Manufacturing system for Industry 4.0 demonstrator

Tomáš Martiník  
Department of Control and Instrumentation  
Brno University of Technology  
Brno, Czech Republic  
xmart95@vutbr.cz

Ing. Václav Kaczmarczyk, Ph.D.  
Department of Control and Instrumentation  
Brno University of Technology  
Brno, Czech Republic  
kaczmarczyk@vut.cz

Abstract— This paper deals with MES systems, their general description, and a search of available open-source MES system solutions on the Internet. One of the found systems is chosen for extension and integration to demonstrator of the Industry 4.0 system. There are discussed some possible ways of extending the system.

Keywords— MES systems, CRM, open-source, manufacturing ERP modules, EspoCRM, automation, Industry 4.0

I. INTRODUCTION

Manufacturing companies today face increasing pressure to improve efficiency and reduce costs to remain competitive. To achieve these goals, many companies are turning to digital technologies and the Internet of Things (IoT) to create “smart factories” as part of Industry 4.0.

Industry 4.0 is the fourth industrial revolution, characterized by the integration of smart technologies and real-time data to optimize production processes and increase efficiency. One key aspect of Industry 4.0 is the implementation of standardized communication protocols and data exchange formats, which enable the seamless integration of different systems and equipment.

ISA-95 is a standard developed by the International Society of Automation (ISA) that provides a framework for integrating enterprise and control systems in manufacturing. By implementing ISA-95, manufacturers can achieve greater transparency and efficiency in their production processes by integrating different systems and exchanging data in a standardized way. [1]

One important system that can benefit from ISA-95 integration is the Manufacturing Execution System (MES). MES systems control a company’s processes, materials, and resources to optimize production, increase productivity, and improve quality. In this bachelor's thesis, we will explore MES systems, their installation, setup, and use in the production process. [2][3]

This paper presents the process of researching available open-source MES systems, selecting one, extending it, and integrating it into an Industry 4.0 demonstrator system. The goal is to replace the current MES system in the Industry 4.0 demonstrator with a more robust and easy-to-extend system that includes additional functionalities and modules. By doing so, the benefits of using ISA-95 and MES systems in an Industry 4.0 context will be demonstrated, as well as how they can be used to improve efficiency, reduce costs, and increase competitiveness in manufacturing companies.

The current solution of MES system includes material, equipment, products, and process modules. It runs on a web server, however, it has been found difficult to extend this system because it’s lacking documentation and it’s not a robust solution.

II. RESEARCH

A. Systems criteria

The main criterion of researched systems is being open-source. The reasons are advantages of extending an open-source project – already created the core of the system (no need to create the system from scratch) that can be used both personally or commercially, possibly community or documentation, that will help developers to extend the system.

The intention is to research MES systems, but easily editable and extendable CRM (Customer relationship management) or ERP (Enterprise Resource Planning) systems may also be possible to integrate into the Industry 4.0 demonstrator system (after some transformation into a manufacturing system).

B. Researched systems

Two MES systems, that match our research criteria, were found. The first of them is Qcadoo. This system showed significant promise in terms of its features and capabilities, with several impressive features highlighted on the system's website. However, because of the lack of a complete installation pack for Windows, it was impossible to run and test this system.

The IMES system, on the other hand, was found to be easy to install but had a very limited range of functionality. The system lacked robustness and was not suitable for use in a large-scale manufacturing facility.

Both systems had some documentation, but for Qcadoo, the documentation is not very reliable. IMES documentation was intended for system users, not for developers. [4][5]

Three Enterprise Resource Planning (ERP) systems, that match our research criteria, were found.

First of them is Odoo - a comprehensive open-source ERP system that offers a wide range of modules, including manufacturing, inventory, and supply chain management. It is compatible with Windows 10, and its installation process is straightforward, with comprehensive documentation available on the system's website. The community support for Odoo is
robust, with a large user community and active developer community. There are many manufacturing modules available for Odoo, including manufacturing planning, scheduling, and execution modules. [6]

ERPNext is another open-source ERP system that has the potential to be used as a MES system. The system's documentation is comprehensive, with user guides, video tutorials, and a forum for community support. The community support for ERPNext is active, with regular updates and bug fixes. While the system has some manufacturing modules, such as material resource planning and production planning, it lacks advanced MES features. The system is not available for Windows OS. Installation on Virtual Machine was impossible as the installation package wasn’t complete. [7]

Dolibarr is an open-source ERP system that includes modules for CRM, accounting, and project management. It is compatible with Windows 10 and has a straightforward installation process, with documentation available on the system's website. The community support for Dolibarr is not as robust as Odoo or ERPNext, but it still has an active user community. Dolibarr has some manufacturing modules, such as inventory management and project management, but it lacks advanced MES features. [8]

One customer relationship management (CRM) system, that matches our research criteria, was found – EspoCRM. It is an open-source CRM system that has some potential to be used as a MES system. The system can be installed on a Windows 10 machine and has developer documentation available on the system's website.

While EspoCRM does not have advanced manufacturing modules, the system can be extended with custom modules and plugins. The administration, developer documentation, and community support provided by EspoCRM make it possible to add additional functionalities and transform them into a MES system with customized manufacturing modules.

C. Research conclusion

During my research, I wasn't able to run Qcadoo and ERPNext. Systems IMES and Dolibarr lacked robustness, advanced MES features, or ease to create new modules for manufacturing. Out of the six systems I investigated, it appears that the systems appropriate for transformation into MES systems are Odoo and EspoCRM. The decision of which system to choose ultimately depends on the company's and developers' specific needs and preferences, such as the features and functionalities they require, ease of use, scalability, and cost (as some features of these systems may be charged).

III. SYSTEM SELECTION AND SETUP

After making research on various systems, I decided to use EspoCRM due to its many advantages, including its ease of use and ability to create custom modules. The system's backend is built using PHP programming language and the Laravel framework. The front end is built using JavaScript, specifically the Backbone.js framework. Additionally, EspoCRM uses a MySQL database to store data. [9]

To get started, a localhost server was set up on the computer and a MySQL database was installed. EspoCRM was then installed. The setup process was found to be relatively straightforward, allowing for quick initiation with the platform – a few minutes after downloading the source code, a user can open (run) the MES system in a browser.

Upon setting up the system, it already possessed several admin features such as user creation, role assignment, rights allocation, notification settings, and more.

IV. SYSTEM CUSTOMIZATION

A. Orders

This module is designed to manage and track orders from creation to production execution. Orders have their database table, which contains details about their items (ordered products) and their quantities.

One of the key features of the Orders module is the ability to set priorities for each order. Users can assign a priority level to each order, which helps to ensure that critical orders are given priority during the production process. This feature can be useful in situations where there are limited resources or capacity constraints, as it enables users to make more informed decisions about which orders to prioritize.

B. ISA-95 Object models

Using the ISA-95 standard, we can define equipment classes with their respective properties. With this information, we can create equipment definitions and assign them to their corresponding classes. This approach allows us to have a clear understanding of the equipment’s capabilities and limitations and enables us to assign values to equipment properties.

In the context of ISA-95 models, materials are also defined using classes, definitions, and properties. These models allow the creation of material definitions and the assignment of classes and properties to those definitions.

Additionally, the models allow for the tracking of material lots, which are specific batches of material that are used in the manufacturing process. By tracking the lot of material, it becomes easier to identify any issues or defects that may occur during the manufacturing process.

With the help of ISA-95 models, we can easily create material definitions and assign them classes with properties. This makes it easier to manage materials and their lots throughout the manufacturing process.

Using ISA-95 models, we can define personnel classes, which can be groups of personnel with similar job roles or functions. Each class can have its own set of properties such as skills, certifications, and qualifications. With this information, we can create personnel definitions and assign them to specific classes with their respective properties. This enables users to effectively manage personnel resources and assign them to appropriate tasks within the manufacturing process.
C. **Product definition model**

Products are defined as a combination of materials and equipment used in a manufacturing process (product segment) to create the final output. Each product segment is defined by a product recipe, which lists the required materials and equipment.

The material segments define the type (definition or class) and quantity requirements of the materials needed to create the product. The equipment segments define the type (definition or class) and quantity requirements of the equipment needed to create the product.

D. **Process segment model**

In the ISA-95 models, process segments are defined as segments that connect material, equipment, and personnel to carry out specific manufacturing processes. These segments describe the steps involved in creating a product, such as mixing raw materials, assembling components, or packaging finished goods.

V. **Conclusions and future work**

A. **Conclusion**

Various modules and models were implemented into the new MES system. The Orders module allows efficient order management and prioritization, while the use of ISA-95 object models enables users to define equipment, materials, and personnel classes with their respective properties, making it easier to manage these resources throughout the manufacturing process.

Overall, the customization of the open-source system into a MES system provides a comprehensive solution for managing the entire manufacturing process, from order creation to product completion, with the ability to prioritize critical orders and efficiently manage resources. This system has the potential to significantly improve manufacturing efficiency and reduce costs, ultimately leading to increased profitability.

B. **Warehouse module**

The next step in this project is to create a warehouse module. This module will allow users to manage the inventory of materials and products that they have on hand. They will be able to track the quantity of each item, its location in the warehouse, and its movement in and out of the warehouse. This will help them to better manage stock levels and ensure that they always have the materials and products we need to keep our production process running smoothly.

C. **OEE module**

One of the next steps in the implementation plan is to develop an OEE (Overall Equipment Effectiveness) module for our MES system. The OEE module will allow us to track and measure the effectiveness of our production processes by analyzing data such as downtime, speed loss, and quality defects.

To implement the OEE module, we plan to leverage open-source chart libraries to display the OEE metrics in an easily digestible format. By doing so, we hope to provide real-time visibility into the performance of our manufacturing processes, identify constraints and optimize our production to maximize efficiency.

In addition to tracking the OEE, we plan to use the module to measure the effectiveness of our production processes. This includes analyzing data such as lead times, cycle times, and defect rates to identify areas where improvements can be made. By implementing an OEE module, we will be able to better understand our manufacturing processes and make data-driven decisions to improve overall efficiency and productivity.

D. **Use of AI**

The use of AI is being considered for potential implementation in this MES system. By using an open-source machine learning library like RubixML, we may be able to predict future demand for certain items based on historical data and adjust our inventory levels accordingly. This could help us to reduce waste and save costs in the long run. However, this is a more advanced feature that may require additional resources and expertise to implement, so it is a longer-term goal for the project. [10]
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