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Cyber Physical Systems for Life Cycle Continuous Technical Documentation of Manufacturing Facilities

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Abstract

Continuous rising of requirements to create technical documentation results in high effort in terms of time and costs to create a complete and up to date documentation for manufacturers. In case of any technical modifications of machines the technical documentation also has to be updated. In fact these updates are lacking in most cases.

In this paper, the authors propose a methodology for a self-organized creation of technical documentation to enable an up to date state throughout the Product Life Cycle. A complete and up to date technical documentation provides benefits to customers as well as suppliers of manufacturing facilities. The new approach is based on integration and communication of all components and modules such as machine tool, transportation and handling technology etc. via "Cyber Physical Systems".

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Keywords: Technical Documentation; Maintenance; Flexibility; Complexity Management

1. Introduction

The accelerating global economy demands increasing product variety and shortened Product Life Cycles (PLC) for all kinds of consumption goods. To cope with these challenges, manufacturers need to reduce the production costs and the time to market by creating an adaptable and flexible production. Products in machinery and plant engineering need to become more flexible, while their complexity rises continuously.

In course of this the requirements to create technical documentation rise continuously. For manufacturers, this results in high effort in terms of time and costs to create a complete and up to date state on delivery. After delivery and initial startup of manufacturing facilities the technical documentation often cannot be kept up to date. Updates in consequence of technical modifications or upgrades arising from product change, optimization or production volume adjustment are lacking. In most cases, these modifications are undocumented or, in best case, added as separate documentation. While arising in particular during the critical phase close to delivery of manufacturing facilities additional personnel capacity required for preparing the technical documentation has a large impact on total costs. In addition the planning and performing of maintenance and service tasks based on an up to date and accurate documentation is an important factor for staying competitive for suppliers. To satisfy manufacturer´s and customer´s needs in engineering, new approaches for creating and using technical documentation are required.

In this paper, the authors propose a methodology for a self-organized creation of technical documentation to enable an up to date state throughout the PLC. The new approach is based on networking of all components or modules via Cyber Physical Systems (CPS).

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2. Technical documentation today

According to legal regulations producers from the field of machinery and plant engineering are committed to deliver a highly accurate technical documentation as an attachment to their products [1-5] Regarding the preparation of maintenance and service operations, the supplier itself cannot abandon the use of documentation contents, which can be applied in various documentation types according to the nature of use. In first instance technical documentation can be separated into two fields:

- External technical documentation
- Internal technical documentation

The external technical documentation [6-7] consists of all digital and print materials, that will be delivered with the products. For instance these include documentation types such as guidelines, security advises or maintenance timetables. Objectives of external documentation are knowledge-transfer and technical editing and illustration of security relevant customer related data, while meeting requirements referring to customers such as uniformity, high quality and mature structure. In practice the gain of creating both internal and external technical documentation cannot mess with its huge effort [8].

The internal documentation can be considered as all information available for the machinery and plant supplier concerning their products. This information is used for planning and preparation of maintenance, service or follow-up jobs during operation.

In today's flexible production systems, number and short cycles of maintaining tasks cause that both external and internal technical documentation is not kept up to date. Therefore only an out of date state of the real machine is represented, which doesn't match with the current state anymore or never did. Fig. 1 gives an example of the development of technical documentation along the PLC.

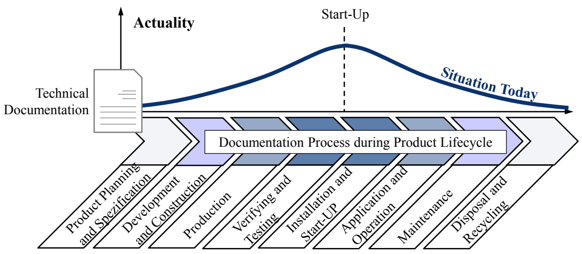

Fig. 1. Technical documentation along the PLC

3. Tasks and objectives

In order to address the introduced challenges for processes of technical documentation in the field of machinery and plant engineering, new approaches are required.

Different new approaches to advance networking and autonomy in production such as "Industrial Internet" by General Electric [9], "Smart Manufacturing" by the Smart Manufacturing Leadership Coalition [10] or the high-tech strategy "Industry 4.0" of the German government [11-13]. These strategies and initiatives strive to automatically and autonomous initiated processes on-demand throughout the production and supply chain. The methodology proposed in this paper contributes strategies for maintenance and documentation tasks according to these goals. The main objectives for the methodology can be summarized as keeping technical documentation up to date well as providing context sensitive data based on modern information technology.

3.1 Up to date documentation

To enable an up to date technical documentation throughout the PLC the corresponding documentation processes must be described. Therefore a standardized description of activities and owners of the processes is necessary.

Adjusting technical documentation automatically is worthwhile, but realizing interfaces between hardware components and software is still a big challenge. Therefore automatically adjustment cannot always be implemented. Due to current security requirements in addition confirming changes in documentation manually is still compulsory in some cases. Furthermore an up to date technical documentation should also contain data history arising from past technical modifications, maintenance operations, troubleshooting or changes in production programs.

3.2 Context sensitive data provision

Due to high quantity of information in conjunction with the various fields of application today's technical documentation is very complex. In particular data types are inconsistent and structure is lacking. Emerging, searching and weighting of relevant data restricts efficiency in all business processes using documentation contents. In addition critical content is not secured from misapplication. To take advantages of an up to date state in these processes, an effective usage and management of the actual data must be implemented. Therefore a context sensitive data provision for users and suppliers as well as customers is required. In this context following roles among others can be distinguished:

- Technical editor
- Internal user (e.g. service or operator)
- External user (e.g. maintenance planning)

The proposed methodology offers an opportunity to meet these requirements by implementing modern technological achievements into the documentation process. The following paragraphs describe the structure and technological approaches considered within the new methodology.

4. Methodology for creating und using an up to date technical documentation

The new approach is based on integration and communication of all components and modules such as machine tool, transportation and handling technology etc. via CPS. Management and provision of documentation contents is implemented by a digital representation of the real system (manufacturing facilities). The digital representation contains all relevant data for all processes using documentation contents. The methodology for creating an up to date technical documentation requires the following implementation steps.

- Networking ability for all components
- Design of future documentation process
- Data structure for new documentation methodology
- Data management and provision

Fig. 3 illustrates three levels of the procedure from creating to providing documentation contents introduced in this paper. Any technical modification or upgrade at manufacturing facilities along PLC (e. g. planning, startup, production) is detected and recorded immediately at the appropriate CPS (Level 1). On Level 2 this information is transferred locally into the component's digital representation at each CPS. Within the network of CPS total information of the digital representations is stored, managed and provided automatically. Thus, the documentation always contains a representative virtual model (e. g. CAD) of the real machines as well as their maintenance states and history or component configurations.

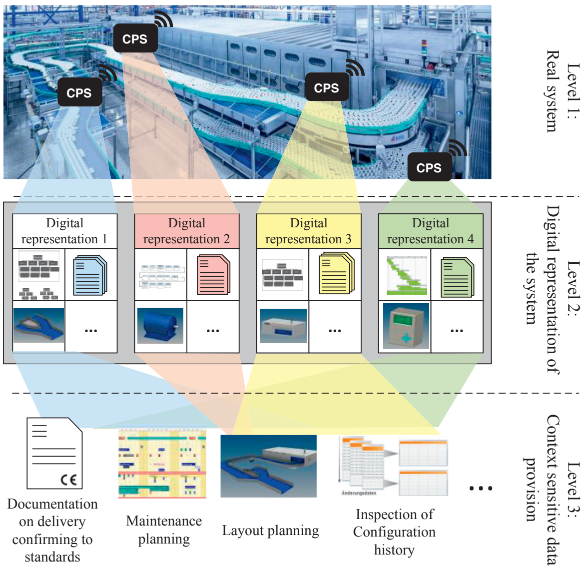

Fig. 2. Structure of new methodology

Level 3 represents the context-sensitive provision of documentation types from the digital representations. Only the right content for the respective task is provided to users. This context sensitive provision of always up to date technical documentation increases flexibility during technical modifications (i.e. machine set-ups, maintenance, technical trouble shooting, or upgrades).

4.1 Networking ability for components

Within the methodology a new hardware solution to detect and communicate the current state (installed parts, maintenance intervals, lifetime of tools etc.) for each component of the real system is necessary.

Implementing and connecting hardware components such as mini computers or controls (embedded systems) to a communication network leads to potentials in data management and provision. Real time tracking of products and all production relevant information (mögl. Quelle ggf MES) is already used in many industries [14]. Communication of these components can be achieved by various information technologies for wireless connections.

Within the smart manufacturing initiatives CPS [15-16] are introduced. These devices contain computers, sensors and controls. Extending components of manufacturing facilities by these systems enables them to capture their situation and to communicate with each other. Within the documentation methodology CPS are introduced for each element both mechanical and electric of the real system (see level 1 in Fig. 3). The outcome of this is a network between each CPS forming a digital representation with always up to date information.

Considering the feasibility to implement CPS products of machinery and plant engineering can be distinguished in three groups. The first group consists of systems or components including computers or controls. These products can easily be enhanced to CPS by software application. Products without integrated IT-hardware components, such as conveyor technology represent the second group. For integrating these systems additional CPS have to be implemented. Beside these two groups, mechanical components including no IT-systems are incorporated in manufacturing facilities. For these components network connection is not feasible due to economical and constructive conditions.

Besides these possible connection types of components class-divided in three groups the transmission of information of each component has to be considered. Within the methodology three types of information transmission from the real system into the digital representation are provided (independent from the network connection type):

The first type of information transmission is automatically initiated as a result from physical manipulation of the system. In contrast to the first transmission type a manual manipulation of the technical documentation is not necessary, due to a one to one translation into digital data.

On second type a self-check of the system is initiated in fixed intervals. Any deviation from the latest digital representation of the real system will be detected, based on integrated sensors at each component. This initiates a notification for internal / external users or the editor to adapt the technical documentation. While here autonomous updating is not possible mobile devices for supporting the editor could be used to reduce manual effort significantly [16].

Last type requires highest amount of manual documentation. Updating technical documentation after non-detectable physical manipulation can't be realized without systematical support. For instance after every service task the system prompts for possible changes. This obliges the service personnel to specify the changes, which leads to an update of the technical documentation.

4.2 Design of future documentation process

Implementing only hardware applications is not sufficient to meet the requirements of the new documentation methodology according to knowledge and content management. Therefore a detailed process model as basis for the implementation of an effective management system for documentation contents is necessary. The model contains every process of creating and using technical documentation for customer as well as producer of manufacturing facilities.

The process model is intended to maximize facilitation of creating and context sensitive provision of documentation information. It contains processes concerning both external and internal documentation. Therefore requirements, challenges and capabilities of each system element (e. g. CPS, digital representation, interfaces, users) need to be incorporated in the process model.

Within the documentation methodology two options for creating technical documentation can be implemented. The first option is based on downloading relevant content from the digital representation as being the central source. Therefore updating the digital model must be performed in real-time to guarantee the up to date state of content requested. Second option is individually creation of content on demand by networking CPS at appropriate machine components.

Besides the definition of the future documentation process the data structure has to be defined to enable an optimized data management.

4.3 Data structure for new documentation methodology

For managing all documentation contents the definition of an applicable data structure is compulsory. Information arising from machine upgrades, maintenance tasks etc. need to be tracked and stored. Furthermore the various documentation types (e.g. CAD-drawings, bill of materials (BOM), manuals) need to be created and managed [17]. Therefore a consistent data structure is necessary. Each documentation type has to be available individually and in addition combinable with any other information while being exported to various types of user interfaces. Consequently a generalized and modular data structure during the whole documentation strategy is required. Therefore all kind of content in the technical documentation needs to be separated into information objects. An aggregation of information objects represents the total documentation content.

For managing and providing the documentation contents according to the defined processes steps the selection and adaption of an appropriate system is in focus.

4.4 Data management and provision

Aiming optimized workflows (for e. g. editing technical documentation and maintenance tasks) the methodology implements context sensitive provision of documentation contents and materials. Therefore filtering relevant data and user interface-specific provision for each appropriate workplace is required [18].

Typical graphical user interfaces (GUI) such as software applications for mobile devices used at the shop floor, applications in the Enterprise Ressource Planning System (ERP), e. g. remote function for maintenance planning, must be taken into account in the methodology.

Content Management-Systems (CMS) are widespread in both social and business activities. CMS are software solutions which enable authorized users manipulation of contents from a central interface [19]. Higher volume and complexity of technical data and the higher number of redundancies lead to increasing effectiveness of introducing CMS solutions for technical documentation. To implement context sensitive data provision CMS are in focus while being already used by service companies offering solutions for technical documentation.

Within the methodology the digital representation of the real machine, is provided to build the storage for all documentation related data. Providing data and technical information depending e.g. on the working task impose requirements to user interfaces and data management.

In addition to optimize workflows by filtering relevant data the requirements to technical documentation conforming to standards must still be met. Therefore safety-checks are obligatory which match the new machine configuration after technical modification with the existing safety settings.

5. Summary and Outlook

To cope with today's challenges in machinery and plant engineering new approaches for creating and using technical documentation are required. Up to date state and context sensitive provision of its contents are the objectives identified to focus within those approaches.

The proposed methodology combines hard- and software applications with a representative process model and a consistent data structure to reach these goals. Hardware components are due to enable tracking of changes at the real system and storing them into a digital representation. Managing and providing the data from this digital representation is based on the processes described in a process model. To handle the various contents with a software system such as CMS and providing it in various documentation types structural consistency for all documentation related data is required.

For today's requirements to technical documentation in machinery and plant engineering the new methodology is suitable. Fig. 3 illustrates the innovation brought with its implementation. The up to date state of the technical documentation is guaranteed after installation and start-up along the following phases of PLC. Until this point the documentation contents represent the current state of the engineered system.

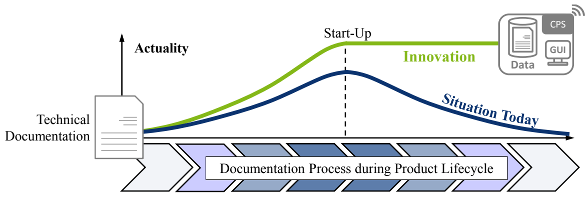

Fig. 3 Innovation for technical documentation in the PLC applying the new methodology

Up to date internal documentation in connection with data provision from the digital representation enhances preparation and planning quality for maintenance tasks as well as follow-up orders. In practice this causes e.g. remote maintenance planning by making use of the access to the current documentation contents of the real manufacturing facilities. In addition machine configurations are examined conforming to standards and legal requirements. As a result compliance with the safety regulations is guaranteed along the PLC.

On customer's side implementing the methodology can be perceived as an additional service value. In particular the effort in service tasks decreases significantly due to manufacturers have access to the current state of the machines and are able to reproduce every modification done by the customer. Some service tasks can be performed directly by customers while being supported by remote instructions. These are contributing to the reduction of downtime.

The application of self-organized documentation within new methodology for creating and using technical documentation poses direct cost savings based on no additional personnel effort necessary. Transparency arising from up to date documentation combined with the changelog as well as stored lessons learned poses chances to avoid failures and safety gaps. Furthermore the new documentation methodology enhances the actual Product service systems of manufacturers in machinery and plant engineering [20-22].

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