Integration of Production Data in CM for Non-stationary Machinery: A Data Fusion Approach

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Abstract. A process control system deals with disperse information sources mostly related with operation and maintenance issues. For integration purposes, a data collection and distribution system based on the concept of cloud computing is proposed to collect data or information pertaining to the assets of a process plant from various sources or functional areas of the plant inc1uding, for example, the process control functional areas, the maintenance functional areas and the process performance monitoring functional areas. This data and information is manipulated in a coordinated manner by the cloud using XML for data exchange and is redistributed to other applications where is used to perform overall better or more optimal control, maintenance and business activities. From maintenance point of view, the benefit is that information or data may be collected by maintenance functions pertaining to the health, variability, performance or utilization of an asset. The end user, i.e. operators and maintainers are also considered. A user interface becomes necessary in order to enable users to access and manipulate the data and optimize plant operation. Furthermore, applications, such as work order generation applications may automatically generate work orders, parts or supplies orders, etc. based on events occurring within the plant due to this integration of data and creation of new knowledge as a consequence of such process

Keywords: process control, XML, cloud computing, CMMS, EAM, condition monitoring, asset.

1 Introduction

Process control systems, like those used in oil & gas industry, pulp & paper industry, or other processes, typically include one or more centralized or decentralized process controllers communicatively coupled to at least one host or operator workstation and to one or more process control and instrumentation devices, such as field devices. The process controller receives signals indicative of process measurements or process variables made by or associated with the field devices and/or other information pertaining to the field devices, uses this information to implement a control routine and then generates control signals which are sent over one or more of the buses to the field devices to control the operation of the process. Information from the field devices and the controller is typically made available to one or more applications executed by an operator workstation to enable an operator to perform desired functions with respect to the process, such as viewing the current state of the process, modifying the operation of the process, etc. While a typical process control system has many process control and instrumentation devices, such as valves, transmitters, sensors, etc. connected to one or more process controllers which execute software that controls these devices during the operation of the process, there are many other supporting devices which are also necessary for or related to process operation. This additional equipment does not necessarily create or use process variables and, in many instances, is not controlled or even coupled to a process controller for the purpose of affecting the process operation, this equipment is nevertheless important to and ultimately necessary for proper operation of the process. In the past however, process controllers were not necessarily aware of these other devices or the process controllers simply assumed that these devices were operating properly when performing process control.

Integration of maintenance information, management and monitoring is essential to close the loop of the process that is why CMMS systems have evolved. EAM (Enterprise Asset Management) are more sophisticated software than CMMS, (Fu et al. 2002). These solutions usually enable communication with and stores data pertaining to field devices to track the operating state of the field devices. This information may be stored and used by a maintenance person to monitor and maintain these devices. Likewise, there are other types of applications which are used to monitor other types of devices, such as rotating equipment and power generation and supply devices. These other applications are sometimes available to the maintenance persons and are used to monitor and maintain the devices within a process plant. In many cases, however, outside service organizations may perform services related to monitoring process performance and equipment. In these cases, the outside service organizations acquire the data they need, run typically proprietary applications to analyze the data and merely provide results and recommendations to the process plant personnel. While helpful, the plant personnel have little or no ability to view the raw data measured or to use the analysis data in any other manner. Fig 1 shows the process of outsourced condition monitoring where the only outcome is usually the report by a third party.

Thus, in the typical plants the functions associated with the process control activities, the device and equipment maintenance and monitoring activities, and the business activities such as process performance monitoring are separated, both in the location in which these activities take place and in the personnel who typically perform these activities. Furthermore, the different people involved in these different functions generally use different tools, such as different applications run on different computers to perform the different functions. In many instances, these different tools collect or use different types of data associated with or collected from the different devices within the process and are set up differently to collect the data they need. However there should be cooperation among different departments in an enterprise and between experts in their respective domain knowledge to succeed with the maintenance policy (Yu et al. 2004).

Typically, maintenance interfaces and maintenance personnel are a real huge of data network, (Davies and Greenough 2000); however it is located apart from process control operators, as you can see in Figure 2, although this is not always the case. In some process plants, process control operators may perform the duties of maintenance persons or vice versa, or the different people responsible for these functions may use the same interface.

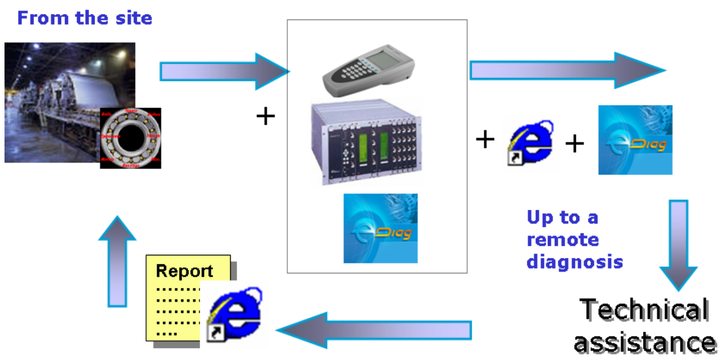

Fig. 1 Typical process of outsourcing in condition monitoring

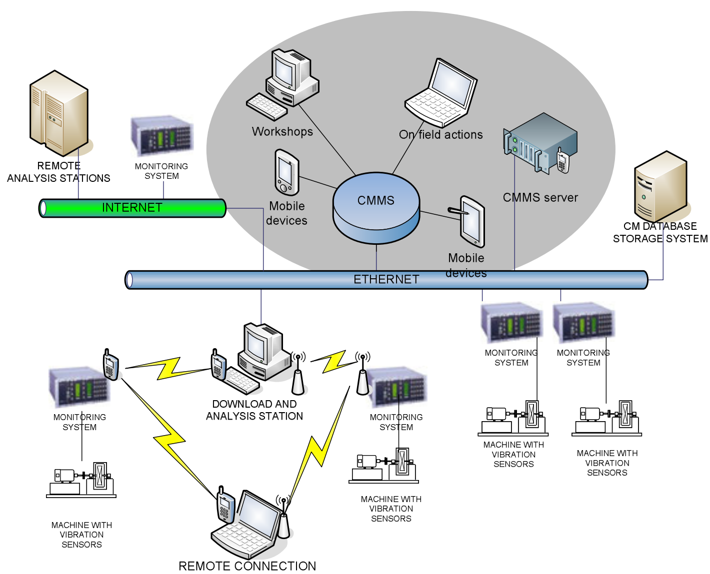

Fig. 2 Typical architecture of maintenance information system

This lack of connectivity affects seriously the performance of maintenance function. Many applications are used to perform the different functions within a plant, i.e. process control operations, maintenance operations and business operations, not integrated, thus, do not share data or information. In many cases, some of the tasks, such as monitoring equipment, testing the operation of devices, determining if the plant is running in an optimal manner, etc. are performed by outside consultants or service companies who measure the data needed, perform an analysis and then provide only the results of the analysis back to the plant personnel. In these cases, the data is typically collected and stored in a proprietary manner and is rarely made available to the plant personnel for other reasons.

2 Data Fusion: A Need in Maintenance of Processes

A process control system includes a data collection and distribution system that collects and stores data from different data sources, each of which may use it own proprietary manner of acquiring or generating the data in the first place. The data collection and distribution system then makes the stored data available to other applications associated with or provided in the process control system or to applications associated with the data sources themselves for use in any desired manner. In this manner, applications may use data from vastly different data sources to provide a better view or insight into the current operational status of a plant, to make better or more complete diagnostic or financial decisions regarding the plant, etc.

Thus, applications may be provided which combine or use data from previously disparate collection systems such as process control monitoring systems, condition monitoring systems and process performance models to determine a better overall view or state of a process control plant, to better diagnose problems and to take or recommend actions in production planning and maintenance within the plant.

This information may then be sent to and displayed to a process operator or maintenance person to inform that person of a current or future problem. This same information may be used by the process operator to correct a current problem within a loop or to change.

A process control expert may use these measurement, control and device indexes along with process variable data to optimize operation of the process. Using the disclosed data collection and distribution system, process variable data and non-process variable data may be combined,.

Likewise, the detection of a device problem, such as one which requires shutdown of the process, may cause business software to automatically order replacement parts or alert the business person that chosen strategic actions will not produce the desired results due to the actual state of the plant. The change of a control strategy performed within the process control function may cause business software to automatically order new or different raw materials. There are, of course, many other types of applications to which the fusion data related to process control, equipment monitoring and performance monitoring data can be an aid by providing different and more complete information about the status of the assets within a process control plant to all areas of the process plant, (Hall and Llinas

1997). However, because the functions are so different and the equipment and personnel used to oversee these functions are different, there has been little or no meaningful data sharing between the different functional systems within the plant.

To overcome this problem, a data collection and distribution system, hereafter the asset cloud is proposed to acquire data from the disparate sources of data, format this data to a common data format or structure and then provide this data, as needed to any of a suite of applications run at, a computer system or disbursed between workstations throughout the process control network. The applications proposed is able to fuse or integrate the use of data from previously disparate and separate systems to provide a better measurement, viewing, control and understanding of the entire plant, (Dasarathy 2001) (Dasarathy 2003).

3 XML: The Protocol for Understanding Each Other

3.1 Common Standards for Maintenance Information Exchange

The complexity of connectivity between applications is enormous since plenty of control system, maintenance management; condition monitoring and enterprise applications are involved in the management of complex, asset-intensive operations. Unfortunately, standards for information exchange have evolved independently for each of these areas. OPC (OLE for Process Control) has gained considerable acceptance as a standard for sharing information between control systems and associated manufacturing applications. MIMOSA's (Machinery Information Management Open Systems Alliance) OSA-EAI standard for sharing condition monitoring and asset health information with maintenance, operations, and enterprise systems is likewise being widely supported, (Thurston and Lebold 2001). The Instrumentation, Systems & Automation Society ISA-95 standard for integration between enterprise and production management systems in continuous, batch and discrete industries is also already being adopted by a broad range of suppliers and users in those industries. Each of these efforts addresses an important issue and has clearly made significant progress in their own right.

OpenO&M is focused on information integration between four different areas: Asset status assessment, through condition monitoring, specialized sensors and analysis tools, have been significant over the last decade. We are clearly at the point where Condition- based Maintenance (CBM) and Condition-based Operations (CBO) strategies, i.e. the performing of maintenance actions based on the information collected through condition monitoring, are becoming realizable. CBM and CBO attempts to avoid unnecessary maintenance tasks by taking maintenance actions only when there is evidence of abnormal behaviours of a physical asset, (Jardine et al. 2006). But in many organizations this information is still only being used by local technicians who maintain the equipment and not accessible for the rest of the personnel.

3.2 XML: The Protocol to Destroy the Communication Barriers

Working within the context defined by ISA-95 further ensures that this same information can be used by higher level enterprise applications like ERP or EAM. The emerging standard is specifically focused on providing value to end users by creating plug and play capabilities for faster implementation and by allowing them to pick and choose the best solutions from suppliers that comply. An extensible, open architecture based on XML and Service oriented interfaces that leverage best of breed technology and support practical interoperability and compliance is implicit in Open O&M.

Nowadays XML is maybe the most popular protocol for this communication exchange of maintenance information, (Szymanski et al. 2003). While HTML is focused on document format, XML is focused on information content and relationships. A class of software solutions is evolving which enables tighter coupling of distributed applications and hides some of the inherent complexities of distributed software systems. The general term for these software solutions is middleware. Fundamentally, middleware allows application programs to communicate with remote application programs as if the two programs were located on the same computer.

XML is accepted as communications over these industrial buses as you can see in (Wollschlaeger and Bangermann 2003), (Hausladen, Bechheim 2004) (Catterson et al. 2005). The process to transfer information between disparate sources in XML environment is as follows: Data from each of the computers involved in asset data exchange must be wrapped in an XML wrapper and sent to an XML data server. Because XML is a descriptive language, the server can process any type of data. At the server, if necessary, the data is encapsulated and mapped to a new XML wrapper, i.e., this data is mapped from one XML schema to one or more other XML schemas which are created for each of the receiving applications.

All existing data (assets, events, failures, alarms) can be modeled with XML. Among them, the most critical and difficult to represent is the layer that represents information regarding sensory inputs and outputs, whether it is a single scalar value or an array of complex data points. The standards define various data formats that may be implemented for representing sensory information. Sensory data, especially relevant in condition monitoring and process control, may be as simple as a single value or as complex as storing several synchronous sampled waveforms.

3.3 Example of Asset Data Integration Using XML

The web based technologies have been widely used and proven for eMaintenance purposes according to (Min-Hsiung et al. 2003) (Kunze 2003) (Han and Yang 2006). One architecture for collecting and integrating data from disparate data sources based on XML server based on web services is proposed in Figure 3.

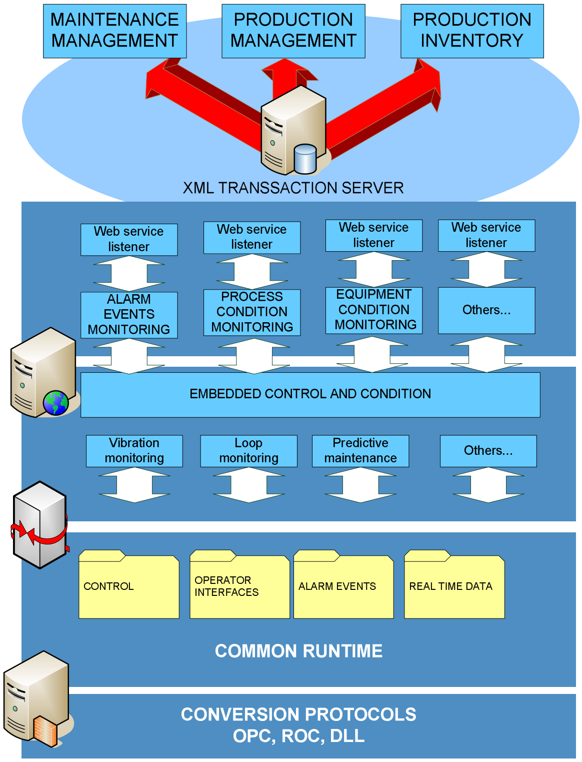

Fig. 3 Integration of disparate data sources

The figure illustrates an architectural overview of a system which implements the collection of data from disparate data sources with a process control system. Generally, the system may include a maintenance management system, a product inventory control system, a production scheduling system, as well as other systems connected by a LAN, the Internet, etc. XML is used as transaction server. The server sends XML wrapped data to the web services indicative of the data.

The web services must include a series of web service listeners which listen for or which subscribe to certain data from other data sources and provides this data to the subscribing applications. The web listening services (which may be part of the data collection and distribution system) may listen for and redistribute alarms and events data, process condition monitoring data and equipment condition monitoring data. Interfaces for this data are used to convert the data to a standard format or protocol, such as the Fieldbus or to XML as desired.

Finally, a configuration database is used to store and organize the data from the process control runtime system, including any data from the remote data sources, such as from the external web servers.

4 Cloud Computing in Asset Management: The Natural Data Repository

4.1 Introduction to Asset Cloud

Cloud computing is the next stage in evolution of the Internet. The cloud in cloud computing provides the means through which everything from computing power to computing infrastructure, applications, business processes to personal collaboration can be delivered as a service wherever and whenever you need. The cloud itself is a set of hardware, networks, storage, services, and interfaces that enable the delivery of computing as a service, (Mell and Grance 2009) (Amrhein and Quint 2009) (Rhoton 2010). Cloud services include the delivery of software, infrastructure, and storage over the Internet (either as separate components or a complete platform) based on user demand. Cloud computing, in all of its forms, is transforming the computing landscape. It will change the way technology is deployed and how we think about the economics of computing. Cloud computing is more than a service sitting in some remote data centre. It's a set of approaches that can help organizations quickly, effectively add and subtract resources in almost real time. Unlike other approaches, the cloud is as much about the business model as it is about technology. Companies clearly understand that technology is at the heart of how they operate their businesses. Business executives have long been frustrated with the complexities of getting their computing needs met quickly and cost effectively.

For asset management, the cloud seems to be the solution with such amounts of dispersed data in different repositories. The end user (maintenance or operators) don't really have to know anything about the underlying technology. The data collection and distribution applications may be dispersed throughout the network and collection of data may be accomplished at distributed locations.

The applications within the cloud may use the collected data and other information generated by the process control systems and, the maintenance systems and the business and process modelling systems as well as information generated by data analysis tools executed in each of these systems. However, the cloud may use any other desired type of expert system including, for example, any type of data mining system, already proven successful in the creation of knowledge for maintenance as one can see in (Iserman 2006) (Wylie et al. 2002) (Yang and Létourneau 2005). It may also include other applications which integrate data from various functional systems for any other purpose, such as for user information purposes, for diagnostic purposes and for taking actions within the process plant, such as process control actions, equipment replacement or repair actions, altering the type or amount of product produced based on financial factors, process performance factors, etc.

4.2 Services Provided by the Asset Cloud

Thus, the cloud, may, in one sense, operate as a data and information clearinghouse in the process plant to coordinate the distribution of data or information from one functional area, such as the maintenance area, to other functional areas, such as the process control or the business functional areas. As a result, the cloud may use the collected data to generate new information or data which can be distributed to one or more of the computer systems associated with the different functions within the plant and may execute or oversee the execution of other applications that use the collected data to generate new types of data to be used within the process control plant.

The cloud should include or execute index generation software that collects or creates indexes associated with devices, like process control and instrumentation devices, power generation devices, rotating equipment, units, areas, etc, or that are associated with process control entities, like loops, etc. within the plant. These indexes can then be provided to the process control applications to help optimize process control and can be provided to the business software or business applications to provide the business persons more complete or understandable information associated with the operation.

The asset cloud must also provide maintenance data (such as device status information) and business data (such as data associated with scheduled orders, etc.) to a control expert associated with the process control system to help an operator perform control activities such as optimizing control. However, these control experts may additionally incorporate and use data related to the status of devices or other hardware within the process control plant or of performance data generated using process performance models in the decision making performed by these control experts. In particular, in the past, the software control experts generally only used process variable data and some limited device status data to make decisions or recommendations to the process operator.

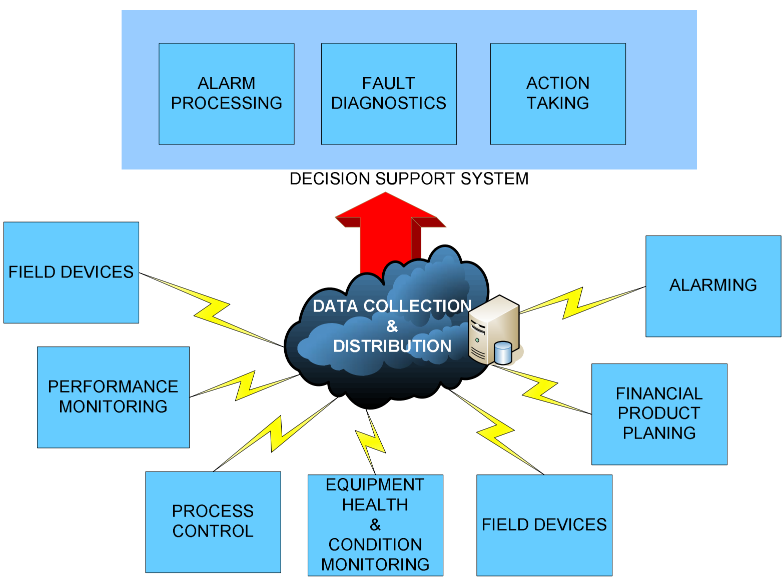

Fig. 4 Services provided by the asset cloud

Figure 4 illustrates a simplified functional block diagram of data flow and communication associated with or used by the asset cloud described herein to enable data from disparate data sources to be used by the asset cloud. In particular, the diagram includes the data collection and distribution system which receives data from numerous sources of data.

An equipment or process health data source (which may include traditional equipment monitoring applications, equipment diagnostic applications, equipment alarming applications, abnormal situation analysis applications, environmental monitoring applications, etc.) also sends data to the cloud. As a result, the source may send data acquired by or generated by any type of traditional equipment monitoring and diagnostic applications or sources.

A performance monitoring data source (which may include performance monitoring applications such optimization applications, process models used to monitor or model process operation, process or equipment health, etc.) also provides data to the system. The data source may include or provide data acquired by or generated by any type of performance monitoring equipment or applications.

5 Conclusion

In the past, the different functional areas, e.g., the process monitoring, the equipment monitoring and the performance monitoring, were performed independently and each tried to "optimize" their associated functional area without regard to the effect that given actions might have on the other functional areas. As a result, a low priority equipment problem may have been causing a large problem in achieving a desired or critical process control performance, but was not being corrected because it was not considered very important in the context of equipment maintenance. With the asset cloud providing data to the end users, however, persons can have access to a view of the plant based on two or more of equipment monitoring data, process performance data, and process control monitoring data. Similarly, diagnostics performed for the plant may take into account data associated with process operation and the equipment operation and provide a better overall diagnostic analysis.

To overcome the limitation of limited or no access to data from various external sources, the asset cloud comes up as a feasible solution that provides to collect data, convert that data if necessary into a common format or protocol that can be accessed and used by applications. The integration of the different types of functional data may provide or enable improved personnel safety, higher process and equipment uptime, avoidance of catastrophic process and/or equipment failures, greater operating availability (uptime) and plant productivity, higher product throughput stemming from higher availability and the ability to safely and securely run faster and closer to design and manufacturing warrantee limits, higher throughput stemming from the ability to operate the process at the environmental limits, and improved quality due to the elimination or minimization of equipment related process and product variations.

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