International Journal of Information Technology and Management

Vol. VIII, Issue No. XII, May-2015, ISSN 2249-4510

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

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International Journal of Information Technology and Management
Vol. VIII, Issue No. XII, May-2015, ISSN 2249-4510

PLC Data Communication System: A Reconfigurable and Distributed Process and Embedded Control System

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Abstract – The impact of automation is visible in all areas of industry as well as in everyday life. Automation makes the process control more efficient, increases productivity of work, manufacturing quality, decreases manufacturing costs. Automation is still in development so that it could succeed in filling all requirements of today's technical advance. For this reason we daily meet new questions about implementation of automation systems, their handling and expanding. One of these is the question of communication in industrial applications. In case of having more PLCs in one industrial network, it is necessary to solve their inter-communication. We should deal with this question in dependence on some facts, for example: used control system, used industrial network, transmission reliability requirements and so on. In this article we would like to present a solution for intercommunication between PLCs in one industrial network by S7 communication. S7 communication via Industrial Ethernet allows program-controlled communication using communication SFBs/FBs via configured S7 connections.

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INTRODUCTION

Reconfigurable concepts and architectures have been used in the research domain for industrial automation and control systems since several years. For example, Kramer et al. have introduced this important topic for distributed systems. In general, the main aim of reconfiguration is related to the altering of functions and algorithms in software models. Especially in the automation domain reconfiguration means the adaptation and adjustment of control functions and algorithms in control, communication, measurement and field devices due to changed requirements. Usually, there are many ways to describe reconfigurability of software elements. This topic can be solved in different ways: reconfigurability can happen on a higher level (e.g., implemented by Multi-Agent Systems) as well as also on a lower level (e.g., real-time control with IEC 61131 or IEC 61499). Moreover, one has to distinguish between static and dynamic reconfiguration –.

Especially on the real-time control level, which is in the scope of the approach introduced in this study, there are some concepts mentioned in the literature. Most of the actual PLC systems based on IEC 61131 support some kind of reconfiguration. This means that control programs can be adapted in PLCs but this is carried out in a relative simple way. Normally, the modified PLC program is downloaded to the PLC hardware and the corresponding software system decide the point in time where the "old" program is replaced by the "new" one. Usually there is no way to control the exchange procedure in modern PLC systems.

In contrast the IEC 61499 reference model for distributed and reconfigurable IPMCS provide a management model and the corresponding Application Programming Interface (API). Therefore, it provides the possibility to control the life-cycle of software components (i.e., FBs) in distributed control devices. Moreover, IEC 61499 defines eight different configuration commands (i.e., START, STOP, KILL, READ, WRITE, CREATE, DELETE, QUERY) which are often used in the literature to adapt FB instances and therefore control applications. The main difference to the approach in IEC 61131-3 is that the reconfiguration is carried out on a more detailed level without the need to adapt a whole control program. In addition, a standardized management interface is missing in IEC 61131-3 systems and also the event driven architecture of IEC 61499 allows to better synchronizing adaptation steps. According to the literature, the IEC 61499 management interfaces is mainly used for adapting control algorithms –. The topic of using the management interface as basis for the reconfiguration of communication links.

Nowadays Modern control engineering concept moving from traditional PLC based centralized control system to Distributed control system. The reason is globalization of market need to make manufacturing industries to rapidly change or customize their production in respond to change in custom need, market need or technology changed. As there is development of smart field instrumentation and embedded controller in process and communication domain, the concept of flexible distributed control system get popular. Modern manufacturing/ production/logistic application need to flexible, fast changing, reconfiguration and reused feature as to respond to fast changing market demand, production variation, technology variation. The high level demanded features need to address by modern control engineering are: Distribution: The ability to distribute software program component among distributed hardware devices Configurability: Any device and its software components can be configured by software tools from multiple vendors. Reconfiguration: The ability to adapt control hardware and software during operation.

Interoperability: Embedded devices can operate together to perform the functions needed for distributed applications. Portability: Software tools can accept and correctly interpret software components and system configurations produced by other software tools. The new international standard IEC 61499 introduce model to implement distributed control system with reconfigurability, reused and interoperatibilty features. Therefore this paper focus on distributed and reconfigurability added to process control devices using IEC 61499 function block model structure by distributed function blocks among several devices.

DISTRIBTED AND RECONFIGURABLE CONCEPT

Distributed conceptbring the change into automation into manufacturing and process industries. In distribution phenomena the control can be distributed among the several hierarchical control layer from field to top layer management. The whole application distributed among various layer to fulfil the complete functionality using various communication protocols standards.

IEC 61499 enable to design and develop flexible distributed control system/applications by merging the features of PLC function blocks and DCS function blocks. It's abstract model is basic function block and support the even based execution. The application can be created by interconnection of even driven software modules with distributed application among the various resources.

IEC 61499 standard define general model and methodology for describing function blocks in a format that is independent of specific application implementation. This model used by designers to develop distributed control application for industries. Basically application based on this standard allow system in term of logically connected function blocks sharing among various resources.

This standard emphasized formal models and methods based on object oriented concept and unified modelling language.

Generalized concept based on IEC 61499 standard is illustrated below figure-1

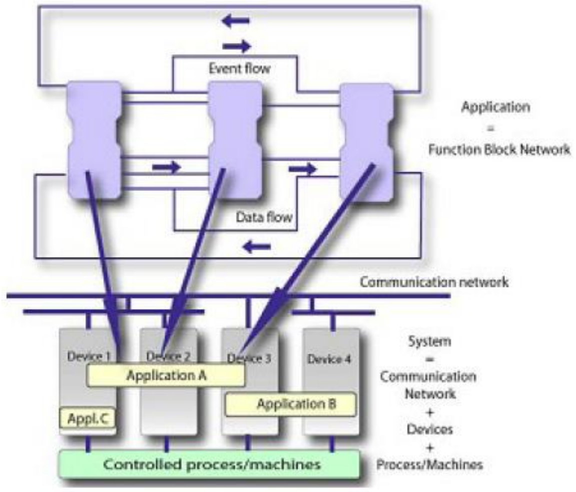

Fig 1: Distributed System in IEC 61499

Device, application and resources are the main elements of distributed process control system based on IEC 61499 model structure. The device is basic control element consist processor, I/O interfacing and communication interfacing. The application is group of function blocks communicating to each other to complete the control tasks. The resource is considered as sub-device which can independent control of its operation and the part of distributed application run on resources.

The 61499 standard facilitate the world trade by removing centralized barriers drawback by providing the portability, configurability & reconfigurability and interoperatibilty features. The configurability of device means device can be configurable by control software. The reconfigurability means device can be reconfigurable by change in its parameters or variable from multiple vendors by software tool of multiple suppliers.

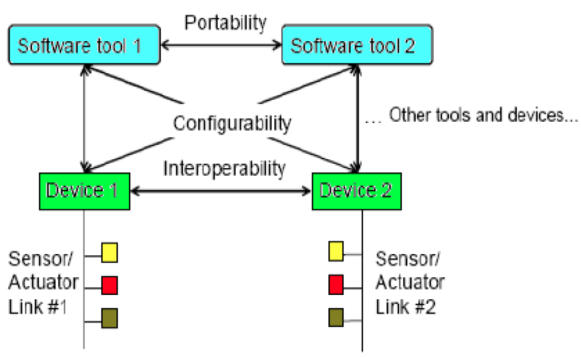

Fig 2 : IEC 61499 feature : interoperatibilty, portability and configurability & reconfigurability.

The Algorithm of function block can support function block diagram, Ladder diagram, statement text and Java as shown in fig-3 In this sense It provide reconfigurability at abstract level of Function block of IEC 61499 standard.

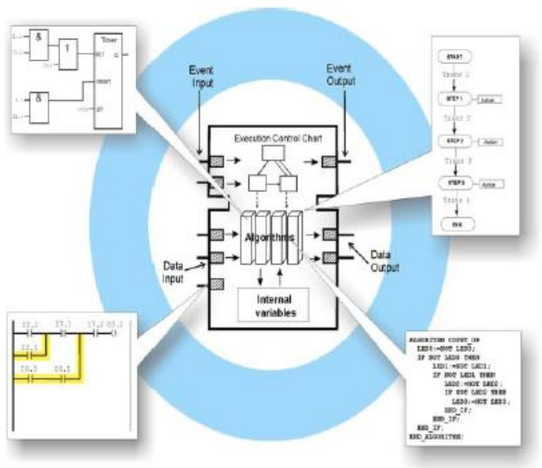

Fig 3: supported languages for the Function Block algorithm.

PLC and CNC are used as lower level production line automation implementation. Reconfiguration control of these controllers can be great challenge due to different characteristics of individual control rules. Combine them both in single manufacturing environment to achieving reconfigurable control architecture in focus interest. For that initially study reconfigurable control of PLC and CNC controller. Then study the reconfigurable transform rules from PLC and CNC to IEC 61499 – describe transform rules from IEC 61131 to IEC 61499 reference structure model and describe STEP-NC reconfigurable numerical controller. Then implement reconfigurable control for single PLC and CNC based manufacturing industries. This work can focus on reconfiguration need for lower level machine control enable to design IEC 61499 compliant PLC controller of machine. That can be move to transform to new structure and then integrate them into lower level manufacturing network of production line. For that first, mapping IEC 61499 and IEC 61499 elements to physical structure of production unit. second, constructing IEC 61499 complaint PLC controller design by reconfiguration concept.

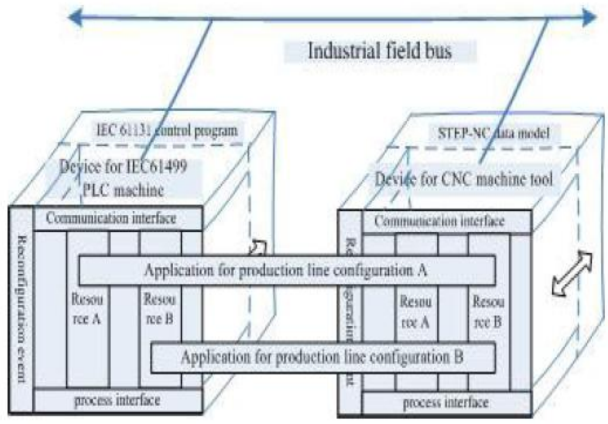

Fig 4: modify IEC 61499 compliant architecture from PLC and CNC controller.

As shown in fig.- 4 PLC and CNC act as lower level manufacturing controller connected by industrial fieldbus. IEC 61499 compliant architecture proposed based on reconfigurable control software structure from lower level production environment. To do that, PLC and CNC controller are act as DEVICE model and even based control execution mechanism used as reconfiguration triggers and action.

To develop methodology to automate the design of distributed controllers of discrete manufacturing systems from a single description of the system is great challenge in automation system. Deriving modular representation of distributed application based on IEC 61499 standard and develop distributed controller for same. So if application can develop into modular form then it can be easily reused and reconfigurable. A key concept of this work is make the partition of the complete application into subsystem as work unit which allows to design modular description based on function blocks: these blocks can integrated into composite models to act as single module.

COMMUNICATION SERVICES IN PLCS AND DISTRIBUTED SYSTEMS

In the domain of PLCs, which are widely used in industrial control applications, the IEC 61131-3 definition for the harmonization of programming languages plays an important role. In this standard no concepts and methods are described for a harmonization of communication concepts and patterns which are seen to be very important in a network of heterogeneous controllers and field devices. Only part 5 of the IEC 61131 standard provide special functions blocks which covers the communication in PLC systems, but up to know they are rarely used in industrial applications. Currently, there is a much more sophisticated development ongoing which has a high potential to harmonize the information and data exchange in PLC-based systems. The international user organization PLCopen for enhancing the IEC 61131 concept is working together with the OPC Foundation to specify an "OPC UA Information Model for IEC 61131-3" .

Similar to the IEC 61131-5 definitions the IEC 61499 model provides high-level communication patterns and functions for the information exchange between embedded control devices. However, the usage of a special communication protocols (e.g., Ethernet, Industrial Ethernet, field bus) is not in the focus 1Programmable Logic Controller of this high-level specification. Some mappings to domain protocols are documented in the literature.

Summarizing, some attempts in the PLC domain has been undertaken to harmonize communication aspects from the modeling and execution point of view but the dynamic change and adaptation of communication links is not really addressed up to know. The OPC UA specification could overcome shortcomings of actual PLC systems. In contrast, the IEC 61499 already covers this important topic and provides some high level communication patterns and services which can be mapped to well-known lower-level domain protocols.

RECONFIGURABLE AUTOMATION AND CONTROL SYSTEMS

Reconfigurable concepts and architectures have been used in the research domain for industrial automation and control systems since several years. For example, Kramer et al. have introduced this important topic for distributed systems. In general, the main aim of reconfiguration is related to the altering of functions and algorithms in software models. Especially in the automation domain reconfiguration means the adaptation and adjustment of control functions and algorithms in control, communication, measurement and field devices due to changed requirements. Usually, there are many ways to describe reconfigurability of software elements. This topic can be solved in different ways: reconfigurability can happen on a higher level (e.g., implemented by Multi-Agent Systems) as well as also on a lower level (e.g., real-time control with IEC 61131 or IEC 61499). Moreover, one has to distinguish between static and dynamic reconfiguration. Especially on the real-time control level, which is in the scope of the approach introduced in this paper, there are some concepts mentioned in the literature. Most of the actual PLC systems based on IEC 61131 support some kind of reconfiguration. This means that control programs can be adapted in PLCs but this is carried out in a relative simple way. Normally, the modified PLC program is downloaded to the PLC hardware and the corresponding software system decides the point in time where the "old" program is replaced by the "new" one. Usually there is no way to control the exchange procedure in modern PLC systems.

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Summarizing, the IEC 61499 approach provides a very good baseline for reconfigurable control systems in a distributed environment but a more formalized approach for defining reconfigurable gateway functions in order to dynamically adapt communication links is currently missing.

DATA COMMUNICATION BETWEEN PROGRAMMABLE LOGIC CONTROLLERS

If the communication in the small applications is not critical than is sufficient to control these by one programmable logical controller (PLC). The role of the communication is exchanging of connection with a common computer in order to create and transmit the program to PLC and to transmit data to superior levels for operator's control of technology. At the direct control it is possible to rely on the response specified by manufactures between input change and adequate reaction (A-A´, Fig. 5).

This response ranges about 10 ms depending on memory size, processor speed or on the longest time of programming repetition cycle (scan time). While building distribution control system for controlling large industrial application it is very important to solve the question of communication. Sometimes there arises the question about controlling output on the remote PLC, which is available only via industrial communication network (B-B´, Fig. 5).

In this case the response will be bigger and depend on a lot of factors. Industrial networks cover mainly production control, so it is very important to ensure high reliability, deterministic mode of communication and high power. On the other hand industrial networks enable connection (C-C´, Fig. 5) with centralized operator layer (PC with function

SCADA/MES) of whole company information system and top company ERP system.

Common corporation (proprietary) industrial networks use only three layers from standard reference communication model (RM-OSI) – physical, link and application layer. See comparison in the Tab. 1. Modern networks based on industrial Ethernet and TCP/IP technologies use five layers, where network layer and transport layer are allocated to physical and link layers to support TCP/IP technology.

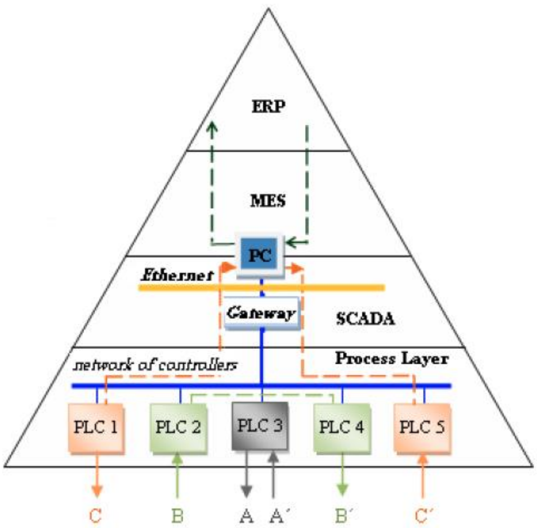

Fig. 5: Business information model.

Managing connections between remote PLC performs the data link layer with use.

CONCLUSION

By the practical example one form of data communication among more PLCs was demonstrated. We chose the model where both processors were the SIMATIC type. We chose the Industrial Ethernet network with service S7 communication. For data transfer we used system blocks SFB 12 BSEND and SFB 13 BRCV, which are able to transfer maximum data capacity 32 kB for S7 – 300 and 64 kB for S7-400. As it has been mentioned and experimentally verified, the data communication speed among several PLCs mainly depends on used hardware (CPU type), industrial network used for data transfer and parameter settings of system blocks including the size of transferred data.

The knowledge, need of IEC 61499 reference standards for developing flexible distributed system is fully describe. FBDK is most popular academic/research oriented software tool to develop and stimulate/test distributed application based on IEC 61499 reference model. Function block is basic element of IEC 61499 provide even based execution mechanism, reconfiguration at algorithm level, easily re-used features to develop application. The application can be distributed among several devices and resources by developing function block networks in IEC 61499 reference model. Reconfigurable phenomena study at various aspect :1.Algorithm level of function block 2. Modular structure of application and 3. Transformation from PLC,CNC controller to IEC 61499 model structure.

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