18th World Conference on Non destructive Testing, 16-20 April 2012, Durban, South Africa

Fusion of maintenance and control data: A need for the process

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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. These devices, which may be, for example, valve, switches, and sensors, perform functions within the process such as opening or closing valves and measuring process parameters.

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.

These additional devices include, for example, power supply equipment, power generation and distribution equipment, rotating equipment, etc., which are located at numerous places in a typical plant. 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. In Figure 1, one can see a fan monitored with two accelerometers in such a way that the information generated by vibration can close the loop and couple the device into the control system.

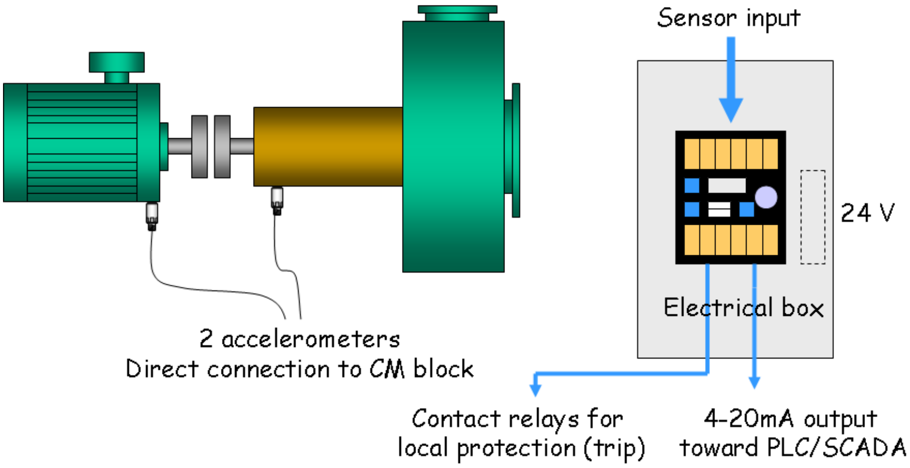

Figure 1. Monitoring of a fan and its integration to the control loop.

Still further, many process plants have other software systems associated therewith which execute applications related to business functions (ERP) or maintenance functions (CMMS). In fact, many process plants, and especially those which use smart field devices, include equipment monitoring applications which are used to help monitor and maintain the devices within the plant regardless of whether these devices are process control and instrumentation devices or are other types of devices.

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, [2]. These solutions usually enable communication with and stores data pertaining to field devices to track the operating state of the field devices. In some instances, the EAM application may be used to communicate with devices to change parameters within the device, to cause the device to run applications on itself, such as self calibration routines or self diagnostic routines, to obtain information about the status or health of the device, etc.

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. Figure 2 shows a flow diagram of the information produced when condition monitoring is outsourced and just a final report is recorded into the system.

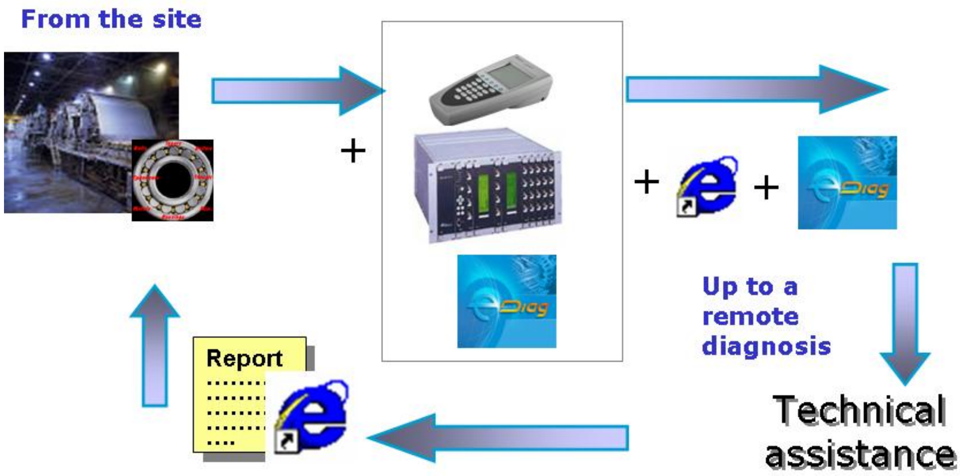

Figure 2. Typical process of outsourcing in condition monitoring.

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 [14].

Process control operators who generally oversee the day to day operation of the process and who are primarily responsible for assuring the quality and continuity of the process operation typically affect the process by setting and changing set points within the process, tuning loops of the process, scheduling process operations, etc. On the other hand, maintenance personnel who are primarily responsible for assuring that the actual equipment within the process is operating efficiently and for repairing and replacing malfunctioning equipment, use tools such as maintenance interfaces, the EAM application discussed above, as well and many other diagnostic tools which provide information about operating states of the devices within the process. Maintenance persons also schedule maintenance activities which may require shut down of portions of the plant. For many newer types of process devices and equipment, generally called smart field devices, the devices themselves may include detection and diagnostic tools which automatically sense problems with the operation of the device and automatically report these problems to a maintenance person via a standard maintenance interface.

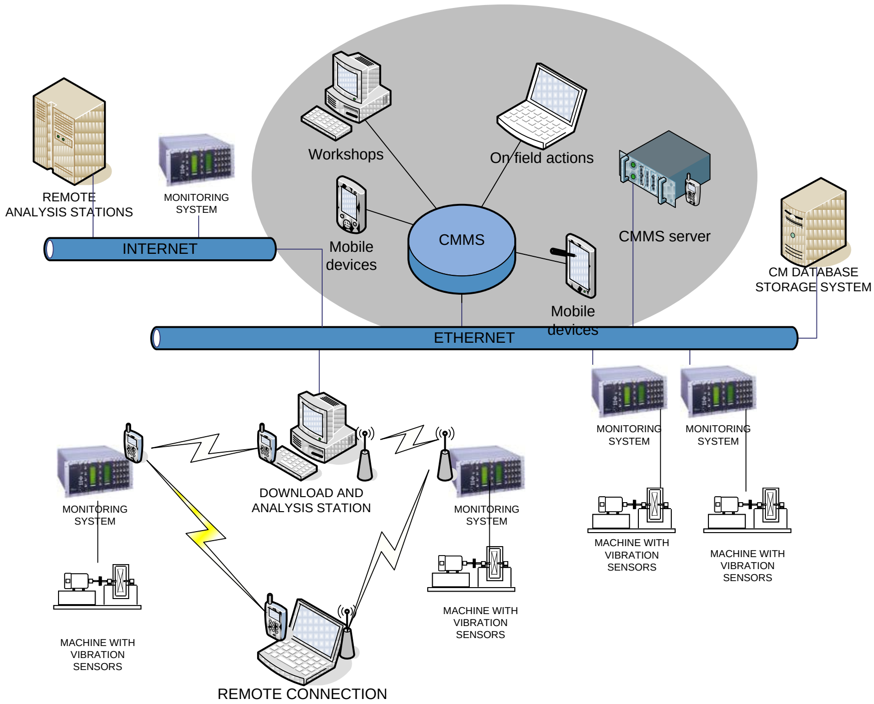

Figure 3. Typical architecture of maintenance information system,

Typically, maintenance interfaces and maintenance personnel are a real huge of data network, [5]; however it is located apart from process control operators, as you can see in Figure 3, 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.

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, and 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.

Due to the abundance of data analysis and other detection and diagnostic tools available in the process control environment, either in the plant itself or via outside service companies or consultants, there is a lot of information about the health and performance of devices available to the maintenance person which could be helpful to the process operator and the business persons. Similarly, there is a lot of information available to the process operator about the current operational status of the process control loops and other routines which may be helpful to the maintenance person. Likewise, there is information generated by or used in the course of performing the business functions which could be helpful to the maintenance crew or the process control operator in optimizing the operation of the process.

However, in the past, because these functions were separated, the information generated or collected in one functional area was not used at all, or not used very well in other functional areas which led to an overall sub-optimal use of the assets within process plants.

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.

The diagnostic applications may generate measurement, control and device indexes pertaining to non-process variables, such as the health of a device. These equipment performance indexes may be determined from models calculating key performance variables, such as efficiency and cost of production.

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, [7].

Referring now to Figure 3, a typical process control plant includes a number of business and other computer systems interconnected with a number of control and maintenance systems by one or more communication networks. The operator interfaces may store and execute tools available to the process control for s including, for example, control optimizers, diagnostic experts, neural networks, tuners, etc.

Still further, maintenance systems, such as computers executing the CMMS/EAM application or any other device or equipment monitoring and communication applications may be connected to the process control systems or to the individual devices therein to perform maintenance and monitoring activities.

Some plants can also include various assets, such as turbines, motors, etc. which are connected to a maintenance computer via some permanent or temporary communication link (such as a bus, a wireless communication system or hand held devices which are connected to the equipment to take readings and are then removed). The maintenance computer may store and execute known monitoring and diagnostic applications or other any other known applications used to diagnose, monitor and optimize the operating state of the assets.

Maintenance personnel usually use the applications to maintain and oversee the performance of rotating equipment in the plant, to determine problems with the rotating equipment and to determine when and if the rotating equipment must be repaired or replaced. In some cases, outside consultants or service organizations may temporary acquire or measure data pertaining to the equipment and use this data to perform analyses for the equipment to detect problems, poor performance or other issues effecting the equipment. In these cases, the computers running the analyses may not be connected to the rest of the system via any communication line or may be connected only temporarily

Similarly, with power generation and distribution systems, again, in many cases, outside consultants or service organizations may temporary acquire or measure data pertaining to the equipment and use this data to perform analyses for the equipment to detect problems, poor performance or other issues effecting the equipment. In these cases, the computers running the analyses may not be connected to the rest of the system via any communication line or may be connected only temporarily.

In the past, the various process control systems, power generating and maintenance systems have not been interconnected with each other in a manner that enables them to share data generated in or collected by each of these systems in a useful manner. As a result, each of the different functions such as the process control functions, power generation functions and rotating equipment functions have operated on the assumption that the other equipment within the plant which may be affected by or have an effect on that particular function is operating perfectly which, of course, is almost never the case. 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, [4] [3].

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, [17]. 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 recognizes that the combination of these standards provides an excellent basis for addressing many of the challenges in asset management. OpenO&M is being developed through a joint working group of professionals with support from MIMOSA, OPC and ISA-95 standards. The goal of OpenO&M is to enable optimal asset performance through collaborative decision making across operating and maintenance organizations. While the standards being used for OpenO&M have their origin in process manufacturing, the joint working group is also charged with addressing the needs of the broader asset management community, including facilities and fleets in both the public and private sectors.

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, [11]. 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.

Integration of asset condition monitoring (CM) information with control systems and operations (OPS), enterprise asset management (EAM) and other decision support systems (DSS) has now become the imperative. OpenO&M exploits the benefits of MIMOSA's common Asset Registry model to eliminate asset identification issues across multi-vendor systems and across different enterprise organization solutions. Integrating this with the standard object models of OPC provides a recognized interface with automation & control systems and all supporting solutions, including in many cases, EAM.

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, [10]. 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.

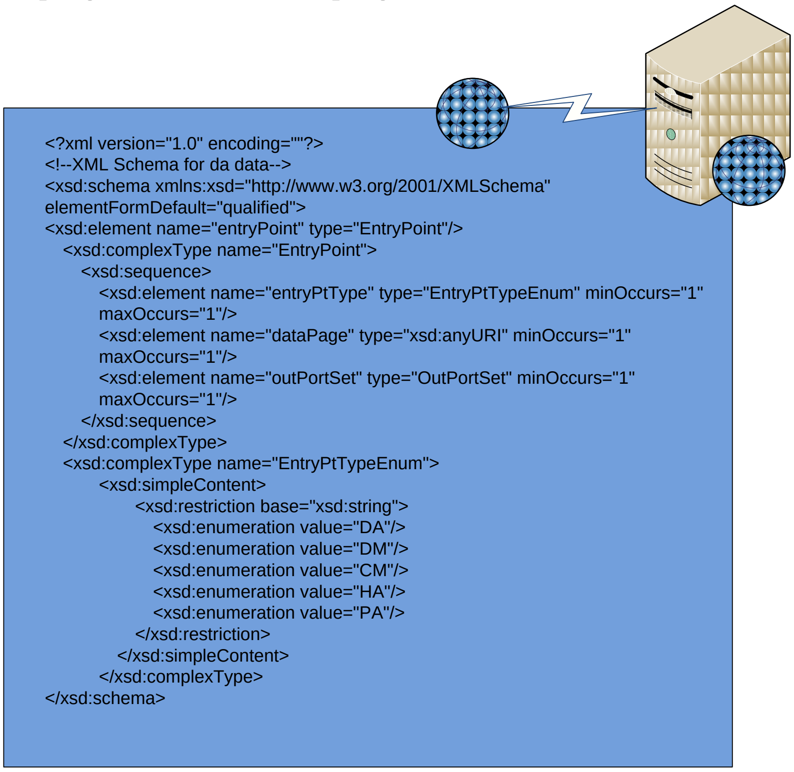

Figure 4. XML schema of transformed and transferred data

XML is accepted as communications over these industrial buses as you can see in [12], [8] [19]. 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.

A XML is a model for describing the structure of information. XML schemas can be used to test the validity of documents; this is an important aspect, especially when web-based applications are receiving and sending information to and from many sources. When mapping the process model to an XML Schema, certain rules need to be established because there are multiple ways to accomplish the same output data structure, and a certain degree of regularity is needed to simplify the data conversion. Once these rules were set into place, creating the Schemas is relatively straightforward. Figure 4 shows an example of XML Schema syntax:

All existing data (assets, events, failures, alarms) can be modelled 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.

With this system, each data originator can wrap its data using a schema understood or convenient for that device or application, and each receiving application can receive the data in a different schema used for or understood by the receiving application. The XML server may be configured to map one schema to another schema depending on the source and destination(s) of the data. It may also perform certain data processing functions or other functions based on the receipt of data. The mapping and processing function rules are set up and stored in the server prior to operation of suite of data integration applications. In this manner, data may be sent from anyone application to one or more other applications.

3.3 Example of asset data integration using XML

The web based technologies have been widely used and proven for eMaintenance purposes according to [6] [18] [16]. An architecture for collecting and integrating data from disparate data sources based on XML server based on web services is proposed in Figure 5. In this model, it will be understood the data collected from disparate sources is converted into a common format using XML. In order to enable data from different data sources to be collected and used in a single system, a configuration database or other integrated configuration system is must be provided to enable different data sources to provide data to the system for use as a single data source. Such a configuration database will be used to collect and store data from other, disparate sources of data and an explorer type display or hierarchy should be provided to allow the manipulation, organization and use the collected data to thereby make that data available to different applications.

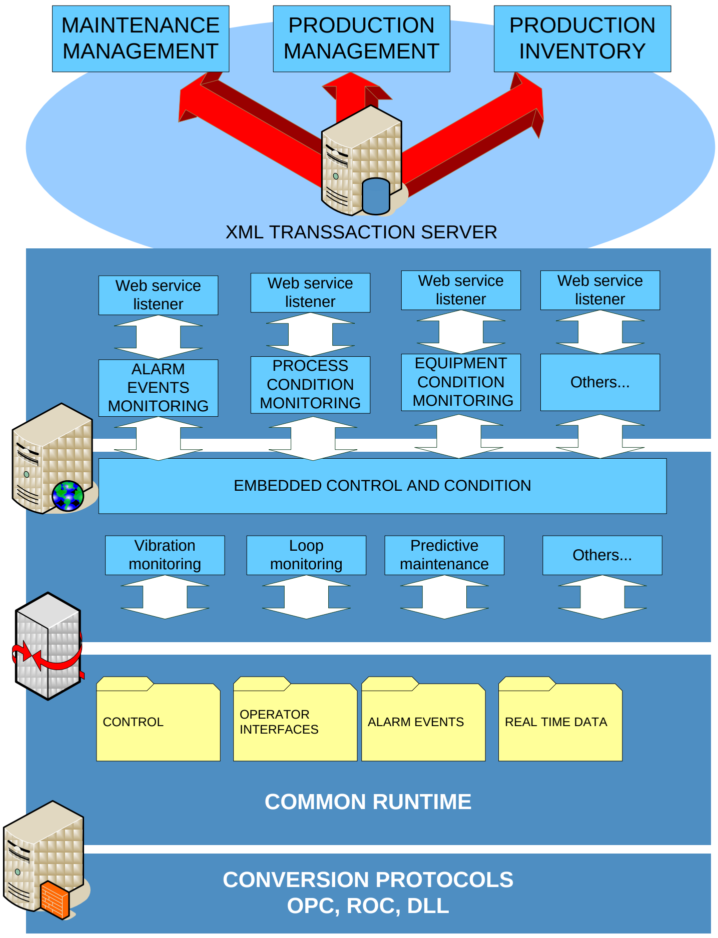

Figure 5. Integration of disparate data sources

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.

The web services will be in contact with and receive data from other external data sources via web servers. These external sources may include vibration monitoring data sources, real-time optimization data sources, expert system analysis data sources, predictive maintenance data sources, loop monitoring data sources or other data sources.

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, [13] [1] [15]. 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 collected data may then be converted to a common format at the distributed locations and sent to one or more central databases for subsequent distribution. These distributed databases will constitute the asset cloud.

Thus, generally speaking, some data collection routines should be provided to collect the data from disparate sources of data and to provide this data in a common or consistent format to the cloud. 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 [9][20][21]. 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.

An application associated with the cloud may also diagnose conditions or problems within the process control plant based on data from two or more of process control monitoring applications, process performance monitoring applications, and equipment monitoring applications. Still further, the applications may take actions within the process plant in response to a diagnosed or detected problem or may recommend actions to be taken to a user, which may be any of, operator, a maintenance technician or a business person in the "front office" of the plant who is responsible for the overall operation.

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.

With the communication provided by or collected by the cloud, especially that related to device status information and the data analysis tools, implemented thereon, the control expert can receive and incorporate device status information such as health, performance, utilization and variability information into its decision making along with process variable information. Additionally, the asset cloud must provide information pertaining to states of devices and the operation of the control activities within the plant to the business systems where a work order generation application or program can automatically generate work orders and order parts based on detected problems within the plant or where supplies can be ordered based on work being performed.

Figure 6 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. For example, a process control data source (which may include traditional process control activities and applications such as process control and monitoring applications, process control diagnostic applications, process control alarming applications, etc.) provides data to the cloud.

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.

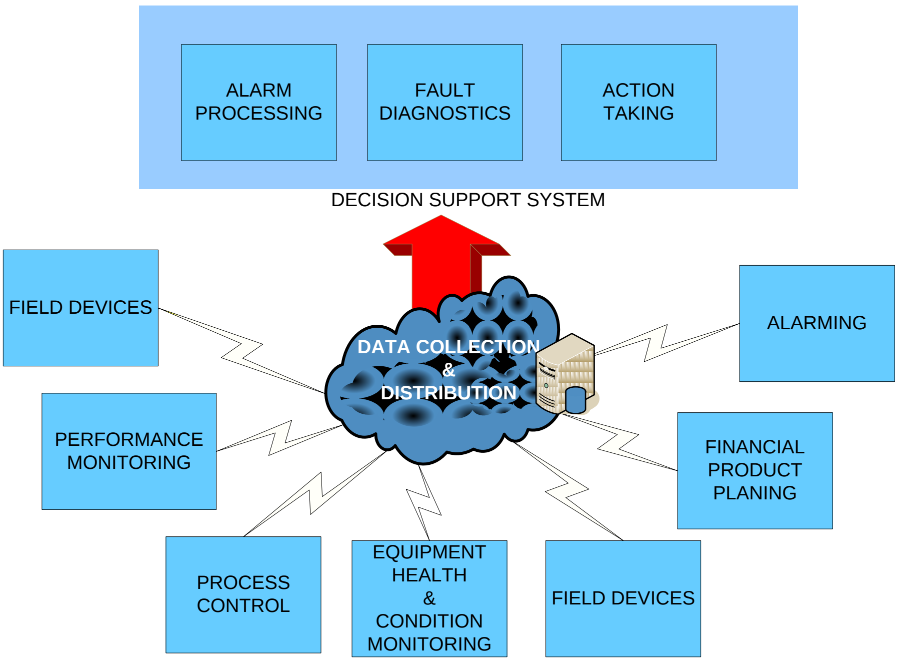

Figure 6. Services provided by the asset cloud

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.

Still further, a financial or production planning data source (which may include applications that perform financial or cost type analysis functions within the process control system, such as deciding how to run the plant to maximize profits, to avoid environmental fines, deciding what or how much of a product to make, etc.) may be connected to the cloud. Also, field devices, such as smart field devices, may provide still further data to the data collection and distribution system. Of course, the data provided by the field devices may be any data measured by or generated by these field devices, including alarms, alerts, measurement data, calibration data, etc.

4.3 The asset cloud as Decision Support System

The data collection and distribution system, cloud, will collect the data from the different data sources in a common format or will convert that data, once received, to a common format for storage and use later by other elements, devices or applications in the process control system. Once received and converted, the data is stored in a database in some accessible manner and is made available to applications or users within the asset cloud. Applications related to process control, alarming, device maintenance, fault diagnostics, predictive maintenance, financial planning, optimization, etc. may use, combine and integrate the data from one or more of the different data sources to operate better than these applications have been able to operate in the past without data from vastly different or previously inaccessible data sources.

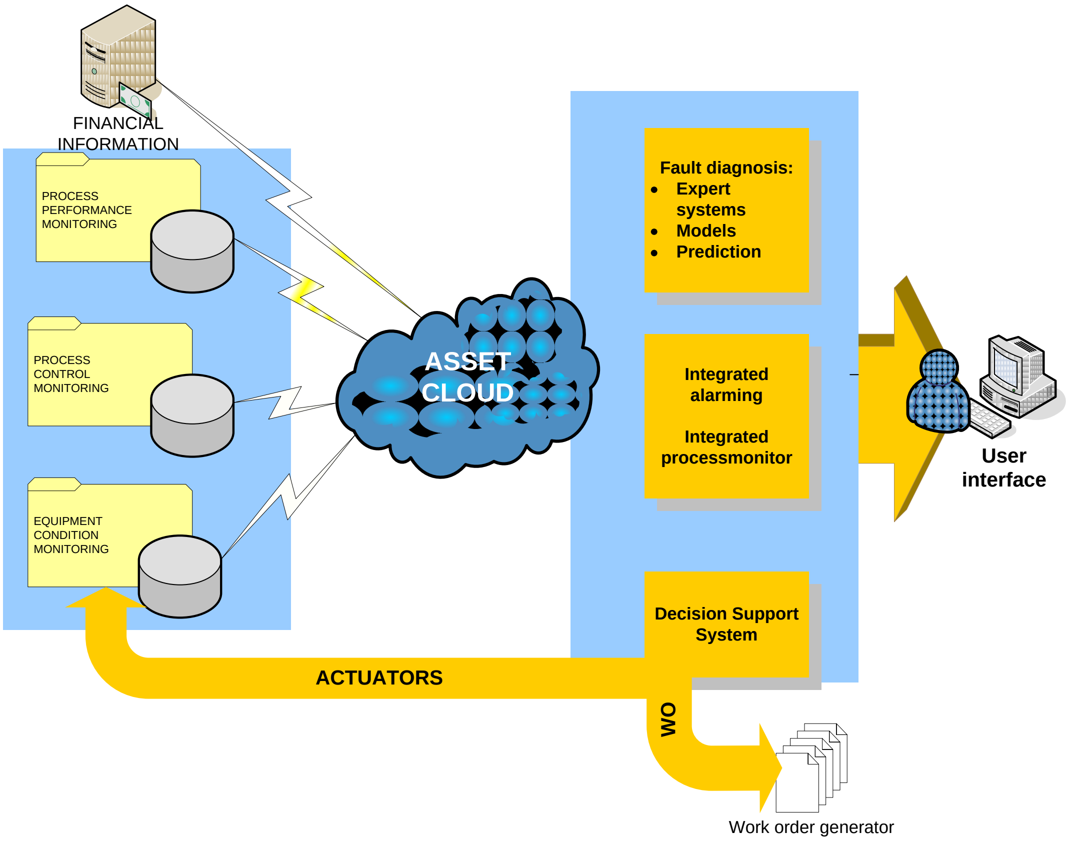

Figure 7. Data flow diagram of info sources in process control

A more detailed data flow diagram illustrating data flow within the process control plant is provided in Figure 7. Beginning at the left side of the diagram, data associated with the process plant is collected by or at different functional areas or data sources within the plant:

- Control data is collected by typical process control devices such as field devices, input/output devices, handheld or remote transmitters, or any other devices which may be connected to process controllers.

- Equipment monitoring data associated with traditional equipment monitoring activities is collected by sensors, devices, transmitters, or any other devices within the plant.
- Process performance data may be collected by the same or other devices.
- Financial data may be collected by other applications run in computers in the process control plant as part of the performance monitoring data
- Collected data may be from applications or sources outside of the traditional process control network, such as applications owned and operated by service organizations or vendors.

This data may be collected in any manner including automatically or manually since many diverse sources con compose monitoring of equipments. Thus, data collectors may include hand held collection devices, laboratory chemical and physical measurements, fixed or temporary on-line devices, devices which periodically (e.g., RF) telemeter data from remote process and equipment measurement devices, on-line device inputs or remote multiplexers and/or concentrators or any other data collection devices.

The process control data, equipment monitoring data and process performance data may be reconciled, verified, validated and/or formatted by data collection and reconciliation applications (which may be part of the cloud) run within the data collection device or within any other device such as at a central data historian, process controllers, equipment monitoring applications, etc. or any other device which receives or processes this data.

After being reconciled in any known or desired manner or, in some cases, not being reconciled at all, the collected data may be provided to one or more applications typically associated with the different functional areas of the process control system. Still further, one or more diagnostic applications may use the collected process control data to perform process control diagnostics.

The equipment monitoring functional block will receive the equipment condition data reconciled version of such data if reconciliation is performed on that data. The equipment monitoring functional block may include equipment or condition monitoring applications which may accept or generate alarms indicating problems with various pieces of equipment detect poorly performing or faulty equipment within the plant or detect other equipment problems or conditions which may be of interest to a maintenance person. Equipment monitoring applications are well known and typically include utilities adapted to the different specific types of equipment within a plant. Likewise, equipment diagnostic applications may be implemented to detect and diagnose equipment problems based on raw data measured pertaining to the equipment.

Of course, there are many different types of known equipment condition monitoring and diagnostic applications which can produce many kinds of different types of data associated with the state or operating condition of different pieces of equipment within a process control plant. Still further, a historian may store raw data detected by equipment monitoring devices, may store data generated by the equipment condition monitoring and diagnostic applications and may provide data to those applications as needed. Likewise, equipment models may be provided and used by the equipment condition monitoring and diagnostic applications and in any desired manner.

5. Conclusions

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.

Generally speaking, the collected data, i.e., the process control data, the process monitoring data, and the equipment monitoring data can be provided to different people, collected and used in different formats and is used by completely different applications for different purposes. Thus, some of this data may be measured or developed by service organizations that use applications that are proprietary and not compatible with rest of the process control system. Likewise, data collected by or generated by financial applications typically used in a process control environment may not be in a format or protocol recognizable or useable by process control or alarming applications. As a result, a maintenance person and the equipment monitoring and diagnostic applications that such a person uses do not typically have access to (and have not be constructed to use) data collected by or generated by any of the process control applications, process models or financial applications. Likewise, the process control operator and the process control monitoring and diagnostic applications used by that person do not generally have access to (and have not be constructed to use) data collected by or generated by the equipment monitoring applications and performance modelling or financial applications.

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.

References

1. Amrhein, D., Quint, S. Cloud computing for the enterprise: part 1: capturing the cloud, DeveloperWorks, IBM. (2009).
2. C. Fu, L.Q. Ye, Y.C. Cheng, Y.Q. Liu, B. Iung, MAS-based model of intelligent control maintenance- management system (ICMMS) and its application, in: Proceedings of 2002 International Conference on Machine Learning and Cybernetics, vol.1, 2002, pp. 376–380.
3. Dasarathy, B.V., Information Fusion as a Tool in Condition Monitoring. Information Fusion, 4, pp 71-73, 2003 http://www.data-fusion.org/article.php?sid=70

4. Dasarathy, B.V., Information Fusion. What, Where, Why, When, and How? Information Fusion, 2, pp75-76, 2001
5. Davies C. and Greenough R.M.. The use of information systems in fault diagnosis, in: Proceedings of the 16th National Conference on Manufacturing Research, University of East London. 2000
6. H. Min-Hsiung, C. Kuan-Yii, H. Rui-Wen, C. Fan-Tien, Development of an ediagnostics/ maintenance framework for semiconductor factories with security considerations, Advanced Engineering Informatics 17 (3–4) (2003) 165–178.
7. Hall D L, Llinas J. An introduction to multisensor data fusion. Proceedings of the IEEE 1997; 85(1):6–23.
8. I. Hausladen, C. Bechheim, E-maintenance platform as a basis for business process integration, in: 2004 2nd IEEE International Conference on Industrial Informatics, 2004 (INDIN'04), June 24–26, 2004, 46–51.
9. Isermann R. Fault-diagnosis systems. Model-Based Condition Monitoring: Actuators, Drives, Machinery, Plants, Sensors, and Fault-tolerant Systems. New York, USA: Springer. 2006
10. J. Szymanski, T. Bangemann, M. Thron, J.P. Thomesse, X. Reboeuf, C. Lang, E. Garcia, PROTEUS-a European initiative for e-maintenance platform development, in: Conference on Emerging Technologies and Factory Automation. Proceedings, vol. 2, 2003, pp. 415–420.
11. Jardine AKS , Lin D, Banjevic D. A review on machinery diagnostics and prognostics implementing condition- based maintenance. Mechanical Systems and Signal Processing 2006; 20:1483–510.
12. M. Wollschlaeger, T. Bangermann, A Web-based maintenance portal based on an XML content model, in: 2003 IEEE International Conference on Industrial Technology, vol. 1, 2003, 405–410.
13. Mell, P., Grance, T.: The NIST definition of cloud computing, version 15. National Institute of Standards and Technology (NIST), Information Technology Laboratory. www.csrc.nist.gov (2009).
14. R. Yu, L. Ye, C. Fu, A multi-agent based, remote maintenance support and management system, in: Proceedings. IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT 2004), 2004, pp. 496–499.
15. Rhoton, J. Cloud Computing Explained: Implementation Handbook for Enterprises. Recursive Press, London (2010).
16. T. Han, B.S. Yang, Development of an e-maintenance system integrating advanced techniques, Computers in Industry 57 (6) (2006) 569–580.
17. Thurston M, Lebold M. Open standards for condition-based maintenance and prognostic systems. In Proceedings of MARCON 2001, www.osacbm.org.
18. U Kunze, Condition tele monitoring and diagnosis of power plants using Web technology, Progress in Nuclear Energy 43 (2003) 129–136.
19. V.M. Catterson, E.M. Davidson, S.D.J. McArthur, Issues in integrating existing multi-agent systems for power engineering applications, in: Proceedings of the 13th International Conference on Intelligent Systems Application to Power Systems (ISAP'05), 2005, 6 pp.
20. Wylie, R., Mottola, L., Kresta, J. & Monk, R. Lessons Learned for the I02 Project. COM 2002. The Conference of Metallurgists (The International Symposium on Knowledge Management in the Metals Industry). Montréal, Québec, Canada. 2002.
21. Yang, C. & Létourneau, S. Learning to Predict Train Wheel Failures. (KDD 2005) Proceedings of the 11th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining. Chicago, Illinois, USA. 2005