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ENTERPRISE INTEGRATION OF MANAGEMENT AND AUTOMATION IN A REFINERY[1]

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Abstract: Traditionally, problems in a petroleum refinery were separately modeled and solved with respect to disciplines. The segregated implementations of various disciplinary technologies resulted in considerable barriers impeding the pursuit of global optimal performance. It is recognized that enterprise-wide integration of the managerial and automation systems is of fundamental significance for refineries to promptly respond to global market requirements. In this paper, the technical implementations are disciplinarily categorized into managerial and automatic systems. Then, typical managerial and automatic implementations in a refinery are depicted to give an insight perception of the heterogeneous data sources manipulated by these systems. Finally, an integration approach based on data reconciliation techniques is proposed to link up the heterogeneous data sources.

Key words: managerial systems, automation systems, enterprise integration, data reconciliation.

1. INTORDUCTION

In the past, problems in a refinery were usually tackled separately in accordance with specific technical or managerial disciplines. In practice each discipline is often initiated by different departments: SPC (statistical process control) by the quality department and production; TPM (total quality maintenance) by the maintenance department; APC (automated process control) by the engineering department [1].

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However, it has been increasingly identified that many problems are difficult to be decoupled into simple technical or managerial sub-problems, and solutions to these complicated problems require synergic efforts from multiple domains. The disciplinary isolation of managerial and technical implementations gives a rise to the obstacles for refineries to achieve the global performance optimization. Enterprise integration becomes a significant way to accommodate the rapid environmental change, emerging new technologies and diversified customer requirements. Refineries are forced to breakthrough the disciplinary segregations by integrating strategies, human resources, production processes and control techniques.

Despite numerous understandings of integration, it is argued that the basic goal of integration is to improve overall system efficiency by linking its elements by means of communication networks and thereby obtaining a higher responsiveness and effectiveness of the whole system compared with the isolated operation of its components [2]. This paper presents an intermediate result of an on-going research project for developing and integrating the managerial and automation systems in a petroleum refinery.

2. REQUIREMENTS FOR MANAGEMENT AND AUTOMATION INTEGRATION

A refinery manufactures from crude oils, through a series of physical and chemical reactions, over a hundred kinds of products such as petrol, kerosene, diesels, naphtha, petroleum cokes, acids, polypropylenes and paraffin. Survival and prosperity in the turbulent environment require a refinery to concurrently tackle a wide range of challenges in many perspectives. For instance, a refinery has to efficiently collect and process the information concerning market demands, oil procurements and supplies, product distributions, and inventories. It has to promptly respond to demand change by optimally adjusting oil processing programs and product structures. It must keep balanced production flows among the pipelined facilities, and, at the same time, to maintain maximal throughputs of the critical facilities. Pursuits of high product qualities demand tight monitoring and control of a huge amount of coupled process variables.

The multiple disciplinary systems developed in a refinery can be viewed from four levels according to scientific disciplines. 1) ***Operation Control*** includes the basic automation techniques, such as data sampling, feedback control, optimal control and predictive control, which are directly used for monitoring and controlling various transmitters, regulators, instruments and facilities on production sites. 2) ***Process Coordination*** includes process modeling and simulation, process supervision, fault-shooting and prediction

techniques. These techniques are applied to coordinate operations of an equipment complex and a group of units in the shop floors. 3) ***Production Optimization*** mainly concentrates on production planning, scheduling, quality control, inventory control, equipment maintenance and coordination of resources. 4) ***Enterprise Management*** basically deals with marketing, resources management, purchases, supplies and sales. Approaches and technologies that support business management and decision-making are used for finding solutions to the company-wide strategic problems.

According to business nature, these systems are classified into two categories: managerial systems and automation systems. Generally speaking, systems dealing with problems of production optimization and enterprise management are attributed to managerial systems. While the systems developed to manipulate problems of operation control and process coordination are attributed to automation systems. To achieve optimal operations, a refinery has to fill up the gap between managerial and automation systems.

3. FUNCTIONALITIES OF MANAGERIAL AND AUTOMATION SYSTEMS

3.1 Typical Managerial Systems In A Refinery

Managerial systems mainly handle structured data and support decision-making on business planning, marketing, finance accounting, human resource management, procurement and inventory control, equipment management, production planning and scheduling (as shown in figure 1).

Marketing and Sales: An important function of marketing is to calculate market demands with regard to actual customer orders and estimations obtained by applying forecasting techniques. Other routine functions of marketing and sales are collecting and processing data concerning customers, orders, market fluctuations, distributors and services. It maintains customer master-files, handles product price-quoting, controls customer credits, and manages bills of lading and invoicing.

Human Resource Management: It manipulates data concerning organization structures, employees, innovative culture, core competencies, and performance appraisals. Optimal business performance requires that human resources be efficiently managed with help of an organization model that explicitly represents organization structures, human attributes, roles and behaviors. Organization structures are used to specify the functional relationships among human resources, and to confine human behavior and activity space.

Procurement Management: Decisions on oil procurements must be made with full considerations of oil compositions and properties, in addition to other marketing factors such as prices. An important task of oil procurement management is efficiently analyzing the compositions, properties and special processing requirements of various crude oils. The procurement management also has to choose oil transportation means: such as by ship, trains, can-trucks and pipelines. It keeps close track of all purchase information, such as the en-route fleets.

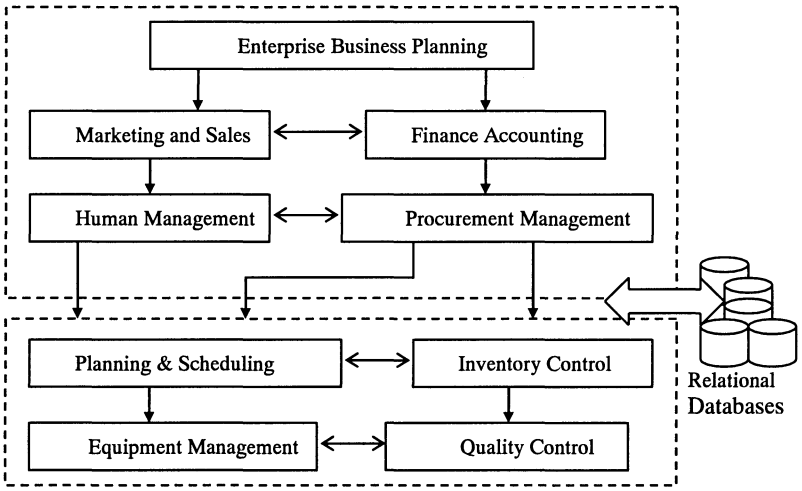

Figure 1. Typical managerial systems in an oil refinery

Production Planning: As crude oil compositions and properties vary in accordance with the yield locations, multiple manufacturing programs, production plans and schedules have to be developed to accommodate change in crude oils. The essence of production planning is to select the appropriate oil manufacturing programs and to optimally decide the volumes of different oil compositions at inlets and outlets of equipment settings.

Production Scheduling: Production scheduling takes as input short-term production plans, dynamically sequences production batches by allocating resources to them in specific time intervals. Production scheduling is to maintain stability in manufacturing processes by adjusting material flows to keep fluctuations in reasonable ranges. Multi-agent systems are very promising approaches for scheduling these decentralized manufacturing processes. Functionally, a scheduling system allows user to define process flows by graphical diagrams and helps users to determine compositions mix ratios of material fluxes. It sets the operation sequences and process parameters, aiming at increasing high market value oil products.

Product Quality Control: Qualities of oil products are basically determined by their compositions, chemical and physical properties. This means that petroleum product qualities depend on interactions and microstructures at molecular level. In practice, it is impossible to directly control product qualities because of lack of sensors that can on-line detect oil compositions and properties. Therefore, product quality models have to be built to associate product qualities (or molecular structures) with process parameters that can be simply sampled, such as flux, temperature and pressure. Product quality control system analyzes the on-line collected data and manually input records about manufacturing process statuses. It generates a variety product quality reports and suggests measures to be taken against quality deviations. In addition, the product quality control system manages quality standards, inspection routines, and problem-handling procedures.

3.2 Automation Systems In A Refinery

Automation systems are those that directly deal with operations of equipment settings. In a refinery, all facilities must operate in equilibrium states defined by precise values of the process variables. Nevertheless, external disturbances and frequent transitions of manufacturing programs for coping with the diversity of oil compositions and properties tend to cause fluctuations in the pipelined production facilities. Amplifications of these fluctuations increase the instability of manufacturing processes and production costs, and reduce product qualities. The main task of automation systems is to monitor, analyze and control the process variables, in order to retain optimal operations in all the production facilities.

Material Balance: The main objective of material balance is to get the demanded products by optimally adjusting the raw materials and the intermediary substances. Basically, there are three functions of a material balance system. First, a variety of manufacturing programs and production flows are applicable to the same crude oils, hence, yielding different product structures, quantities and profits. To obtain the desired products and to decrease invaluable products and wastes, a material balance system needs to determine what raw materials and how many are the inputs, and what products and how many are the outputs. Second, it accurately calculates and adjusts the flux compositions and volumes in different production lines. In another word, the inbound material flows and the outbound material flows in an equipment unit, a production zone and/or a line must be chemically balanced. Thirdly, it keeps material balances in multiple production zones to avoid amplifications of disturbances. Material balances reduce the risks that disturbances in a production zone be transferred to the adjacent zones.

Real-Time Monitoring: Most manufacturing processes in a refinery are partitions of compounds on basis of molecular movements. Product qualities are highly sensitive to change in process parameters, which need to be closely observed. The main functions of a real-time monitoring system are as follows. Configuration utilities provide visual development tools for configuring manufacturing processes, which permit human staffs to observe on-line process evolutions on screens. It provides I/O drivers that support the commonly used communication protocols, such as RS232/245, Ethernet and PROFITBUS. Thus, the equipment and devices supplied by different vendors can be easily interconnected with the monitoring system. The monitoring system also has interfaces with the commonly used database management systems. And the Alarm and Event function generates alarms on disturbances, deviations and errors in production processes. It also keeps historical records of alarms and events to support the after-event analysis.

Process Optimization and Advanced Control Systems: Operations of the petrochemical facilities involve a large number of tightly coupled variables. Disturbances to a control variable can easily influence other variable, exhibiting bullwhip-effects. The objective of operation control is to keep all variables within desired ranges and to maintain optimal performance of the facilities. The operation control is conducted by two systems: namely process optimization and advanced control.

Process optimization creates process models and based on which calculate the optimal control parameters subject to economical, technical and managerial constraints. A process optimization system, working in an off-line mode, aims at increasing qualities and volumes of desired products, while decreasing material and energy consumptions. To this end, it determines which variables are to be controlled, and which variables are to be manipulated. It decides what process parameters are measured and what control strategies or laws are applied during operations. It calculates optimal or near-optimal process parameters specifying the target trajectories, and transfers them to the advanced process control (APC) system. Objectives of advanced process control are reducing disturbances, increasing equipment adaptability and stability and gaining maximum profits, subject to process constraint conditions. An APC system evaluates the real-time sampling data of outputs collected by various sensors against the target values. Once, drifts or errors are detected, an APC system will apply control strategies, such as PID and multi-variable predictive control, to force unit operations returning to target trajectories.

4. INTEGRATION OF HETEROGENEOUS DATA SOURCES

In refineries, data sources handled by applications are managed in different databases on basis of data processing frequencies and influencing scopes. As shown in figure 2, the essential foundation of enterprise integration is information integration across different hardware platforms.

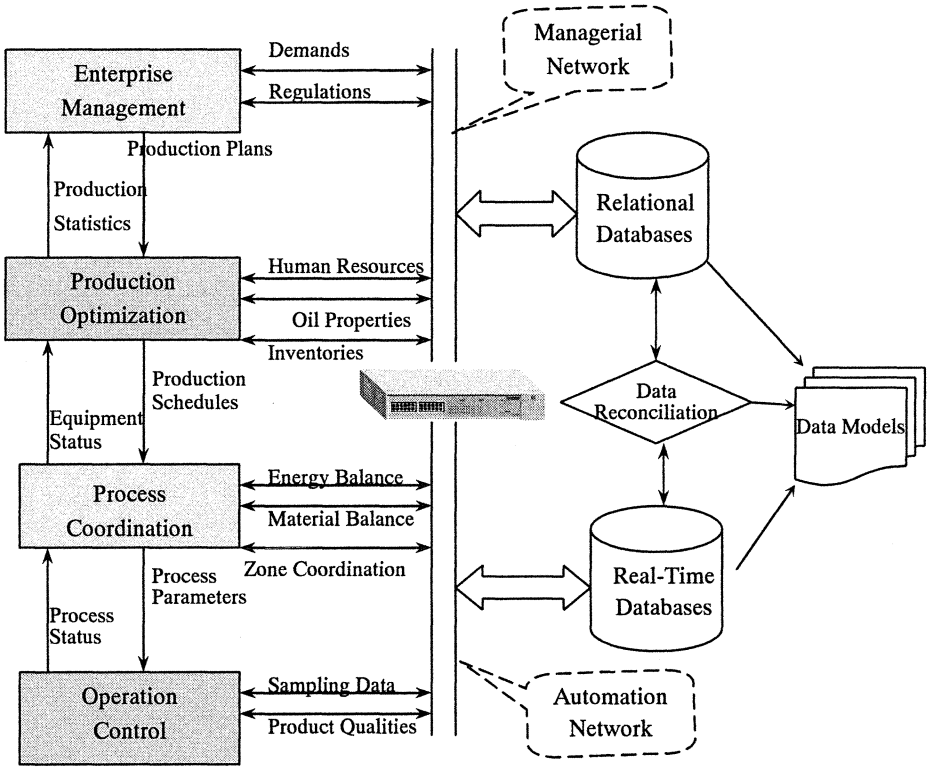

Figure 2. A framework for management and automation integration

In perspectives of process optimization and control, real-time databases are built to include real-time collected on-site data, graphical system configurations, interfaces for control systems and alarm sets. Real-time database management systems are a disciplinary conjunction of the real-time system and database management, which are required to process data and transactions in limited time intervals. Cost-effective technologies of time scheduling, data compression and resource allocations are core competencies of real-time database management systems. Real-time database systems also provide configuration utilities, APIs, and equipment interfaces.

Integration of the above-mentioned heterogeneous data sources is attained by data reconciliation technologies in respect to enterprise data models. Here, data reconciliation has two basic functions. First, data reconciliation maintains information consistency among the data sources. In manufacturing environments, there are many reasons that will cause information inconsistencies or mismatches, which include lower sensor precisions, inaccurate device calibrations, misinterpretations, signal drifting, duplications and operation errors. Data reconciliation evaluates the nominal values against enterprise data models, and detects inconsistencies. According to intrinsic data relationships, data reconciliation trims off errors and smoothes the data to actual values. Second, data reconciliation provides an interoperation mechanism among the databases and binary files. It creates data snapshots from an information source and copies them to target sources. For instance, data reconciliation continuously duplicates the changing real-time data and sends the duplications to update existing data in relational databases. Data reconciliation provides a data subscription service for notifying related applications and data sources about change in each data source. To this end, data reconciliation continually filters and mergers data objects from multiple data sources to present specific data views.

5. CONCLUSIONS

Comprehensively integrating the managerial and automation systems in a refinery is a tremendously challenging task that requires synergic efforts of professionals from multiple disciplines. It is identified that seamless integration of heterogeneous data sources is the basic concern of integrating the managerial and control applications. Consequently, the managerial and automation systems are presented to unveil what types of data and how they are handled. In practice, numerous data sources are built on basis of intrinsic characteristics of business functions that uses these data. It is proposed, in this paper, that information integration can be attained by data reconciliation approach with regard to global data models.

REFERENCES

1. Schippers W. A. J. (2001). An Integrated Approach to Process Control, *International Journal of Production Economics*, 69, 93-105.
2. Kosanke K., Vernadat F., Zelm M. (1999). CIMOSA Enterprise Engineering And Integration, *Computer in Industry*, 40, 83-97.