Standardized Dynamic Reconfiguration of Control Applications in Industrial Systems

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ABSTRACT

Industrial areas like manufacturing, logistics and power systems require highly flexible and adaptable control solutions in order to fulfill future requirements. An industrial automation system has to provide technologies, concepts and mechanisms allowing the adaption of control logic during operation. Proper engineering approaches as well as execution environments with dynamic reconfiguration capabilities are needed to turn this vision into reality. This article provides an overview of applying the IEC 61499 reference model for distributed automation as basis for a standard-compliant reconfigurable method in industrial environments. It covers the modeling and engineering of reconfiguration applications and their execution on distributed embedded controllers using IEC 61499. This approach significantly increases engineering efficiency and reuse in component-based design of industrial automation and control applications. A special focus of this contribution is the discussion of implemented industrial use cases from the manufacturing, robotics and power systems domain.

Keywords: *Distributed Control, IEC 61499, Industrial Automation, Manufacturing Systems, Power Systems, Reconfiguration, Robotics, Smart Grids*

INTRODUCTION

Modern automation is characterized by the need of changing and adapting functions, services and applications during operation of controlled industrial processes in order to fulfill future requirements. There are several industrial areas where such a support is needed. For example, the market success of the manufacturing industry (e.g., automotive, process, part makers) is only possible if producing companies are able to react fast and flexible to changing customer

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requirements. Today, they have to demonstrate a high degree of adaptability in their manufacturing processes (European Commission, 2004). This comprises the ability of companies being flexible enough to fulfill varying market demands, which impacts all levels of product manufacturing. In particular these are the agility at a strategic level, the transformability at a factory level and the reconfigurability at the manufacturing system and machine level (Koren, 1999).

Another representative example with changing demands is the ongoing modernization and the integration of renewable energy sources into the power distribution systems in the western hemisphere. In order to manage the electrical energy supply from green but often fluctuating generation (e.g., from solar and wind resources) a higher automation degree is necessary in the future (Farhangi, 2010; Gungor, 2011). Due to recent developments in new grid components as well as Information and Communication Technology (ICT) for the power and energy domain it is nearly impossible to take all future requirements into account. The ICT infrastructure of the future energy system, also denoted as the Smart Grid, has therefore provide the support for the dynamic reconfiguration of control algorithms and functions in order to guarantee the functionality and availability of the electricity supply.

The consequences of the above mentioned demands are extensive and many technological breakthroughs will be necessary. Beside others, the development of an adequate automation and control infrastructure with dynamic reconfiguration support and distributed architecture is essential (Strasser, 2011). Current systems do not conceptually support the required services.

The main aim of this article is to discuss an approach for dynamic reconfiguration of distributed control logic in industrial automation systems. In order to support interoperability in a network of heterogeneous embedded control devices, a standard-compliant solution using the IEC 61499 reference model for distributed control has been chosen. A special focus of this contribution is the analysis of the cross-domain usage of the introduced reconfiguration method in the industrial areas manufacturing, robotics and power systems. The concepts used in this article are based on the results described in a book chapter from the authors (Strasser, 2011) but this work is focused on the usage of them in selected industrial uses cases which have been implemented in the meanwhile.

The rest of the paper is organized as follows: The following section gives a brief overview of the related work on reconfigurable automation and control systems followed by the introduction of the IEC 61499 standard. The standard-based reconfiguration concepts and engineering method is described afterwards. In the following section selected reconfiguration cases from the industrial fields manufacturing, robotics and power systems are introduced and discussed as the main contribution of this article. Finally, conclusions are discussed and an outlook about the future work is provided.

RELATED WORK

The possibility to reconfigure control functions, software modules and applications in industrial automation and control systems is a research and development topic since several years. Kramer et al. (1985) introduced this useful approach for distributed systems already in 1985. It can be described as the possibility of altering functions, services and algorithms in software programs due to changed requirements.

In general two main types can be distinguished in the literature: static and dynamic reconfiguration (Brennan, 2002; Brennan, 2008; Brinkschulte, 2005; Bussmann, 1999; Strasser, 2011). Static reconfiguration can be understood as a quite simple method where a software program has to be stopped at first, then all necessary changes and adaptation steps are carried out offline and afterwards the whole application is restarted again with the new functionality. Depending on the application, the usage of this very basic approach can be sufficient but as already stated in the introduction section, there are many applications in industrial systems which