An Open CPPS Automation Architecture based on IEC-61499 over OPC-UA for flexible manufacturing in Oil&Gas Industry

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Abstract: The rapid progress of technology such as Big Data, Historians, MES, Intelligent sensors, and control systems offers Oil&Gas companies the chance to automate high-cost, dangerous, or error-prone tasks. For all these reasons, Industry 4.0 will have a profound impact on Oil&Gas industrial companies in the years to come. Low-cost automation promotes profitable reference architectures and new development approaches to increase the flexibility and efficiency of production operations in an industrial plant. This has led to the adoption of standards and open network standards for plant-level communications. OPC-UA can help industrial companies to integrate into the vision of Industry 4.0, allowing remote access to plant information, therefore, vertical integration is achieved. The main objective of this work is to enable vertical integration to become a reality through a CPPS architecture and IEC-61499 standard, that allows low-cost access to process data in a plant. Using this architecture along the entire automation system production can certainly reduce the Total Cost of Ownership (TCO) in the industry.

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1. INTRODUCTION

In the Oil&Gas sector, the stakes are high, the conditions harsh. Reliable communications and the secure transmission of business information are critical. As much as information technology is very relevant in other industrial fields, it is highly essential in the Oil&Gas industry. Different operations in the Oil&Gas industry depend solely on information technology and can only achieve efficiency thereof.

Today’s intelligent oil field is flush with digitally enabled wired systems, equipment, and components. A typical production platform can have more than 40,000 data tags, not all connected or used. Converting this complex flood of data into better business and operating decisions requires new, carefully designed capabilities for data manipulation, analysis, and presentation, as well as tools to support decision making.

In the downstream Oil&Gas operation, corporate communication is very important in order to determine efficiency in the various processes. This makes it possible to achieve enormous cost savings and economies of scale. Management has genuine real-time information for its decision-making processes. The results of any action taken can be directly measured, identified and then corrected as needed. In the short term, even those aggressively pursuing Industry 4.0 will have a mix of smart devices and equipment with traditional products and machines that need M2M communication to guide the process of vertical and horizontal integration.

Industry 4.0 is based on Cyber-Physical Production Systems (a fusion of the physical and the virtual worlds) CPPS, the Industrial Internet of Things(IIoT) and the Internet of Services, will collectively have a disruptive impact on every aspect of manufacturing companies and now we need to introduce these concepts in real industries like Oil&Gas sector. The 4th industrial revolution, which unlike all others, is being predicted, therefore allowing companies to take specific actions before it happens.

On the other hand, the IEC 61499 standard promotes a model based development of distributed control systems. Industry 4.0 will allow to model and develop software and hardware for independent distributed control systems. The key entity in the IEC 61499 standard is the Function Block (FB), which wraps the control and communication algorithms in different programming languages, including IEC 61131, Java, C++, or virtually any other programming language. The Service Interface Function Block (SIFB) is one of the types of FBs provided that allows wrapping and abstracting the hardware access as well as the resources from the Application Programmer Interface. In summary, currently available technology is mature enough as to achieve the goal of M2M but there is still a gap between technology and real industries.

The use of standards such as IEC-61499 and architectures CPPS implies that advance in information technology would result to the improvement of the Oil&Gas industry as well as every other field of life. This is why lots of intensive researches are being carried out on information technology in
the recent time and these have resulted in unimaginable impact on this kind of industry.

In previous works of authors (Perez et al. 2015) the general architecture for CPPs was presented. It consists of a model-based approach identifying the different models needed for achieving vertical integration. This paper contributes to the application of the generic architecture to the special case of oil production industry and to the data collection from field devices using IEC-61499 and OPC-UA protocol for the production process and information supplier devices.

The layout of the paper is as follows: Section II shows some related works that have been used as starting point for this research. Section III presents a CPPS Architecture in order to be used in an advanced industrial automation environment. Section IV describes a proposed software implementation using IEC-61499 and OPC UA. Section V proposes a set of SIFB for IEC 61499, describing in detail the configuration XML file for the OPC UA server. In order to validate the work, Section VI shows a case study in Petroamazonas Company where Modbus/TCP and an OPC-UA server into Information Components are implemented. Finally, some conclusions are drawn in Section VI.

2. RELATED WORKS

This section reviews related research directly related to the areas of machining and industrial production. It also describes the approach and scope for our research when looking to develop a methodology for agile distributed process planning and adaptable to continuous processes especially in the area of oil & gas.

Researches about the use and implementation of the IEC-61499 function blocks in different control applications have been ongoing for a while. It seems that the absolute majority of these applications are limited to control low-level processes for PLCs, which are not able to handle problems of uncertainty regarding the design layout and process planning in high-level manufacturing systems. According to this literature survey, it seems, they have a limited use of FBs for adaptive processes and control machining/assembly for this reason, the aim of this research is to use FBs architecture in a real continuous process.

A common application of FB architecture of IEC-61499 is the design of distributed autonomous systems with intelligent control components (Wang et al. 2001), maintenance of distributed control system and engineering web-based (Schwab et al. 2005.), automated verification of industrial control systems based on FB (Völker & Krämer 1999), FB-oriented support systems engineering (Thrampoulidis & Tranoris, 2001) and reconfigurable concurrent FB models (Brennan et al. 2002).

Studies on implementation of IEC 61499 in process control systems are shown (Olsen et al. 2005), an implementation of a distributed control model in real time using a Java-based platform is presented, where a control application is distributed across two devices, supported by a MANAGER FB, capable of providing management services for devices. Real-time execution of IEC 61499 applications, which describes the elements of execution within a device and different approaches to programming and implementation, is presented by (Zoitl et al. 2005), as well as criticism and solutions, ambiguities concerning the implementation of the norm, leading to different behaviors of execution of the elements in different control devices, (Strasser et al. 2011). The development, implementation and use of an IEC 61499 FB library for embedded closed loop control is presented and demonstrated (Strasser et al. 2004), in a real experiment: a see-saw problem. (Jain et al. 2002), (Yuan & Ferreira 2003) and (Yuan & Ferreira 2004) has developed a system called EMBENCH. This is a design environment simulation and rapid prototyping at different levels of control machining using IEC 61499 for modularization and reuse of services implemented control. The system allows different types of commands to controllers in different layers from the complex flexible manufacturing cell to a single servo binding. An example of how IEC 61499 can be used to model a distributed, flexible and reconfigurable application is demonstrated (Hussain & Frey 2004). But so far, IEC-61499 has only been focused on discrete control processes, this research use IEC-61499 to integrate industrial communication and its use in the monitoring of analog processes.

Using the FB for process planning has emerged as an innovative approach in manufacturing systems, mainly since the introduction of the IEC 61499 standard. With the new standard, FBs can be triggered by events to execute internal algorithms in a controlled manner. This feature opens up many new exciting application scenarios. The possibility of handling changes during the generation and execution of process plans as well as the linkage to scheduling for optimal system performance are challenging effects from the distributable and modular nature of the FB technology.

FBs applied to assembly process planning are reported in (Wang et al. 2008), in which assembly features (pairs of mating components) are identified and mapped to appropriate assembly FBs. Each FB possesses a set of processing algorithms to determine how to do a specific assembly operation by a robot or a human assembler. In order to facilitate the design of FBs, (Wang et al. 2009) developed an FB designer, crucial to adaptive process plan generation and able to encapsulate generic process plans into FBs for runtime execution.

A group-based programming abstraction for CPPS is proposed by Vicaire et. al. (Vicaire et al. 2012). The abstraction model covers sensors and actuators. Heterogeneous devices are supported by this model, that sensors and actuators can be modeled and simulated simultaneously. The abstraction model given in this article is called "Bundle" and is suitable for plant floor devices. However, this kind of models is not addressed to be used with new communications standards such as OPC UA.

Stojmenovic (Stojmenovic 2014) considers M2M as a key technology for CPPS. The author identifies the problem that all researches in the field of M2M communication is based on small-scale models and centralized solutions. For this reason,
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