400 LPG High Residue	Sudden drop in off-spec processing	Install reflux / off-spec processing ratio control

Guidance System Output

Key components

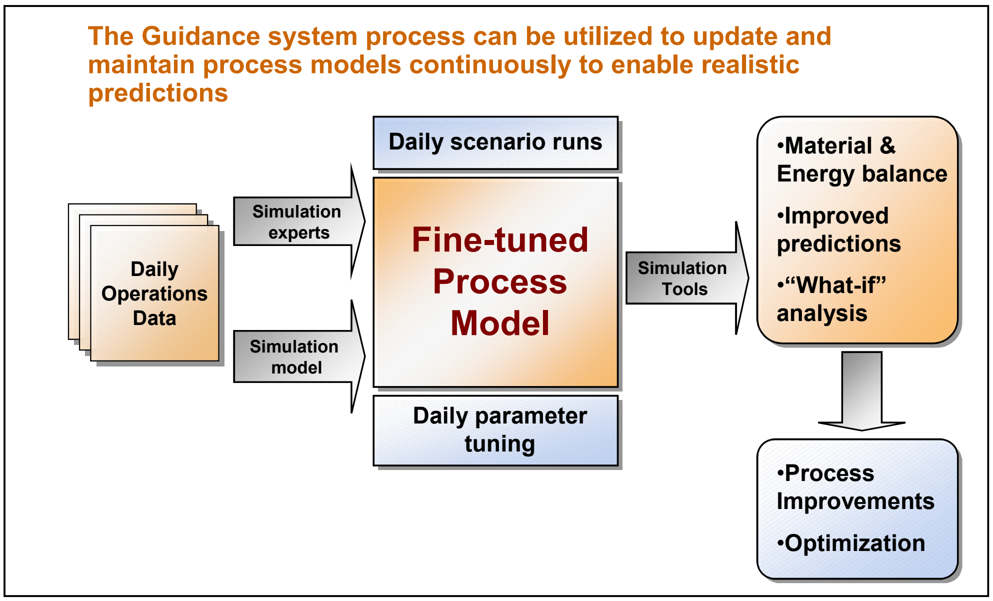
The key enablers of the Guidance system are:

- The team of multi-functional experts continuously performing engineering calculations and analyzing the data
- The remote connectivity to the data collection systems at the plant
- Maintenance of Mirror-like models of the process

Significance of the mirror-like model[4]

The mirror-like model is a combination of rigorous models based on the fundamental laws of nature and empirical models. Both these models need to be tuned to reflect actual plant operation. Hence, these models tend to be very different from the design models that would have been used to design the plant. The differences arise from changes to process configuration over a period of time and changes in conditions of the equipment over a period of time. The tuning is done using raw plant measurements obtained from the process monitoring system. The gross and random errors in the raw data, make the process of tuning complex. Gross errors have to be identified and weeded out and the data reconciled, before being used, which is an iterative process of simulation, minimization of statistical function[5] and expert interpretation. The effort to maintain such a model is often arduous, but well worth it. Such model maintenance can be ideally carried out as part of the Guidance system process. The utility of having such a model is described in Fig 6.

Fig 6: Utility of maintaining fine-tuned mirror-like models of the process



The need for a Separate Guidance Process

Despite the difficulty…every department and/or work process must find new opportunities to reduce costs. In most process manufacturing operations the guidance function is that of the Technical Services Depts. However, in most cases, it is found that,

- Both the Plant Operating Staff and Technical Support Staff are drowning in a sea of data that they do not have the bandwidth (time and tools) to analyze
  - Past technology investments have produced an explosion in the amount of data that is available
    - Process variables
    - Equipment data/metrics
    - DCS/Data historians
    - Laboratory and other online analyzers

- Budget constraints and economic conditions preclude hiring more people dedicated to analyze this data for manufacturing improvements

The end result is that several possible **cost reductions** and other **operational improvements** go **undetected**

Benefits from the Process Guidance System

Such a Guidance system provides the following benefits:

- Captures “missed” operational improvements
  - Lower production costs (energy, raw material) through incremental efficiency capture
  - Higher throughput/production
- Enables operation at technical limits
- Cost avoidance
  - Equipment monitoring; reduced repair/downtime
- Soft benefits
  - Increased safety via “second set of eyes”
  - Enhances return on existing technology investments
  - Increases employee value
- Focus on value added tasks

The guidance business process can ideally be outsourced to a remote low cost geographic location, thereby circumventing the need for new resources, skill sets or job descriptions. Such a system can be very easily made totally compatible with existing work processes and staffing levels. The benefits from such a structuring of the business process exceeds the cost of setting the process by an order of magnitude.

Performance Improvement Examples

The type of performance improvements resulting from such a guidance system is illustrated by the various real life examples below. Offline benefit studies combining technology tools with experts have been reported to proffer similar benefits[6].

1) Efficiency improvement

Continuous monitoring of fouling factors of the crude preheat train in a 500,000 bpd refinery, indicated a 5 degree Celsius loss in outlet temperature due to rapid fouling in three exchangers. The economics of on-stream cleaning was evaluated. On-stream cleaning at optimal intervals between regular maintenance shutdown cleanings, helped increase throughput, improved fuel efficiency and provided a net gain of over 10 times the cost of on-stream cleaning.

2) Trend monitoring
Continuous monitoring of skin temperatures of furnace tubes of the vacuum distillation heater, indicated rapid unexpected coke build. The root causes were identified to be low coil steam injection rates and power surges. Timely steam/air decoking helped prevent an unexpected tube burst. The low coil steam pressure problem and power surge problems were fixed to prevent recurring rapid coking problems on its account.

3) Energy savings
Continuous observation of time-temperature relationship charts of the air fin coolers (AFC) on the overhead condensing unit of the vacuum distillation unit, indicated the possibility to save energy by controlling AFC operating time, minimizing sub-cooling, while keeping the C3 loss in the gas at the same level. A two stage software alarm was activated to instruct panel operators to stop fans of selected AFCs during the night shift and restart during the day shift, resulting in a 10-25% power saving.

4) Recurring problems
The bottoms pump of the asphalt stripper was getting damaged periodically. The root cause identified by the analysis was false level indication in the stripper bottom which was the measured parameter being used to control the flow rate through the pump. Related problems were incomplete stripping and dislodging of trays. The false level indication was caused due to plugging of instrument taps with Asphalt splash. The installation of an anti-splash device on the level indicator taps, lead to reliable level measurement, lower unplanned maintenance and lower maintenance costs.

5) Proactive maintenance
Analysis of the vibration spectrum collected at the motor vertical from an impact test, indicated that a pump with recurring bearing failure problems, and high radial vibration, requiring excessive in-situ balancing efforts, was operating near its resonant frequency. A stiffener was placed under the motor as a solution to this problem, thereby shifting the resonant frequency and minimizing vibration and lowering maintenance efforts and costs.

6) Low cost debottlenecking
A change in feedstock quality to a propane deasphalting unit, reduced the capacity of the unit. The Asphalt Recovery Furnace capacity was identified to be the bottleneck. The plant capacity was restored without adding furnace capacity, by simply adding a heat exchanger to preheat the feed to the furnace by recovering heat from the stripper bottoms.

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About the authors

Pratap Nair

Founder member and CEO of Ingenero, has extensive experience with Operational Performance Improvement and Optimization projects in the Process Industry. Based out of Houston, for 15 years, he has managed numerous projects and completed several studies with major Oil refining and Petrochemical companies in the USA, Japan, Venezuela and Germany and has served on several panels and presented several papers at the NPRA, ISA, IFAC and AICHE. He has developed and implemented model based on-line optimization/data reconciliation/simulation systems for companies in Japan and USA. He has also served as a Sr. Vice President & Executive Committee member, and SBU head, Emerging Businesses, at a large Pharmaceutical company in India, for over six years.

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Vilas has three decades of functional & industry experience with oil refining, petrochemical and engineering project management companies, in India and Netherlands Antilles. His experience spans process engineering at the Bombay ESSO refinery and a variety of Technical, Economics & Planning, Project management, Corporate & Top management functions with three major oil companies. He has conceptualized major Greenfield refinery projects and has set up & managed the technical service function in refineries & Petrochemical plants. He was associated with the Oil Industry Safety Directorate in India as Author of their industry standards on Safety in Process Design & Operation and was a co-author of the Perspective Plan of the Petroleum Refining & Distribution sector for 1990-2004, instituted by the Indian Government.

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Founder member of Ingenero, was part of the 27 Mtons/yr refinery and petrochemical complex commissioning team at Reliance Industries Ltd. He has extensive experience in economic planning and scheduling for the refinery and petrochemicals industry. He has developed several models at Reliance and has operational experience on crude purchasing.

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He has 20 years of operating experience in the Fertilizer plants in India and in Petrochemical plants in Bahrain. He has significant expertise with implementation of DCS systems and Process Monitoring Systems. He has served as a Quality auditor and an Environmental auditor.

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