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Kortela, Jukka; Nasiri, Babak; Lahnalammii, Antton; Jämsä-Jounela, Sirkka-Liisa
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Advanced teaching and process monitoring environment for the factory of the future

Jukka Kortela, Babak Nasiri, Antton Lahnalampi, Sirkka-Liisa Jämsä-Jounela

Aalto University, School of Chemical Engineering, P.O. Box 16100, FI-00076 Aalto University, Finland

Tel: +358 50 4380128, E-mail: <mailto:jukka.kortela@aalto.fi>, kepo.aalto.fi

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ABSTRACT

ABB Industrial IT Extended Automation System 800xA has been set up for centralized data collection, analysis, real-time monitoring, and advanced control. The ABB system is further expanded by cloud based advanced control and monitoring system. The state-of-the-art ABB setup includes OPC UA, providing a single entry point into a system. Each piece of equipment is automated using a dedicated PLC-station and different fieldbuses, diversifying the teaching and research benefits. The cloud based system will include an OPC UA client which allows access to ABB OPC Server using OPC UA Specifications. OPC UA scales very well in several directions. It allows OPC UA applications to run on embedded devices with very limited hardware resources, as well as on very powerful machines like mainframes. The final set up will run on the high velocity web framework Play that has been especially designed for Java and Scala. Play 2 provides native Akka support (toolkit and runtime) for Play applications enabling writing highly-distributed systems in the cloud. In addition, it follows model-view-controller (MVC) software design pattern, separating the software application into three interconnected parts: models, views, and controllers. The model manages the data, logic, and rules of the application. The monitoring and optimization algorithms are implemented in the model component. In addition, OPC UA client library will be utilized for reading and writing the data from the industrial processes. The proposed advanced teaching and process monitoring system is evaluated with test-algorithms implemented in the Spark cloud and the results are presented, analyzed, and discussed.

1 INTRODUCTION

Advances in communication and computing devices have enabled a new generation of low cost, high performance electronic components, increasing communication capabilities and processing power. Particular emphasis has been put on platform independence, security, and scalability of solutions. These advances are associated with the 4th industrial revolution (Industrie 4.0) /1/, where physical devices (Internet of Things, IoT) /2/ are connected together to form Cyber-Physical Systems (CPS) /3,4/. The broader context of CPS includes Service-Oriented Architectures (SOA) /5/ and cloud computing /6/, etc.

A service-oriented architecture in process automation combines cloud computing and Web services technologies /7/, among others. The aim is to develop tools, algorithms and methods to achieve flexible, reconfigurable, scalable, interoperable network-enabled collaboration between decentralised and distributed cyber-physical

systems. Play framework /8/ in this work was utilized to build the cloud environment, as it is lightweight, stateless, supports programming languages used in the research (Java, Scala, and Python), and highly scalable. The paper is organized as follows: Section 2 presents the advanced teaching and process monitoring environment. The test results are given in Section 3, followed by the conclusions in Section 4.

2 DESCRIPTION OF ADVANCED TEACHING AND PROCESS MONITORING ENVIRONMENT

2.1 Functional areas of the System 800xA

The System 800xA functionality is divided into a Base System and a set of options that represent functions that can be added to the system based on the needs of the process that should be controlled, as shown in Figure 1.

Field buses
Asset Optimization
Engineering
Control and I/O
Information management
Batch Management
Operations
Safety
Base System

Figure 1. Functional areas of the System 800xA

Integrated Engineering Workspace environment handles the complete lifecycle of the automation project, from configuration, visualization and library management to commissioning. Safety follows IEC 61508 and IEC 61511 compliant Safety Instrumentation System (SIS), spanning from the SIL rated field devices, I/O modules, and controllers to field actuators. Control and I/O consists of standards-based hardware and software with industrial I/O interfaces. Information management system collects, stores and presents real-time process, historical and business data. Batch management system handles recipe management, batch and procedural control according to ISA S88.01. Finally, Field Buses / Device Management system integrates intelligent field devices via all major field bus standards.

2.2 System topology of the System 800xA

The System 800xA architecture consists of computer and devices that communicate with each other through different types of communication networks.

2.2.1 Servers of the System 800xA

The Aspects Objects architecture is the cornerstone of the System 800xA. It provides information-centric navigation – a consistent way to instantly access all information without having to know how and by which

application the information is handled. For example, a valve is real object, including manufacturer's specifications, mechanical drawings, a maintenance schedule and history, ordering information for parts, physical location in the plant, faceplate for operator interface, graphic symbol for display on graphics, etc. An Aspect object presents this data as a menu of choices accessible by right linking on the object anywhere it appears in the system.

The Connectivity server provides access to the controllers and other data sources over the network. These include services, such as OPC Data Access, OPC Alarm and Event, OPC Historical Data Access, and System messages. For redundancy, two Connectivity servers exist in the system.

The System 800xA supports a full array of historical and reporting functions. The Information Manager system with the database get its data from the Connectivity server's basic historical logs utilizing the OPC's HDA standard protocol. If the Information Manager machine is off line for a while, there is no loss of data because it can retrieve the whole time period from the Connectivity Server when it comes back on-line.

The configuration of users and security in a Windows is done from the central location – the Domain server.

2.2.2 Communication networks of the System 800xA

The Control network is a local area network (LAN), optimized for high performance and reliable communication, with predictable response times in real-time. It is used to connect the controllers that run the control software to the servers.

The fieldbus interconnects field devices, such as I/O modules, PLCs, and connects these devices to the system, either via a controller or directly to a server.

2.3 OPC UA Wrapper

The OPC UA Wrapper provides OPC UA client with access to the System 800xA. The UA Wrapper exposes COM OPC servers as folders in the OPC UA server's address space. This allows applications to run on embedded devices with very limited hardware resources, as well as on very powerful machines like mainframes.

2.4 Play framework

In the test environment, the cloud system runs on the high velocity web framework designed for Java and Scala. Underneath the covers, the Play framework uses a fully asynchronous model and, combined with being stateless, the Play scales simply and predictably in the cloud. The core of the cloud computing system is Apache Spark framework, a fast and general-purpose cluster computing system. It provides high-level APIs in Java and Scala, and an optimized engine supporting general execution graphs: GraphX component in Spark for graphs and graph-parallel computation. Time Series for Spark enables analysis of data sets comprising millions of time series, each

with millions of measurements. This package runs atop Apache Spark, and exposes APIs above. The Spark SQL (Historian) is used for structured data processing.

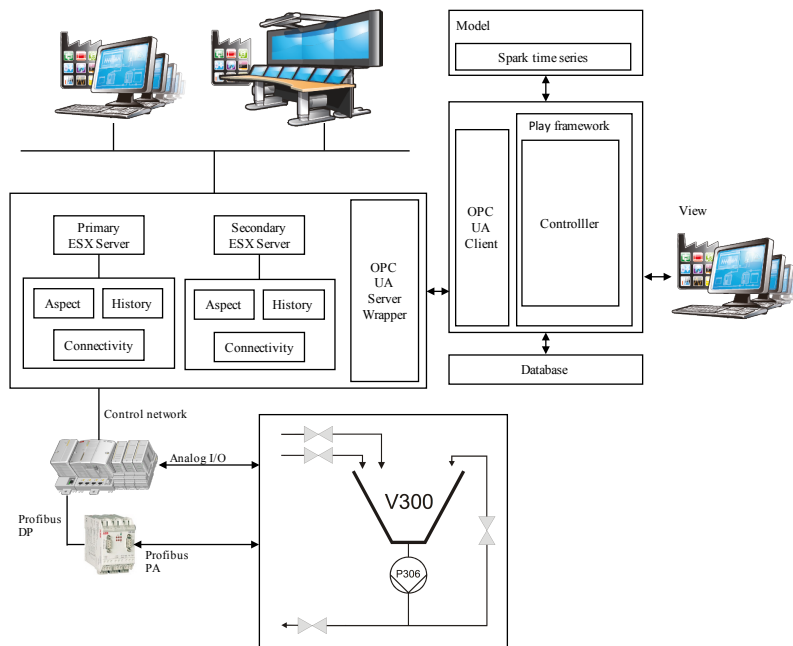


Figure 2. Functional areas of the System 800xA

3 Results

The control of the mixing tank process was used as a use case to test the performance of the developed system. This section addresses the results of the use case by explaining, the mixing tank process, the evaluation methods and the obtained results.

3.1 The mixing tank process and its control strategy

Hot and cold water come to the ca 300 liter mixing tank, as presented in picture 1, through the control valves. The flows (magnetic flow-meters) and temperatures are measured from incoming streams. In the mixing tank there are level measurements based on temperature, conductivity and pressure. Under the tank is on/off pump that pumps water to the circulation and outflow lines. The pressure after the pump is measured for faster process response and safety reasons. In both circulation and outflow lines there are magnetic flow meters and control valves.

The aim is to control the tank level with cascade control by adjusting the desired outflow amount that in turn controls the outlet valve. Sufficient outflow capability is assured by controlling the circulation line pressure with the pressure after the pump. Tank level measurement plus circulation and outflow line valves are in the Profibus PA fieldbus network. All other measurements and control signals use traditional analog signals: 4-20mA is used for analog inputs and outputs and 0/24V for the digital output (analog).

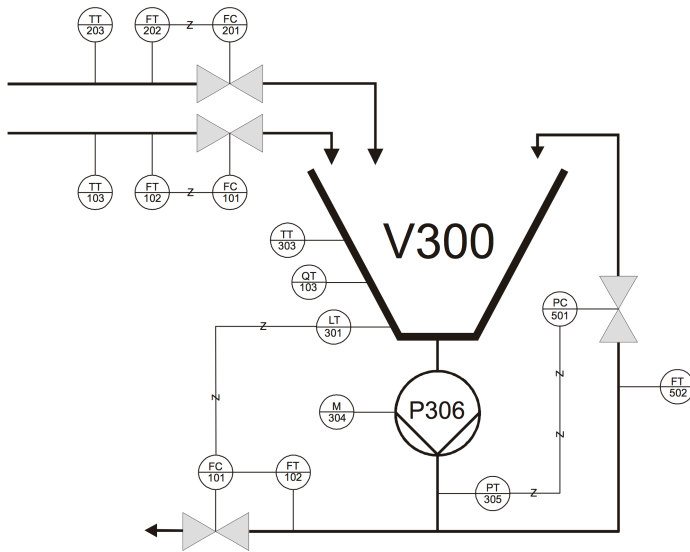


Figure 3. The influence of pressure and temperature on process supply.

3.2 Tools and methods

The performance is evaluated to see how the overall system performs under a heavy load. Performance also depends on the computation resources presented in Table 1.

Table 1. Components of the test environment

Component	
Secondary ESX Server	E5430 4 cores, 32 GB
PLC	ABB PM856 24 Mhz (48 Mhz for communication) 8 MB
Play framework server	MacBookPro13.3, Intel Core i7, 2.6 GHz, 16 GB

3.3 Test results

First, the network speed was tested by measuring the round-trip from the Play framework server to the virtual Aspect server of the Secondary ESX Server, resulting maximum value of 0.548 ms, as shown Table 2. Second, the maximum interval time of PLC was checked by altering the requested interval time of the PLC. This resulted maximum interval time of 16 ms. Finally, 50 ms was chosen as a safe control interval from OPC UA Client to OPC UA Server. To conclude, the control of the overall system can be easily located in the cloud based system and it is usually only limited by the interval time of PLC.

Table 2. The speed of the overall system

Measurement points	Result
Max round-trip from OPC UA Server to OPC UA Client	0.548 ms
Max Interval Time of PLC	16 ms

4 CONCLUSIONS

ABB Industrial IT Extended Automation System 800xA was set up for centralized data collection, analysis, real-time monitoring, and advanced control. ABB setup included OPC UA, providing a single entry point into a system. The cloud based system included an OPC UA client which allowed access to ABB OPC Server using OPC UA Specifications. Play framework was chosen to build the cloud environment, as it uses a fully asynchronous model, is stateless, and scales simply and predictably in the cloud. Test results showed, the control of the overall system can be located in the cloud and the speed was only limited by the interval time of PLC.

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