Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

DISTRIBUTED CONTROL SYSTEMS MODELLING USING PROFINET CBA

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Abstract: *This paper deals with international standards IEC 61131-3, IEC 61499 and their application in process of distributed control systems design using PLC Siemens Simatic S7. Simatic Step7 is a software tool based on IEC 61131-3 standard and it is used for Siemens PLC's programming for years. Expansion of distributed systems caused in creation of IEC 61499 standard. Siemens company responded to this expansion by introduction of Simatic iMap software tool, which is based on IEC 61499 fundamentals. The aim of this paper is to compare options of distributed systems creation using both of these approaches and software tools.*
Key words: *control systems, standards, programming*

1. INTRODUCTION

IEC 61131 is a worldwide standard approved by International electrotechnical commission characterizing (IEC) all about Programmable logic controllers (PLCs). As define IEC 61131-3, standard programming languages for PLC are Structured Text (ST), Ladder Diagram (LD), Instruction List (IL), Sequential Function Chart (SFC) and Function Block Diagram (FBD). (Lewis, R., 1998) The International Electrotechnical Commission has now developed a new standard IEC 61499, that defines how function blocks can be used in distributed industrial process, measurement and control systems. (Lewis, R., 2001)

PROFInet is an open automation standard based on Industrial Ethernet. Within this standard, PROFInet CBA - based on IEC 61499-1 - describes a technology for implementing modular and distributed automation solutions on the basis of predefined components. PROFInet CBA can be seen as a mapping of the IEC 61499 elements to the world of traditional scan based PLC systems (Pigan, R. & Metter. M., 2008).

The purpose of this article is to find out practical advantages of distributed system created using Profinet CBA.

2. RECENT RESEARCH

For years IEC 61499 was in focus of research works. Many research groups worldwide have contributed to developing case studies and even prototypes of supporting tools. There are several software tools focused on IEC61499 research, for example FBDK, ISaGRAF, FBench.

FBDK is the first software tool based od IEC 61499. It is written in Java and function blocks are implemented as Java classes. FBDK is mainly used in academic environment and research community. It was developed by Rockwell Automation, currently maintained by Holobloc Inc. ISaGRAF is the first fully fledged automation product supporting the complete design chain. It was developed by ICS Triplex ISaGRAF. (Vyatkin, V. & Chouinard, J.,2008)

FBench is an open source project initiated by OOONEIDA. FBench is capable for IEC 61499 FB design, development, debugging, run IEC 61499 application, verification, etc. FBench open-source project is continuing by our research group at the University of Auckland. (Dai, W.W. & Vyatkin, V., 2009)

Component Based Automation is the implementation of Profinet CBA for automation systems from Simatic S7 and Simatic NET ranges. This includes the following products:

- Simatic Step 7 as engineering tool for configuration and programming of Simatic S7 and Simatic NET automation systems as well as creating Profinet components. Step 7 is the world's best known and most widely used programming software in industrial automation and complies with the IEC 61131-3 standard.
- Simatic iMap as the engineering tool for configuration of distributed plants and for integration of device-specific programming, configuration and diagnostic tools into a PROFInet CBA engineering environment. PROFInet is an open automation standard based on Industrial Ethernet. Within this standard, PROFInet CBA - based on IEC 61499-1 - describes a technology for implementing modular and distributed automation solutions on the basis of predefined components. (Pigan, R. & Metter. M., 2008)

3. EXPERIMENTAL SYSTEM

Four identical Simatic CPU's 315F-2 PN/DP were chosen for our experimental purposes. Every CPU has built-in PROFInet interface. These PLC's are situated in laboratory and connected via local 100 MBit Ethernet network, to minimize communication lags. One PLC acts as master – it requests and writes data, all other PLC's are slaves and responds to master requests. (Fig. 1) There are loaded only blocks required to ensure communication to minimize CPU scan cycle time.

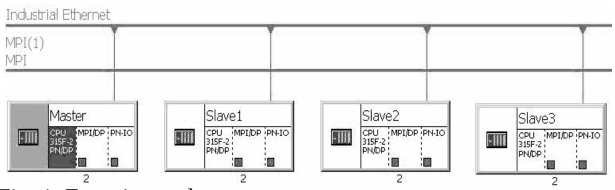

Fig. 1. Experimental system

4. PRINCIPLE OF INTERCONNECTION CPUS USING STEP7 AND IMAP

Using Step 7 the PLC can communicate with up to 16 channels. Communication is not cyclical and it is realized using system functions GET and PUT. Every time CPU needs data from remote CPU it is necessary to call GET function with correct communication channel address and address of requested data. PUT function must be called with identical parameters as GET. Every GET or PUT function occupies one communication channel.

iMap communication is different. It is necessary to create function blocks and appertaining communication datablocks inside every networked PLC. Every PLC acts as PROFInet component with inputs and outputs (elements of communication datablocks). These inputs and outputs are triggered automatically every time value changes. PROFInet components are connected with graphical interconnections.

5. CRITERIA FOR COMPARISON

There are more important criteria, which will affect suitability of using iMap to build distributed control system, for example remote variable modification response time, network utilisation, number of network nodes, time needed to develop and implement control software, complexity of programming, etc.

6. RESPONSE TIME OF REMOTE SYSTEM BENCHMARK

Every test consists of 1000 values exchange between master and slave systems. Duration of single exchange is calculated as arithmetical average. Every test is 10 times repeated to guarantee proper test results.

Minimal response time of Step7 system with just one connection was 21 ms. Every communication channel increased response time by approx. 7 ms. Response time of distributed system with all 16 channels will be at least 125 ms, in real conditions of large industrial network probably more.

Minimal response system of iMap system with one connestion was around 23 ms. Adding new connections did not affected response time of system. Number of connection does not have influence to system performance.

7. NETWORK UTILIZATION OF DISTRIBUTED SYSTEM

Transparent bridge with two network interfaces was used. Bridge was connected between master system and Ethernet switch with slave systems connected. Software sniffing tool Wireshark was used.

Utilization of Step7 distributed system raises from 25 ms up to 30 kB/s, consequently response time decreases.

Communication utilization using iMap 8ms cyclical transfer started at 8 kB/s and every another connection increased utilization by approx. 8 kB/s. This result is not accurate because response time of iMap system is lower than Step7 response time. That was reason to perform another test with 32 ms cycle time. Communication utilization using iMap 32 ms cyclical transfer started at 2 kB/s and every another connection increased utilization by approx. 2 kB/s.

8. INFLUENCE ON PLC SCAN CYCLE TIME

Every PLC was uploaded with appropriate program. To avoid influence of any other program blocks only necessary communication blocks were uploaded. Stations were restarted and scan cycle times were determined in Step7 Hardware manager.

Average scan cycle time of Step7 one communication channel system was 1 ms. Every another connection increased scan cycle time by approx. 1 ms. Maximum scan cycle time of system with 16 connections will be raised by 16 ms.

Scan cycle time of iMap system was 1 ms independently of number of communication channels.

9. INFLUENCE ON PLC MEMORY UTILIZATION

Every PLC was uploaded with appropriate program. To avoid influence of any other program blocks only necessary communication blocks were uploaded. Stations were restarted and memory utilization was determined in Step7 Hardware manager.

Station with no program uploaded already contains some data (hardware configuration, etc.). EPROM contains 3446 b, work memory 38 b and retentive memory 0 b.

Step7 system with one connection consumed 13672 b of EPROM, 7996 b of work memory and 802 b of retentive memory. Every additional connection increased memory consumption by approx. 2 kb EPROM, 1,3 kb work memory and 600 b retentive memory.

iMap system with one connection consumed 5560 b of EPROM, 974 b of work memory and 84 b of retentive memory. Every additional connection increased memory consumption by approx. 100 b EPROM, 100 b work memory and 4 b retentive memory.

10. CONCLUSION

Distributed system created just with Step 7 is influenced by number of connection. Every additional connection increases communication response time. Number of connections is also limited to 16. Distributed system created with iMap does not have these limitations. Response time is not affected by number of connections and larger distributed systems could be created.

Utilization of Step7 distributed system raises up to 30 kB/s, consequently response time decreases. iMap distributed system utilization is much lower while response time is co-equal.

Scan cycle time of Step7 system raises by 1 ms per communication channel. Scan cycle time of iMap system is not affected by number of communication channels.

Memory utilization of Step7 system raises by approx. 4 kb per communication channel. iMap system memory utilization is affected far less by approx. 200 b.

Step7 is suitable for creating small distributed systems with no regard for communication response time, network utilization, PLC scan cycle time or memory utilization. Advantage is no need to buy another development tool. iMap is suitable for creating large distributed systems or systems with regard for tested criteria (Tanuska, P. et. al., 2009).

Further research could be focused on non-technical aspects of these systems, such as complexicity of programming.

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