PADME Final report

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Summary

PADME (Process Automation for Discrete Manufacturing Excellence) is a cooperation between ABB, RISE, MdH and Level21 and is a part of the strategic innovation program Produktion2030, a joint venture by VINNOVA, Formas and the Swedish Energy Agency. The main idea of PADME is to investigate how the digitalized and proven systems and technologies of the process industry can be used in Discrete Manufacturing (DM) to improve competitiveness and drive growth. To do this the project have implemented a pilot system at a production line at ABB Robotics in Västerås. The result is a Collaborative Process Automation System (CPAS) that connects and visualizes information about a number of systems and equipment in a common environment made available to different groups of employees at the factory. Potential for shorter stops, higher quality, more motivated staff etc. is identified which in turn lead to increased productivity and lower costs.

One of the most important capabilities of CPAS is to ensure the best possible collaboration between people, systems and equipment. In the process industry, it has been found that this collaboration reflects directly on productivity and digital maturity. With this as a base, the project has conducted interviews and created a tool to measure digital maturity in companies. The survey also provides insight into the strengths and weaknesses of the digital maturity in various areas.

By applying a CPAS system in the robotics factory we have improved collaboration in all areas but primarily between the people and the equipment and system used in production. By connecting equipment and systems into one platform and opening up for a rich information flow the understanding, of how the equipment and systems work internally and how they collaborate, has been dramatically improved. By making this information available to several groups of users the collaboration has also improved between users.

The project has also tested to optimize production scheduling models at the same production line with the goal to enhance modeling techniques to improve the cycle time by simulation.

Background

Several signs indicate a shift of global industry towards customized Low Volume High Mix (LVHM) manufacturing closer to customers and skilled workforce. Customized LVHM manufacturing requires increased flexibility. Flexibility and performance of a manufacturing process is, however, negatively affected by incorrect, late, contradictory, and/or inadequate information, as well as operators or machines not being able to benefit and access all available information. Countermeasures to problems in Discrete Manufacturing (DM) are typically based on events that have occurred, e.g. a machine downtime, incomplete order data, or material shortage, machine to machine collaboration problems, all leading to lower productivity i.e. action is based on "corrective information". The process industry has, on the other hand, successfully and for a long time, used digital systems like Collaborative Process Automation Systems (CPAS) to continuously control and monitor the complete process lines, enabling countermeasures before a production stop occurs. Actions is based on "preventive information".

Project results

Use cases

PADME project has identified use cases that demonstrate how a digital twin and AI can generate real business values. Six use cases have been created with corresponding measurable improvements and relevant KPIs.

UC1: Real-time update of location of products

Process stops increase lead time and decrease on-time delivery (OTD). Being able to identify where all products in the process are, reaction times on countermeasures to stops will be shorter.

UC2: Real-time update of status of factory

Unpredictable process deviations generate problems in the workflow while solving existing deviations. By communicating product status on process map in real-time, preventive reactions and will be faster leading to decreased lead time and increased OTD.

UC3: AI planning of mixed-model production

The best possible sequence alternative is hard to identify. The Artificial Narrow Intelligence (ANI) algorithm test all possible sequences to find the most optimal. Decreased Lead Time, Reduced Workstation Idle Time, Improved Levelling of Production, Increased OTD

UC4: Predictive Maintenance by Digital Twin

Machine maintenance causes downtime. Continuous supervision predicts optimal time for maintenance actions results in decreased process stops, decreased costs and increased OTD

UC5: Continuous Time-Studies

Time studies are uncertain without accurate data. Automated continuous time-studies enable corrections and preventive actions resulting in decreased process stop time and increased OTD

UC6: Support in problem resolution

Stop in production is time-consuming. In order to predict stops, real-time monitoring enables predictive maintenance possibilities result in decreased process stop time, decreased cost and increased OTD

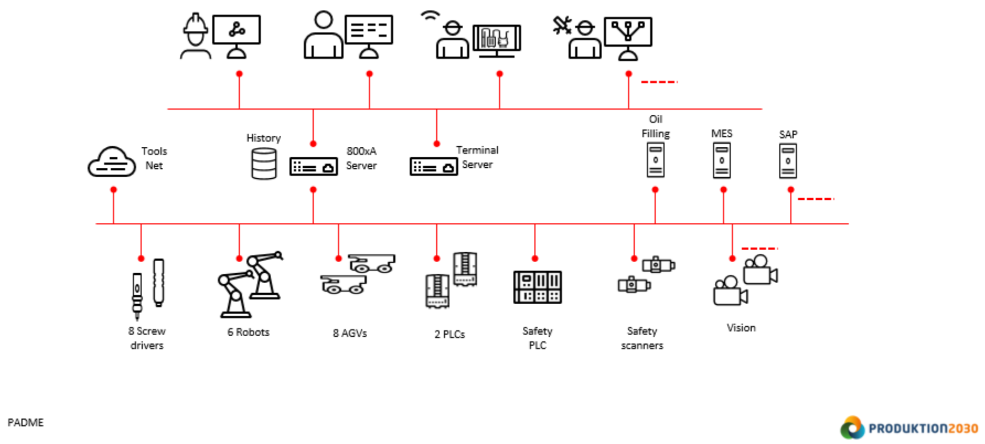
CPAS -Pilot system

A pilot system based on CPAS has been implemented as a proof of concept during the project. Getting a hands-on system has been very valuable to evaluate the effects of using CPAS in discrete manufacturing. For each equipment and system that has been connected the value has increased. Most of these equipment and systems are intelligent and have tools for analysis etc. but are all digital islands. Since they do not contain information from surrounding systems, you do not have access to all information in a common environment. Getting them connected into one environment in the CPAS system makes it possible to do a full analysis which is powerful.

PADME system Topology

The figure below shows an overview of the PADME system topology. In the bottom we have the connected equipment, before the project each equipment was connected to a few of the other equipment units with point to point connection. Now we have connected all equipment to the collaborative process automation system (CPAS), with synchronized time and extended communication capabilities. The electrical screw drivers are used by the robots to mount the robot parts. Robots also moves equipment to the AGVs from the component feeders. The AGVs receives and hosts the product manufacturing “recipes” received from SAP via the MES system. Auxiliary equipment and safety related system are controlled by PLCs with input from equipment and safety scanners. Vision systems are used by the robots to check the position of parts during the mounting.

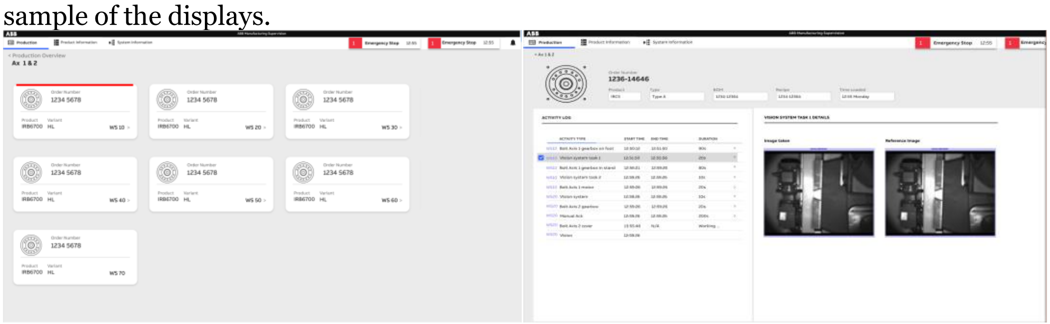
PADME Systems Topology



In the middle we have the connected systems with the CPAS (800xA Server) in the center, with a history, digital twin collaboration model and terminal server. Tools Net is a cloud supported system for quality control of the nut runners. Oil filling controls the oil filling of the robots. MES takes care of the distribution of production order information received from SAP.

Information from all systems and equipment are connected to the digital twin model in the 800xA system. Many different protocols are used both conventional OPC and OPC UA are used.

The collaboration system has several different workplaces and displays to fit the different users. Supervisors, maintenance personnel and cell operators are typical users, below is a sample of the displays.



The Test system is hosting a set of services and applications with first objective to provide means, method and tools to strengthen the manufacturing crew's s situation awareness through:

- Assist the front-end maintenance crew to perceive, comprehend, project and apply corrective measures against the unexpected faults and failure scenarios in manufacturing operations and machineries. Special focus and priorities are placed on personal Safety, manufacturing work cell safety and operability and finally product safety and survival.

- Provide applications and engines for using the historical database and tools for post mortem and data mining analyses, on the experienced faults and failures.
- Provide applications for traceability of quality status, parts, position and location of the emerging product (The Robot) on the manufacturing line.
- Provide applications for traceability status on the availability of the manufacturing work cells.
- Provide application for archiving, and Excel format reporting of the above information on as required basis.

Visualization

To limit the scope in PAMDE we have mainly focused on visualization of data for the production maintenance team with the goal to make the information available to several roles (e.g. operators) later.
Fault finding and corrective actions is one of the key responsibilities for the production maintenance team. Operators call the maintenance personnel to get them to the shop floor to solve problems that caused the production line to stop. Some of these problems, such as signal or sensor faults may not be visible to the human eye and could cause unnecessary delays in the production.
By incorporating both historical information from different equipment and data sources, as well as creating situation awareness, maintenance personnel could resolve problems and trace faults more effectively.
Before visiting the shop floor, or while talking on the phone, maintenance personnel could get a sense of the current situation, as well as go back in time to find earlier problems that might be related.
After talking to maintenance personnel and incorporating knowledge and experience form the process industry and 800xA, a visualization has been created to show how these situations could be helped. For more information see Visualization presentation – PADME

Optimization models

This is the part of the PADME project, where we explored mathematical planning and simulation modeling techniques to improve the cycle time at ABB Robotics. The detailed findings and analysis are provided in a separate technical report, we provide a summery here though.

1. The cycle time can be reduced if a mathematical planning approach is used to determine the best dispatching sequence of jobs to the shop floor. An average of 17% reduction in cycle time was observed over all the test cases.
2. If it is required to produce a batch of products, some of which have considerably high processing times on the assembly line, then these products should be dispatched

consecutively to the shop floor, as opposed to being randomly dispatched in between the remaining products. Such a policy has a lower cycle time.

3. The variation in processing times between different products on different workstations causes low workstation utilization. This can be improved in two ways:
    a. Dispatch jobs in an optimal order as in point 1 above. An average increase of 16% in workstation utilization was observed across all test cases.
    b. Redesign some of the product and/or workstation to have more consistent processing times, compared to what we have now. The developed models help in guiding the engineering design team to what the new processing times should be, in order to increase utilization and reduce cycle time.

The expected outcomes were:

- *A process flow map identifying critical paths and the inputs and outputs of workstations.*

  Status: not enough data was available to produce this; instead, we identified critical workstations based on their utilization.

- *A list of the additional data that needs to be gathered and will go into the models that calculate optimal WIP and cycle time reduction*>

  Status: cycle time reduction was achieved as in point 1 above, using only design processing times of different jobs on different workstations, and the design routing of a product. However, optimal WIP level could not be determined due to the lack of real-time data.

Digitalization maturity

One of the important parameters in this project was to consider legacy equipment and devices in a factory where digitalization is under development. Digitalization should be done to improve the right areas in the production. Therefore, the first step is to assess the digital maturity level of production in the target company. We worked on two aspects within this project. In the first phase, we proposed a method to assess the maturity level by measuring collaboration considering three dimensions of (i) equipment, (ii) systems and (iii) people. Equipment refers to machines which are working in the shop floor, e.g., robots, while systems refer to management systems, e.g., Enterprise Resource Planning (ERP) system. People, equipment and systems are supposed to work collaboratively to achieve an optimized production. In this project we investigated the level of collaboration among these three entities. This method allows us to collect related information in a digital survey format and to measure the level of maturity for each dimension quantitatively. In the second phase, we looked at the state of the art and practice to better understand the current available solutions for digitalization in discrete manufacturing. The comparison between the solutions shows that most of the proposed architectures have similar components, yet with different communication and technologies. We also performed an applicability study of the solution proposed within PADME on other manufacturing domains. Although the solutions are proposed in the context of ABB Robotics, within this study we have visited another manufacturing company, GKN Driveline, to investigate what are the limitations preventing the use of the PADME solution. The study concludes that the PADME solution is modular and can be adapted for the other manufacturing domain, while it needs few changes. In particular, the PADME solution is based on ABB 800xA SCADA system, thus any other manufacturing company requires to adopt the system.

Experiences and findings

During the PADME project we have gained a lot of experience. This is a summary on a high level. The main finding was that there it is very important to get a corelated detailed insight in what is going on inside all systems that are related to production. This insight should be provided to as many roles as possible to create an environment built for continuous improvements based on collaboration.
Connecting the digital islands with a CPAS makes it possible to compile information from all different equipment and systems and visualize them to people in several roles. The result can be used directly to reduce downtime in production disruptions and in the longer term to optimize output, productivity and utilization rate.

Digitalization of existing manufacturing industry is much harder than you expect.
There are challenges in different areas such as

- Choice of technical solutions for communication, data storage etc.
- Infrastructure. Such as networks etc.
- Cyber security aspects
- Safety aspects
- Existing equipment and systems that are not designed to communicate, which gives a risk for disturbances and overload. In these cases, you must find solutions and architecture that handle this. Alternative equipment upgrade.
- Equipment does not have unique names and identities which generates problems when they are connected in one common system.
- Implementing new solutions in parallel with production that must not be disturbed.

There is no general solution, the solutions need to be adapted to each company. Knowing the current status via maturity assessment will help to understand the fundamentals.

When it comes to simulation the biggest challenge was to collect data to create more accurate models. We collected data enough to schedule production on a part of the shop floor, not the entire process. Plus, data collection was manual as this had to be done before all system was connected. The upside is that we got a motivation to automate such data collection. The production planning found valuable insights on how to improve the current scheduling policies, and how to assess performance for multiple measurements like cycle time and machine utilization.

Future ideas

The project has focused on getting a proof of concept to evaluate the possible benefits of using CPAS for Discrete Manufacturing. There are more ideas discussed than those that has been implemented.
The Test system has, also, the potential capability to share its collected data and information's with;

1. Hosting services to channel historical data further to the upstream stake holders (Robotics R&D, Quality Assurance, production planners') for data warehousing, data mining, analytics and future machine learning services and why not **Artificial intelligent projects, which has fascinated a group of early believers!**
2. Provide calculation engines and applications for derivation of **Key Performance Index** and other statistical purposes.
3. Provide services and clients to be able to interact and be interacted by other organizations with in the Robotics hierarchical, Data bases.
4. Keeping a tracking eyes on the status of developments and availability of the up and coming edge and cloud solutions, their operational bottlenecks, safety and Cyber security issues.
5. Hosting services to support the future use of Edge technology and Cloud services.

Documents and Publications

Information about the project, reports and documents can be found at https://new.abb.com/se/padme.

Project Documents

Title	Organisation
PADME Summary report (this document)	ABB with input from RISE, MdH, Level21
DVA423_thesisReport , APPLICABILITY STUDY OF SOFTWARE ARCHITECTURES IN THE DISCRETE MANUFACTURING DOMAIN	MdH
Report on applicability study	MdH
Report on digital survey	MdH
Visualization presentation - PADME	ABB
PADME Pilot system, architecture and implemented functions	ABB
PADME - Implemented Use Cases.	Level 21
Simulation technical report	RISE

Publications

Title(Year), Name of journal,conference,etc. Authors	Organisation
Investigating alternatives for system architectures to enhance discrete manufacturing (2019), International Journal of Distributed Sensor Networks Sara Afshar , Fereidon Koroorian, Mohammad Ashjaei, Anna Granlund	ABB, MdH
The role of simulation optimization in process automation for discrete manufacturing excellence (2018), Winter Simulation Conference Jawad Elomari, Kerstin Olsson, Stefan Svensson	RISE, ABB
Digitala tvillingar - alla pratar om den men få har sett dem- påverkas jag? (2018), Tidningen Bättre produktivitet Mats Åhgren	Level 21