Implementation of ”MTP - ModuleType Package” on linux based control platforms

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***Abstract*—This thesis is about the implementation of the so-called concept of ”Module Type Package” (further called MTP) on linux-based control platforms.**

The markets of the process industry are becoming more and more volatile. New products are coming onto the market in rapid succession. In connection with this, the demands on production are changing. Whereas in the past plants were operated almost unchanged for decades, today they are subject to a constant adaptation process. A modular design supports this. It facilitates process changes and expansions, and new plants can be assembled from existing and additional modules according to the modular principle. Such flexibility brings with it new requirements for process automation. To meet these, the user organization NAMUR and the manufacturer organization ZVEI are working together on the concept MTP for the manufacturer-independent description of the automation of process modules as well as a higher-level automation layer for their integration and orchestration.

In this sequence, a test system was defined that is as close to reality as possible and that is intended to represent a real application in the pharmaceutical industry. In this course, a concept was developed how MTP can be applied to this test application.

In the interface technology, suitable hardware was then found that was predestined to make the application MTP-capable. Subsequently, a so-called MTP code generator was developed on this device, which makes it possible to transmit an MTP protocol to the process control system. This protocol contains all the necessary data that the individual participants (process sensors and actuators) have and that are required so that communication can be established. This process control system controls the entire process in the plant and is therefore dependent on this partial information so that the participants can be properly integrated into the process. Since standardization will allow all control systems to decode this unified code in the future, this has significantly shortened the commissioning time for new and existing plants. As a result, new drugs can be brought to market much faster.

***Index Terms*—Module Type Package, pharmaceutical industry, modularization, process industry, time-to-market**

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I. Introduction

NOWADAYS, computers easily allow connecting various equipment such as keyboards, computer mice and speakers. This computer equipment requires a so-called driver, which ensures that the computer and computer mouse speak the same language and they can communicate with each other. In a way, the driver is a translator. While this driver used to have to be installed and configured manually, it is now installed automatically when the computer mouse is first connected, and the mouse can be used by the user without further ado.

This analogy can be translated to the process landscape in the pharmaceutical industry. The computer in this case is the entire plant and the computer equipment is the process equipment such as fermenter tanks, pumps, proximity sensors and distance sensors. The driver in this case is a defined protocol that translates the language of the proximity sensor into the language of the process control system of the entire plant. The only difference is that this communication and the exchange of data is not established automatically as with the computer driver, but must be programmed during commissioning.

In order to create an automated communication between the process sensors and the plant during the first wiring, the Association of German Engineers (VDI) has developed a concept together with the Association of the Electrical and Digital Industry

(ZVEI) and the Standards Working Group for Measurement and Control Technology (NAMUR). This concept is called ”Module Type package” and is an interface standardization.

Modular plants are increasingly used in manufacturing and process engineering. MTP enables these modular plants to communicate with each other more quickly and subsequently to be put into operation.

II. State of the Art

A. Implementation of process equipment in the pharmaceutical industry

As has now been discussed, the implementation of process plants is a very extensive process that is often accompanied by very cumbersome linkages of different plant components.

Modular plants are increasingly used in manufacturing and process engineering[1]. The aim here is to significantly shorten both the planning time for new plants and the time required for plant modifications. This reduces the downtime or significantly shortens the time-to-market for new plants. These simple, self-contained modules can be interconnected with little effort to form complex overall plants.

The Module Type Package (MTP) is used to describe the module types. It defines and describes the interfaces and functions of the automation technology of modules and ultimately enables the integration of modules into a process orchestration level (POL).

NE 148 defines three module variants:

- autonomous modules - these are characterized by the fact that they form closed units. They are connected to supply and disposal facilities, also integrated into a POL if necessary, but cannot be directly controlled by it and fulfill their function completely autonomously. Engineering on the POL side is therefore not necessary. Therefore, complete automation of this module variant must take place.
- integrable modules/PEA - These are fully specified in terms of function and integrated in terms of energy and materials as well as automation. The specified functions are orchestrated by a higher-level POL and thus integrated into an overall network of modules. These should be able to be integrated largely automatically into an existing or new POL.
- modular modules - These are also built up by modules within a module. This means that a second module level is integrated into the first module level. The overall module can in turn be integrated into a POL, like the integrable modules. This allows mixed forms of integrable modules and modular modules to be implemented.

MTP fokussiert sich in erster Linie auf die integrierbaren Module. Betrachtet man das Engineering einer modularen Anlage, so muss grundsätzlich zwischen zwei Engineering-Phasen unterschieden werden. Das ist einerseits das Modulengineering und auf der anderen Seite das POL-Engineering. Das Modulengineering befasst sich mit den Abläufen innerhalb einer Teilanlage während sich das POL-Engineering auf das Zusammenwirken der einzelnen Teilanlagen konzentriert. Die Verbindung der beiden durch MTP ist in Abbildung 1 ersichtlich.

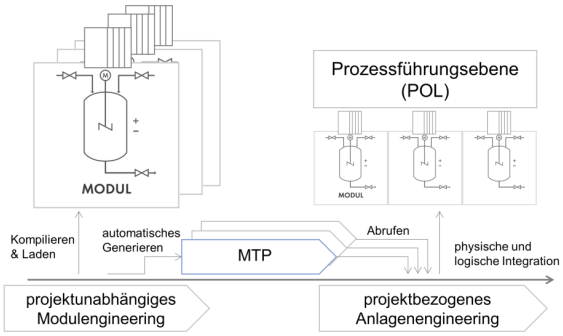

Fig. 1. Engineeringphases on Modular Plants[2]

B. benefits of MTP

MTP (Module Type Package) offers several benefits in the pharmaceutical industry. Here are some of the key advantages:

- Flexibility and Scalability: MTP enables a high degree of flexibility in pharmaceutical production. The modular nature of MTP allows for

the customization and combination of different modules based on specific manufacturing needs. This flexibility enables the production of a wide range of products without significant reconfiguration or downtime. Additionally, MTP facilitates scalability, allowing for the easy addition or removal of modules to match production demands.

- Efficient Resource Utilization: With MTP, resources such as equipment, space, and labor can be optimized. Since modules are designed for specific tasks, they can be utilized more efficiently, reducing idle time and increasing overall productivity. MTP also allows for better space utilization, as modules can be arranged in a compact manner, optimizing the use of available floor space. Furthermore, as modules can be operated independently, labor resources can be allocated based on specific module requirements, maximizing workforce efficiency.
- Reduced Time-to-Market: One of the significant benefits of MTP is the ability to shorten the time required to bring products to market. Traditional pharmaceutical manufacturing processes often involve sequential steps, leading to longer lead times. In contrast, MTP allows for parallel processing, enabling multiple modules to work simultaneously on different stages of production. This parallelization reduces the overall production time and accelerates the time-to-market for new drugs or variations of existing products.
- Improved Quality Control: MTP enhances quality control capabilities in pharmaceutical production. Each module can be equipped with its own monitoring and control systems, ensuring continuous monitoring of critical process parameters and product quality indicators. This proactive approach enables early detection of deviations or issues, allowing for prompt corrective actions and minimizing the risk of product defects or failures. Improved quality control ultimately leads to higher product quality and compliance with regulatory standards.
- Enhanced Manufacturing Flexibility: MTP offers pharmaceutical manufacturers the ability to adapt quickly to changing market demands and product variations. With modular units, it becomes easier to introduce new products or modify existing ones without major disruptions to the manufacturing processes. This agility is particularly beneficial in situations where there are frequent product changes, seasonal demand fluctuations, or the need to address niche markets with specialized formulations.
- Cost Efficiency: MTP can contribute to cost savings in pharmaceutical manufacturing. By optimizing resource utilization, reducing production time, and enhancing quality control, overall operational efficiency is improved. The modular approach also allows for better cost control as investments can be made in specific modules based on current needs, avoiding excessive upfront expenses. Additionally, the ability to scale production capacity based on demand helps prevent overinvestment in unused equipment or underutilization of existing resources.

Overall, MTP in the pharmaceutical industry offers significant advantages, including increased flexibility, improved resource utilization, reduced time-to-market, enhanced quality control, manufacturing agility, and cost efficiency. These benefits make MTP an attractive approach for pharmaceutical companies aiming to optimize their production processes and respond effectively to dynamic market requirements.

C. components in use

The goal is to decrease the engineering effort and the time-to-market by using equipment, which is already in use by the pharmaceutical industry. Some of the most-commonly used components in these systems are control units, digital sensors, pumps and control cabinet guards.

D. control cabinet guards

Control cabinet guards are utilized in the pharmaceutical industry to protect and maintain the integrity of control cabinets. These guards have various functions, including:

They provide physical shielding, safeguarding sensitive electronic components from potential damage caused by contaminants like dust, dirt, and moisture. Additionally, they enclose control cabinets to prevent accidental contact with live electrical parts, reducing the risk of electric shocks and injuries to personnel. Control cabinet guards also assist in meeting regulatory requirements by creating a barrier that prevents unauthorized access, tampering, and contamination of critical control systems. Furthermore, these guards protect control systems from external interference or damage, such as accidental impacts, vandalism, or unauthorized adjustments, ensuring the reliability and stability of the cabinets. Lastly, control cabinet guards contribute to an organized and visually pleasing production environment, aiding in maintenance, troubleshooting, and easy access to control systems. The control cabinet guard type IM18-CCM60-MTI/24VDC can be seen in figure 2

Overall, control cabinet guards play a crucial role in the pharmaceutical industry by providing protection, ensuring safety, promoting regulatory compliance, preventing interference, and enhancing the organization of the production environment.

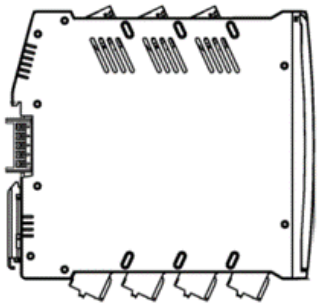

Fig. 2. IM18-CCM60-MTI/24VDC control cabinet guard

III. OBJECTIVE

A. Introduction of MTP in the pharmaceutical environment

The objective is to implement MTP in already existing pharmateutical plants. this means that no new components may be used. For this, a platform must now be found where an MTP protocol can be generated via software and whereby this can be transmitted via the existing network to the process control system and to the other participants.

B. Definition of a test model

In order to ensure that the implementation is as close to the process as possible, a test system is now defined that illustrates a typical application in the pharmaceutical industry. This test system includes the following components (Vendor TURCK Automation[3]):

1) TBEN-S1-8DIP control unit [4]
2) IM18-CCM60-MIT/24VDC cabinet monitoring guard [5]
3) Ni10U-M12 Inductive sensor 1 [6]
4) Ni15U-M18 Inductive sensor 2 [7]
5) K50ANTGRYC4Q Signallamp [8]
6) Q4XFNLAF110-Q8 distance-sensor [9]

C. Quantify benefits and market value

To quantify the benefits and market value resulting from the implementation of MTP (Module Type Package) on a test model, it is important to consider various aspects. Firstly, assess the cost savings achieved through the implementation of MTP. This includes comparing the investment required for modules and associated equipment with the traditional manufacturing setup. Consider factors such as optimized resource utilization, reduced equipment redundancy, streamlined maintenance processes, and minimized downtime.

Next, measure the increase in production efficiency resulting from MTP implementation. This can be done by quantifying metrics such as production cycle time, throughput, yield improvement, and reduction in errors or defects. It is essential to compare the performance of the MTP-based model with the traditional model to demonstrate the efficiency gains.

Another crucial aspect is evaluating the impact of MTP on reducing time-to-market. Measure the reduction in product development and manufacturing lead times achieved through parallel processing and modular production. Assess the time saved

in product changeovers, setup times, and overall process optimization to demonstrate the time-to-market benefits of MTP.

Consider quantifying the improved flexibility and adaptability achieved with MTP. Assess the ease and speed of introducing new products or product variations, accommodating changing market demands, and scaling production capacity. By comparing the time and effort required for product or process changes before and after MTP implementation, the benefits of flexibility and adaptability can be demonstrated.

Evaluate the impact of MTP on product quality. Measure the reduction in defects, improved adherence to quality standards, and enhanced traceability of processes and components. Consider any improvements in regulatory compliance and customer satisfaction resulting from the implementation of standardized and optimized modular processes.

Furthermore, analyze the market value and competitiveness gained through MTP implementation. Assess the ability to offer a broader range of products, respond faster to customer demands, capture market opportunities more efficiently, and establish a reputation as an innovative and efficient manufacturer. Market research, customer feedback, and market share data can be considered to evaluate the market value of the MTP-based model.

Finally, calculate the return on investment (ROI) of implementing MTP. Consider the cost savings, efficiency gains, time-to-market reduction, and other quantifiable benefits achieved. Compare the financial returns with the initial investment and ongoing operational costs associated with MTP implementation to assess the overall economic viability.

By comprehensively quantifying these benefits and assessing the market value resulting from the implementation of MTP on a test model, a clear understanding of the advantages and economic feasibility of adopting MTP in pharmaceutical manufacturing can be obtained.

IV. CONCEPT, APPROACHES, METHODS, CALCULATIONS

A. Bringing the MTP capability into the chain.

To begin with, a component must be found that is capable of executing an MTP code generator that recognizes and correctly assigns the individual participants in the subsystem. The MTP capability is generated by the fact that this component simultaneously generates MTP protocols and can also receive and decode them correctly.

B. Device requirements and selection

The most important feature to be able to execute a corresponding code generator is the appropriate working memory and the connection of the component to the bus system, which leads to the process control system.

After reviewing the given components, the choice fell on the IM18-CCM40-MTI/24VDC control cabinet monitor, because it has a TI Sitara 32-bit ARM Cortex-A8 processor. Additionally this processor has 128 MB DDR3L RAM memory, 4GB eMMC flash memory and appropriate interfaces to integrate other components (Ethernet, CAN, RS485; temperature detection; humidity detection; distance detection; supply voltage 24VDC; DIN rail mounting).

C. Software requirements and interface

The CENA software is a framework designed to enable rapid development and deployment of control applications on PEA controllers. To this extent, the CENA contains all MTP relevant classes along with high-level functions that allow you - the developer - to quickly implement fully MTP conformant PEAs that can interact with any MTP conforming POL. CENA also provides the required OPC UA[10] framework and the mechanism for OPC UA to interact with the MTP model With CENA, all that is left to do is to tie up hardware-level interaction with service callbacks, i.e. describe what the PEA should do when services run or valves open/close[11].

Though CENA is a collection of loosely coupled SDK components, it was designed to work by applying a software design pattern that we call the

"Control Engine Pattern". This pattern segments any application into the following domains:

- The Model Core that contains the information/class model with their associated business logic
- The Process Controller that handles any interaction with the physical by hosting Data Input/Output "drivers"
- The Reflection component (OPC UA Server + Model Reflection class) that can expose the model contents to a client
- The Control Logic that ties the information flow from the devices to the model together to form a unique, customer defined PEA or NOA Gateway

D. Concept for test system

A simple application was chosen as the test system, which can be used by users in the pharmaceutical industry to make different signals, which are currently not MTP-capable, MTP-capable. For this purpose, the process participants must be connected to the IM18-CCM device and parameterized accordingly. This figure shows the structure of this test application:

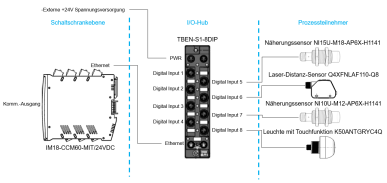

Fig. 3. Testsystem in pharmaceutical context

E. Measurement of the optimization potential and results

Most recently, this MTP code generator was implemented on the IM18-CCM platform via Ethernet[12][13]. As a comparison, a small application was programmed at the beginning, which resembles a real application in the pharmaceutical field. Individual signals were assigned and the components were programmed out individually and the logic was then implemented.

After the MTP code gererator was introduced on the system, the process could be simplified considerably. Here, at the beginning, only the list of the individual detected participants was transmitted to the process control system and ready-made system building blocks for them could be integrated into the code. Subsequently, these system blocks were only parameterized to match the circumstances on the real system and the code was ready.

In sum it can be said that the programming expenditure sinks thereby by approximately 50% and the know-how, which the programmer needs sinks also in such a way that even inexperienced programmers can start this system fast.

V. SUMMARY AND OUTLOOK

The fact that the programming effort for integrating different systems in the pharmaceutical industry has been halved means that 1. the time-to-market for new patents has improved considerably, and 2. the systems can now be designed in a more versatile way and can be interchanged, since different systems now communicate better with each other. This reflects the current demands of the pharmaceutical industry on its equipment, as more products are entering the market that meet the specific and different requirements of the market.

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