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A method for estimating and evaluating life cycle costs of decentralized component-based automation solutions

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Abstract

Increasing product variety and shortening product life cycles call for a fast reconfiguration of production systems. To face these challenges one common solution is the encapsulation of subsystems by creating modules. However, modularization raises the initial costs of the production system which is why the optimal degree of modularization must be determined in order to minimize the life cycle costs. The decision on the modularity of the system has to be taken in the early planning phase although the quality of the system data is poor. A method for estimating and evaluating the life cycle costs of a decentralized component-based automation system is presented in this paper. To establish a solid basis for the evaluation the system is divided into cost packages and an estimation method is proposed in order to obtain reliable data on each cost package. Based on these cost packages, the user of the method can easily build up different life cycle scenarios for the production system. Particular attention within this method is paid to the system availability which is a very important criterion for economic success. The result is a thorough analysis of the life cycle costs in order to take decisions concerning the suitable degree of modularization in the early planning phase of a production system.

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Keywords: Life cycle costs, Modularization, System architecture, Automation Component

1. INTRODUCTION

Manufacturing is undergoing a profound change. Turbulence creates market fluctuations, the individualization of products results in a great diversity of products in small lot sizes and the shortening life cycles force manufacturers to react faster to the influences of the environment [1][2]. These are the challenges that need to be faced to keep up with the market requirements of the future.

In order to adapt production systems to these requirements flexibility and reconfigurability have to be improved [3] [4]. This means that changes to the structure of a production system must be executable at a minimum of costs and in shortest implementation time possible to avoid downtimes. Modularization is one approach to increase the reconfigurability and thus to meet these requirements. The concept is based on autonomous modules which can be easily combined with other modules [5].

Modularization reduces the complexity by migrating functionality to modules. This increases the quality of the system because each module is realized by experts on the specific area. The main advantage of modularization is the exchangeability and reusability of the different modules. Lean and intuitive interfaces allow modules to be combined and recombined and thus the functionality of the system can be changed in a quick and easy way.

But modularization also presents disadvantages. The creation, encapsulation and implementation of modules causes an increase of hardware costs compared to a component in a centralized architecture.

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Considering the statements on modularization mentioned above, it is necessary to identify a suitable degree of modularity in order to minimize the costs of automation solutions.

2. Architecture of production systems

2.1. Classical centralized control architecture

For a long time automation solutions were defined according to a centralized architecture whose levels are represented in the automation pyramid *(Fig 1)* [6]. The Enterprise Resource Planning (ERP) and the Manufacturing Execution System (MES) are focused on planning and monitoring production resources. These higher levels of the automation pyramid are beyond the scope of this paper.

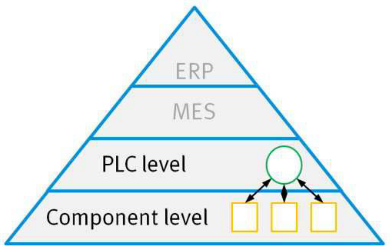

Fig 1Automation pyramid representing standard automation

The PLC level is the centralized platform to control the components. Automation components are directly wired to the programmable logic controller (PLC) and behave according to the signals sent by the PLC.

The software is implemented and executed in the central PLC. This involves a high level of specialization of the monolithic code for the current configuration of the production system. Modifications of the configuration cause adaptations to be made to the central PLC code which demands a big effort and a high degree of complexity. Nonetheless, this architecture has advantages in terms of low component costs as they don't need embedded controllers. Furthermore, the coordination of the components is simplified due to a clear structure.

2.2. Decentralized control architecture

With advances in micro technology more and more embedded intelligence has been integrated into components. This development has meant that components can provide control features, thus blurring the distinction between the PLC and the component level. *(Fig 2)*

The migration of functionality towards the components allows a new kind of communication. Instead of sending detailed single signals to the components, the controller can now hand over tasks which are executed autonomously by the component controlled by embedded intelligence.

This architecture also allows a new kind of engineering which is based on the skills of the automation components. The process planner is now able to interact with the functionality of the components instead of working with signals and software code. The functionality is implemented locally by an expert on this component, providing the functionality of the component to the process planner via a lean and intuitive interface.

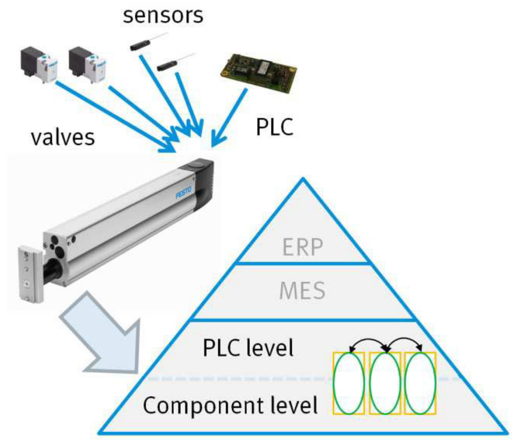

Fig 2 Changes in automation architecture due to intelligent components

Modularization can be executed at different levels, from the basic components up to subsystems or even whole production cells which are encapsulated in a module.

The modularized and task-oriented approach of engineering reduces the effort for wiring as well as for implementing the functionality during development of the automation system. The disadvantage of this approach is the high costs for the embedded controllers in the distributed architecture and the effort required for encapsulating and implementing the modules.

2.3. Choice of a suitable control architecture

As both architectures provide advantages the production planner has to decide on this issue in dependency of the application. This decision can be taken independently for each component. This means that components in centralized and decentralized architecture can be used in one production system. Thereby the degree of modularity is not one fix value for the entire system but it can be chosen individually for each component.

The decision on the architecture of the component is driven by the component costs during the life cycle. In this paper a cost estimation method is presented to evaluate the life cycle cost of automation components and to take a decision on the suitable architecture for the component under consideration.