White Paper | March 2017

The MES Experts!

Industry 4.0 disarmed

The autonomous factory

MPDV White Paper
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The topics of the MPDV white papers:

- Manufacturing Integration Platform
- The autonomous factory
- The reactive factory
- Smart Factory in four steps
- Industry 4.0 needs Horizontal Integration

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Preface by Prof. Dr.-Ing. Jürgen Kletti

People in the center of the Smart Factory

The interest in Industry 4.0 remains unabated. However, the questions about specific application scenarios and the benefits of Industry 4.0 are becoming more and more frequent. This is precisely where we step in with our four-stage model for the Smart Factory and in the attached white paper we would like to outline the third stage „Autonomous Factory“. Even if this sounds more abstract and fashionable, we are talking about ways to make production more efficient and, above all, fit for the future.

What‘s more, I am convinced that we will not have deserted factories with Industry 4.0. People will become part of a self-regulating factory and modern Manufacturing Execution Systems (MES) will provide essential information and planning options. As an „Augmented Operator“ the employee takes the central role, which has been awarded to the employee since the first mention of Industry 4.0.

An example of a current application of Industry 4.0 is the flexible and cost-effective manufacturing of products in small batches. What has mainly been termed „multi-variant sequential production“ in the automotive industry, is also gaining relevance with Industry 4.0 in other sectors. You will learn in this white paper how to flexibly monitor and control the associated complex assembly processes with an MES.

In the spirit of our company motto, we stand by your side as „The MES Experts!“ and accompany you on your way to the Smart Factory.

Have fun reading!

Prof. Dr.-Ing. Jürgen Kletti
CEO MPDV Mikrolab GmbH

Step 3 on your way to the Smart Factory

The autonomous factory

Concepts such as self-regulation, self-optimization or self-learning machines have already appeared in the beginnings of Industry 4.0, have been persistent and are increasingly mentioned of late. But what is behind this topic? And more importantly, could these issues be beneficial to the production industry?

Admirer of Industry 4.0 are still dreaming of a self-regulating production site without human intervention. In order to master the pre-programmed complexity, one would have to transfer the entire experience and intelligence of humanity into an IT system. As this scenario is a long way off and deserted factories are not the aim of Industry 4.0, this article focuses on self-regulation as a relatively clear definitive discipline. Innovative concepts like self-optimization or self-learning machines should be seen as more advanced approaches, which are highly likely to build on top of self-regulation. As a definition of self-regulation, it should be noted that this is essentially a modern concept of feedback control systems. What´s new is in particular the increased transparency, which makes it possible to respond to deviations from the target earlier, or to ideally anticipate a deviation and to counteract beforehand.

Simply put, self-regulation is if a certain sequence or process regulates itself in such a way that specified parameters are adhered to. We know this principle from radiators and air conditioning units. The difference between conventional thermostats or adjusting knobs and modern feedback control systems is that the conventional method is only used to determine how much power is provided, but in a feedback control system the target situation is defined. Precisely said: conventional steering means „Level 3“ and regulation (closed loop control) means „room temperature 22°C“. How the unit reaches the desired temperature is down to itself - the main focus is on the requested temperature and, above all, to keep it.

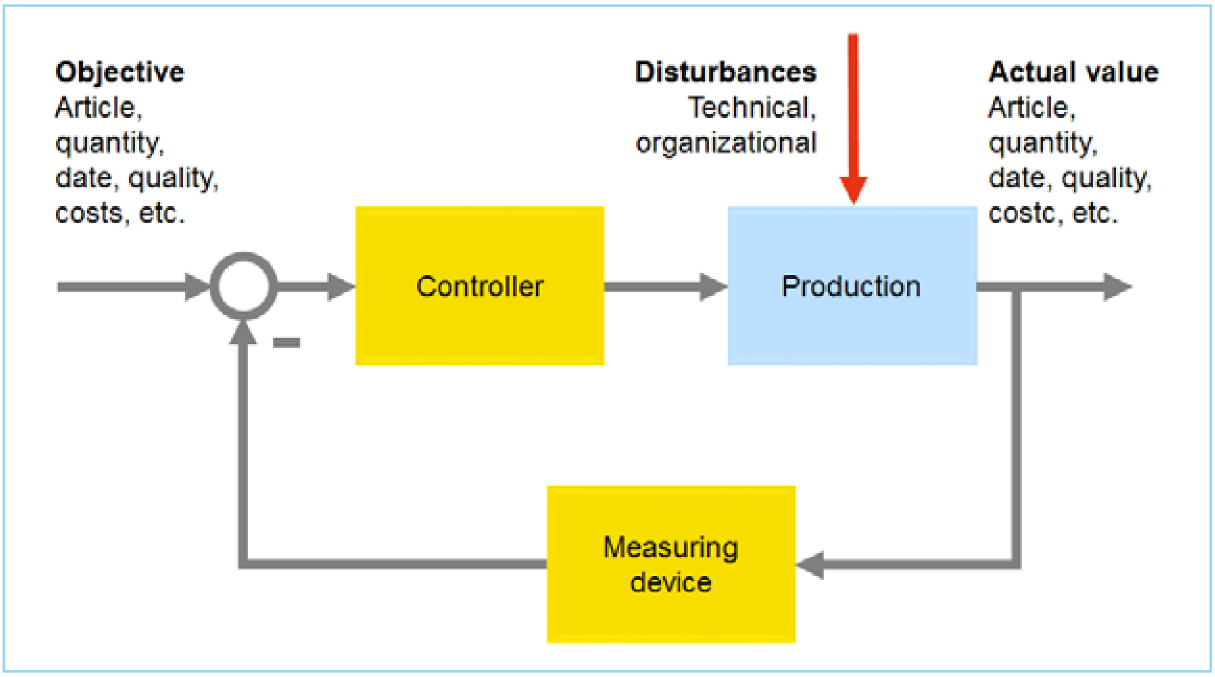

Figure 1: Illustration of the production as a closed loop - the level of detail matters

Self-regulation in production

The target condition in a production environment is far more complex. For example, target conditions are about the optimum total utilization of machines, the assurance of quality, the adherence to guidelines or the increasing of productivity. The number of possible manipulated variables as well as the specified target parameters is arbitrarily large. Also, some parameters can only be changed by manual intervention. Nevertheless, the approaches of self-regulation lead to success - provided that specified control loops (Figure 1) are defined and equipped with the necessary competences and responsibilities. Self-regulation presupposes a certain degree of decentralization, often based on decentralized targets, which certainly should be synchronized centrally.

Stage 3 - Smart Factory

According to the four-stage model „Smart Factory" from MPDV [1], modern production needs first of all transparency and reactivity in order to establish self-regulation. The basis for the first two stages is an integrated Manufacturing Execution System (MES), which both captures data in real time and also provides functions to visualize and control production [2]. Self-regulation is now the next step to use collected data and integrated control mechanisms (Figure 2).

Different types of self-regulation

The simplest form of self-regulation is to monitor one or more parameters and to send a note or to give a signal when set thresholds are exceeded (Figure 3) in order for someone to react manually.

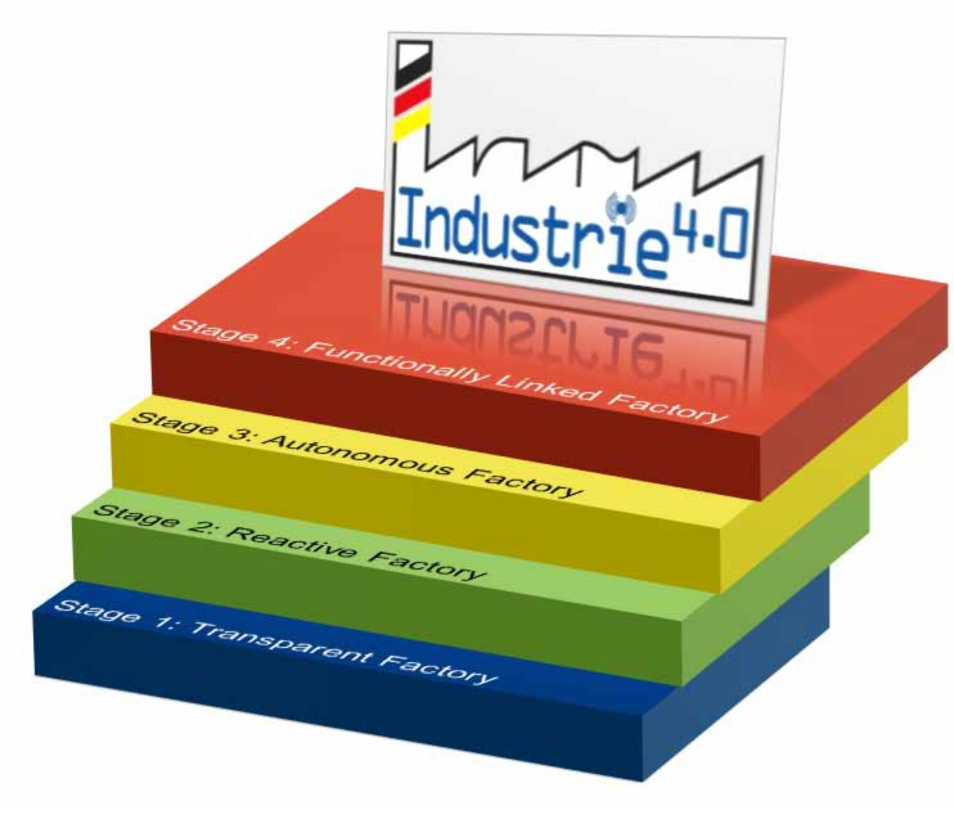

Figure 2: Four-stage-model "Smart Factory"

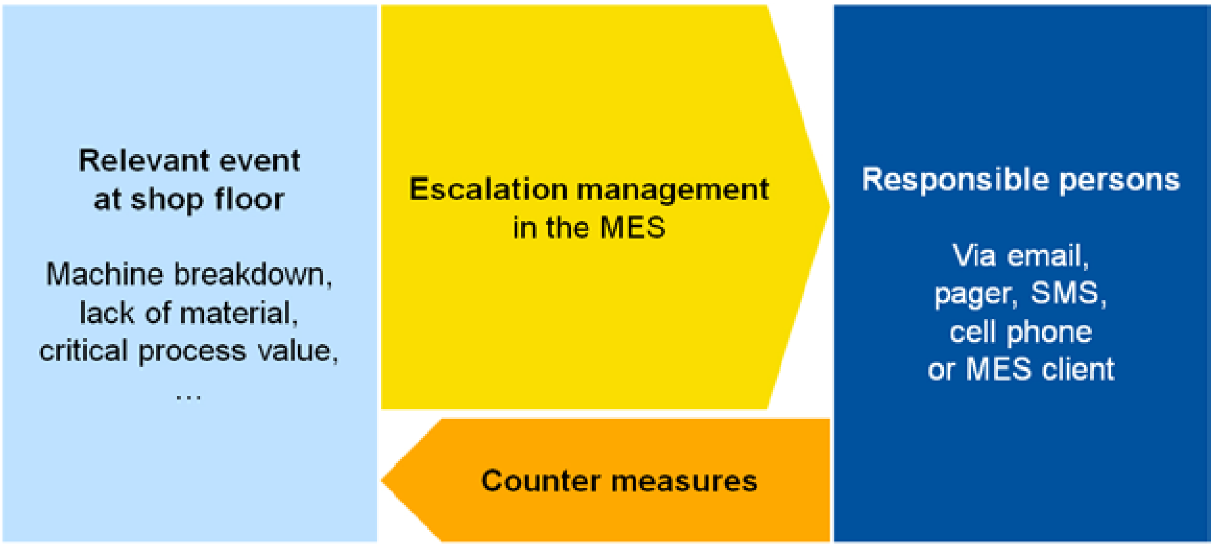

Figure 3: An escalation management integrated into the MES informs employees about crucial incidents in production

These kind of functions are called in today's MES systems for example „Escalation management" [3] or „Messaging & Alerting".

Increasing functionality can be found in MES components called „Workflow Management". These functions not only show a deviation from the target but also suggest or take countermeasures. A practical example would be to trigger an inspection due date, if the machine temperature exceeds 60°C. This process ensures that no external factors have an impact on production quality.

If we go a step further we arrive at completely self-regulating systems like Kanban or the digitally supported equivalent eKanban. Therewith, the system cares automatically for constant supply, if the stock is running low. However, a built-in control avoids the piling up of unnecessary warehouse stocks.

The premium class of self-regulation is process interlocking which ensures for example that only material is used that is specifically provided or released for the respective work step, and that only flawless parts are further processed. Especially in the multi-variant sequential production, process interlocking is crucial as zero-defect production is the aim respectively demanded by the customer. All these types of self-regulation can be mapped with an integrated MES, since the required information is already included in the system and the persons involved interact with the MES, too.

Human-technology-interaction

It remains to be seen how the connected machines or alternatively the MES communicates with the employees on the shop floor or with the management. It should be paramount that technology supports men and not vice versa. The operator becomes an „Augmented Operator" with the help of the MES (Figure 4). Behind this concept is the idea that the operator has direct access to further information critical to a particular situation and thus, to make substantiated decisions. A suitable human-technology interface enables the operator to be a part of the self-regulated system in an ergonomic manner. In order to increase the effectiveness of this integration process, the employees in their divisions should be equipped with the necessary competences in order to make decentral decisions where needed.

Keys to decentralization

Heading to self-regulation and, thus, also to decentralization, it takes more than just an MES or other IT support. It is rather about a paradigm change in the production culture, which is often reflected in entrenched structures. Therefore, we recommend at the outset, a comprehensive analysis of the actual situation: processes and sequences, responsibilities, documented and non-documented rules and accumulated experiences that are pivotal for decisions in the respective division. On this occasion, the actual situation should at least be questioned and the underlying processes should be, at best, streamlined. Lean manufacturing methods have proven to be effective. It is now essential to map the recorded and optimized overall situation in control loops. Both simple IF-THEN relations and complex, possibly mathematical, dependencies are appropriate for this purpose. These control loops can then be mapped into a suitable IT system in a third step. Most of the manufacturing control loops can be realized with a modern MES.

Examples from the every-day production life

The fact that control loops and, thus, also the self-regulation are not an invention of the Industry 4.0 is substantiated by numerous applications, which have been successfully implemented in production companies of different industries and sizes with the aid of an MES.

Figure 4: Mobile MES application with HYDRA by MPDV: As „Augumented Operator" the worker has all the information on hand needed to make valuable decisions

Smart intralogistics

A medium-sized metal processing company uses the status change of machines in production to inform employees in the warehouse about material shortages. Warehouse staff can, in turn, instantly identify by the machine and order numbers in the MES, which material is required at this machine. For this purpose, only a very small range of functions is required in the MES. With a little more functionality, warehouse staff could be informed, even before an acute material shortage occurs – for example with an MES-based inventory range monitoring function for certain materials. The control loop would then look as follows: If the input material on the machine falls under a defined stock level and the current order cannot be finished with the available material, then the system requests a fixed amount of material from the warehouse. With an eKanban system, the material supply would work even smoother. The system then ensures by itself that sufficient material is available at the machine.

Smart maintenance

A plastic processing company uses the recorded energy consumption of the machines in correlation with the logged on orders (Figure 5) to determine when the equipment requires the next maintenance. For this purpose, the MES compares the target consumption with the actual consumption, which is defined as a control loop like that: If the recorded consumption is more than 30% above the specification, an unscheduled maintenance order must be carried out [4]. In turn, the corresponding maintenance order is automatically logged on via the pool of orders. After the unscheduled maintenance took place, the regular maintenance interval is also reset, resulting in a much more efficient use of equipment.

Smart quality inspection

Generally, random quality inspections are based on produced quantities or periods. If an MES is in use, a change of the machine status can also trigger an inspection due date. This enables a prompt reaction to incidents such as malfunctions or material changes, thus assuring the required quality without additional efforts. Employees in the quality department can also constitute inspection points by taking a sample. As soon as material samples reach the quality department, relevant inspection points can be processed away from production. It is also possible to generate a transport order for the sample automatically if the quality department is some distance away.

Smart assembly lines

In the production of multi-variant parts for the automotive industry, the complete manufacturing process must be documented on the one hand and on the other, it must be guaranteed that only flawless parts are processed and delivered – usually in a predefined sequence. Such a process interlock checks every part for each work step whether the item is approved for the current step (Figure 6) and whether the previous handling has taken place without faults. Based on a continuous documentation of all parameters, this request is checked easily in the MES comparing target data with the actual data.

Back to the real world

As with many of the topics discussed under the disguise of Industry 4.0, it is recommended to define exactly in which environment self-regulation can be implemented and then to define which targets should be pursued. Afterwards, the decision can be taken which methods and technologies to use. In doing so, proven and already self-employed techniques often present themselves as efficient for the respective requirement.

In the case of the self-regulating factory, both lean manufacturing methods and the applica-

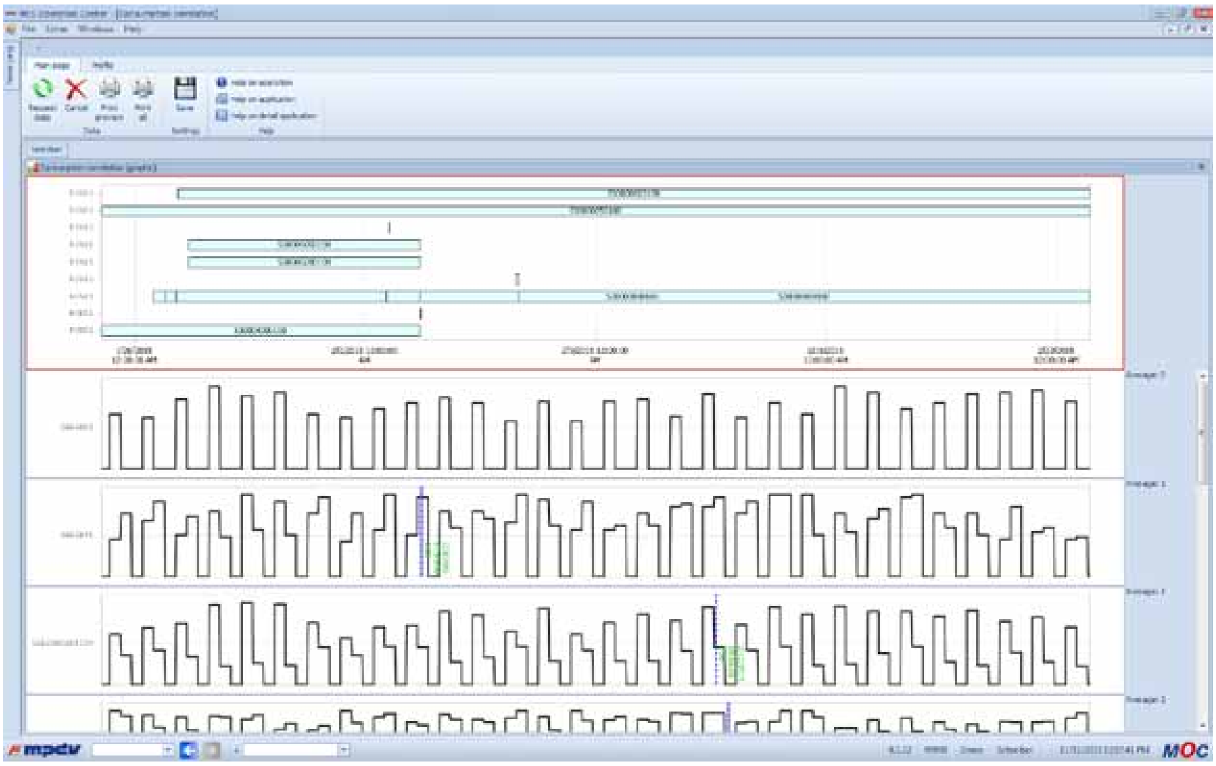

Figure 5: Energy management with MES HYDRA from MPDV: Correlated data serve as a basis for complex control loops

tion of a classical feedback control system are suitable. Both activities bring companies closer to a smart factory. It is also clear that an integrated Manufacturing Execution System (MES) like HYDRA from MPDV can make a significant contribution to this. Nevertheless, we will always have processes for the foreseeable future, which cannot be completely regulated without human intervention. In fact, people will always play a central and necessary role in the ever more complex world of manufacturing industry and thus also in self-regulation.

Figure 6: Process interlocking ensures that only released material is processed

Literature

[1] White paper „"Smart Factory" in four steps – Industry 4.0 disarmed", MPDV Mikrolab GmbH, March 2016, http://mpdv.info/whitepaperen

[2] White paper „The reactive factory – Industry 4.0 disarmed ", MPDV Mikrolab GmbH, September 2016, http://mpdv.info/whitepaperen

[3] MES-Manufacturing Execution System, Prof. Dr.-Ing. Jürgen Kletti (Hrsg.), English Edition 2007, Springer-Verlag

[4] White paper „MES – but do it the right way! Industry 4.0 needs Horizontal Integration", MPDV Mikrolab GmbH, August 2015, http://mpdv.info/whitepaperen

Multi-variant sequence production with MES

Flexible software beats conventional technology

Nowadays, sequence production also referred to as multi-stage assembly processes of multi-variant products, is already known from the automotive industry. This type of production method is gaining importance across all industries, not only where Industry 4.0 is concerned. Therefore, the question arises about flexible software systems to assist integrating specific requirements in a standardized manner. For this purpose, a state-of-the-art Manufacturing Execution System (MES) is the perfect tool.

Assembly processes of multi-variant products require on one side rapid working cycles and on the other, a continuous and targeted flow of information. For this, electronic working instructions are contained as well as control commands for the connected periphery like tools or Pick-by-Light systems. To date, such requirements have mostly been mapped to PLC technology using JIT/JIS systems (Just-in-Time/Just-in-Sequence) that must be programmed elaborately. This method was appropriate to product configurations applicable over longer periods of time. However, this will change due to ever shorter product life cycles. In future, companies will need the pace of today's JIT/JIS systems and the flexibility of state-of-the-art MES systems. Therefore, the integration of functions to support complex assembly processes in an MES is indispensable. This is the only way to produce small batch sizes efficient and cost-effective in terms of „Mass Customization“.

Changed requirements

At production workstations, the supply of information on current operations is quite customary for a state-of-the-art MES. The collection of relevant data in real-time is one of the basic features of such software systems. It is no longer sufficient for complex assembly processes to structure work flows only roughly. If operations have hitherto been the smallest unit known in the MES, the assembly process forces them to form finer subdivisions, namely work steps. Also, the importance of relevant information for the operator and the control of connected peripherals is steadily increasing. The operator needs the necessary information appendant to his work step at a glance and in electronic form due to the high cycle rate and the large number of variants.

Mapping assembly processes with an MES

Therefore, sequence production demands for new and real-time control and information concepts that are ideally integrated into an MES. After a production line is mapped in the system, all work flows including possible ramifications must be modeled (Figure 2). All specified product variants must be considered according to the relevant work instructions including all work stations and the locally connected peripheral devices. Rework loops must also be depicted as part of the sequence scheme. In a second step, individual product variants are defined as subsets of the overall model. As soon as the production of a specific product instance is triggered, a corresponding flow of work steps serves as a template for the line and the operator. In general, a „green light“ is given by the call-off for a part in specific variants and often in a stipulated sequence (Just-in-Sequence).

Individual operator guidance

The product to be manufactured or its load carrier is identified at each work station for which the MES knows the suitable work steps. Subsequently, the system shows the operator the relevant work instructions, which are then carried out or acknowledged. In addition, the operator receives information that should prevent errors and subsequent rework. Step by step, the required product variants emerge (Figure 3). The integration of semi-automatic and fully automated work steps is also possible.

In order to assure the quality of the products, inspections are repeatedly executed that have an immediate effect on the further processing of the respective part. For example, if faults are detected,

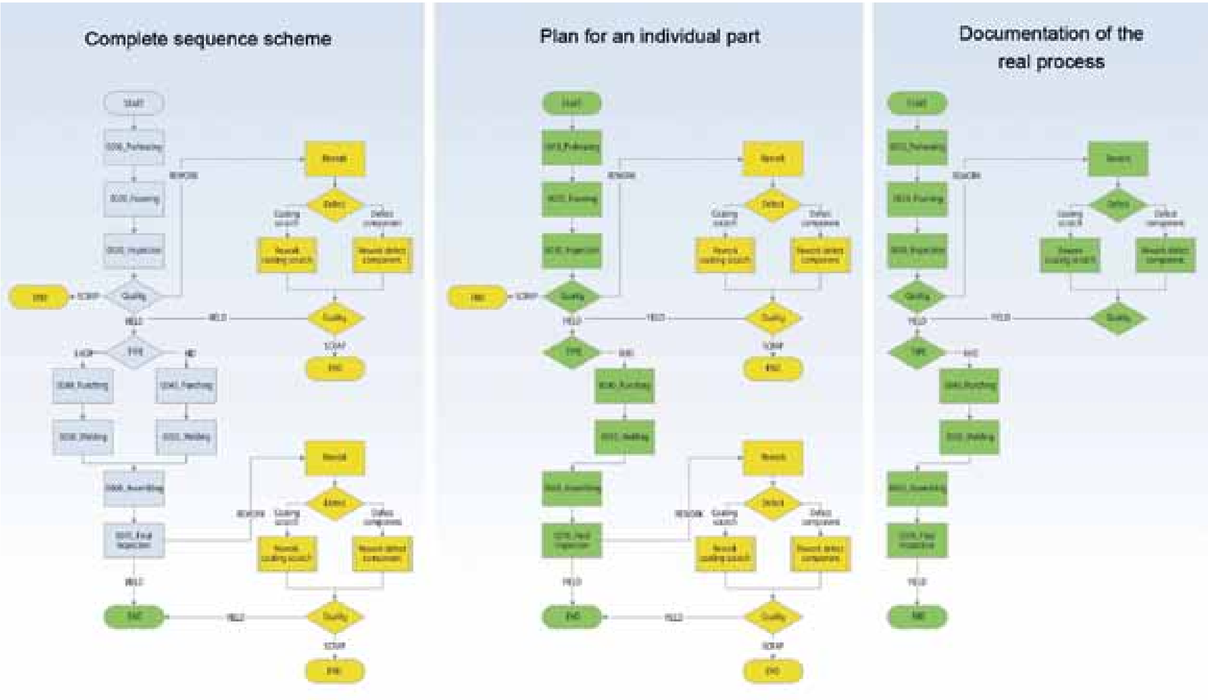

Figure 2: Modelling of complex assembly processes including rework loops

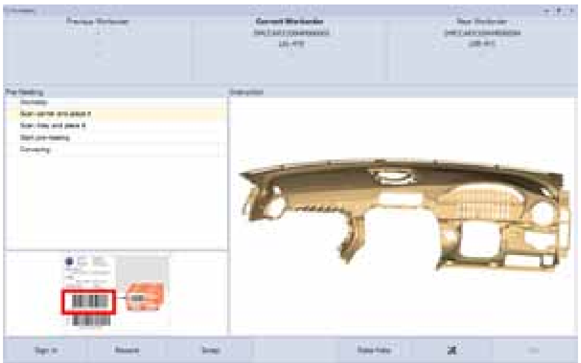

Figure 3: HYDRA Dynamic Manufacturing Control guides operators on the Dynamic Line Panel

an automatic process interlocking ensures that a defect part is not processed further and is destined for reworking. A previously rejected part can also become a good part again after some defined actions (e. g. repairs).

The central component of the individual operator guidance is the ergonomic user interface, which shows every operator exactly the information needed for the current work step at this work station. Here, reports have been proven beneficial that are designed according to the Poka-Yoke principle. Conventional industrial PCs, mobile tablets or even data glasses (Smart Glasses) can be used as a display device. It is essential in any case, that the choice of device takes into account the needs of the operator at his workstation. Connecting required periphery devices can also be useful. For example, the torque of a connected screwdriver must be monitored to ensure parts are screwed together correctly and the activity requires documentation.

Documentation and interdisciplinary evaluations

In terms of transparency it is necessary that all data collected during the production can be comprehensively consolidated and evaluated - including those recorded in-line of specific production lines. Here, the seamless integration of the assembly lines into an MES system offers enormous advantages as the MES is familiar with all data collected during the upstream and downstream production steps and during assembly. This data can then be displayed in virtually any view in order to generate correlative evaluations of material, process and quality parameters, machining times or machine behaviour. Furthermore, the MES can also calculate meaningful key figures from the acquired data, which are then monitored in the sense of continuous process optimization. In addition, for traceability and confirmability reasons the manufacturing process of the products must

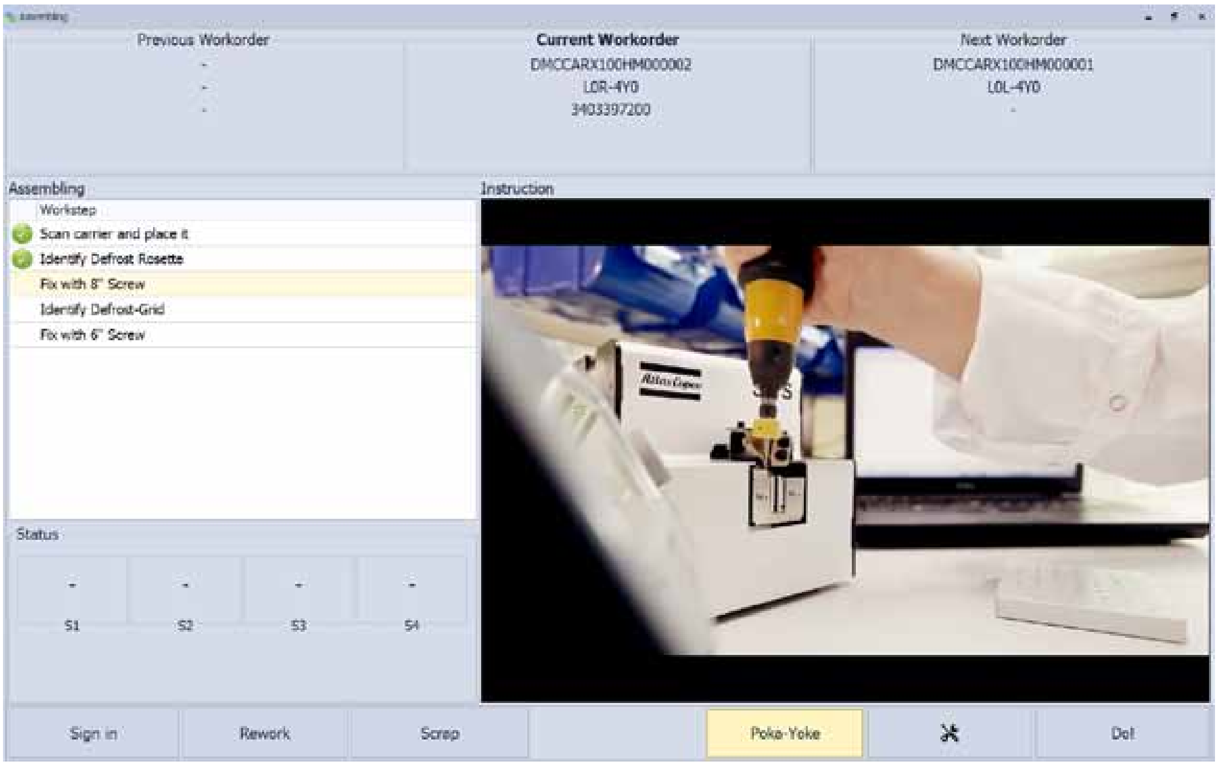

Figure 4: Dynamic Line Panels show work instructions in an ergonomic form

be documented in many industries. Integration of production lines into the MES enables an end-to-end view – meaning from the first to the last work step.

Working examples with HYDRA

During the HYDRA Users Group conference in September 2016, MPDV was the first MES provider to present a new application package for the integration of multi-variant assembly lines into an MES: Dynamic Manufacturing Control (DMC). DMC comprehensively covers the above-mentioned requirements, which are becoming a real challenge for more and more production companies.

By using a high-performance subsystem on the basis of the so-called Dynamic MES Weaver, HYDRA DMC manages to provide all required information in the right cycle time at the relevant work station and intervenes in the process in real-time. Individually designed Dynamic Line Panels guide the operator easily through the specified process (Figure 4). The decentralized process logic guarantees that the production line can continue to produce even if the network or central IT components have failed. DMC is fully integrated into the MES HYDRA and ensures that data, collected from the assembly lines, can be consolidated and evaluated comprehensively with further information from production without additional interfaces. Thus, a digital image of the complete product manufacturing process, including the corresponding data, can be realized – right as defined by Industry 4.0.

MPDV Mikrolab GmbH

headquartered in Mosbach/Germany is developing Manufacturing Execution Systems (MES) and is looking back on 40 years project experience in the production environment. MPDV‘s product portfolio comprises of MES products, services, and entire MES solutions for the MES environment. MPDV currently employs more than 330 people across ten sites in Germany, Switzerland, Singapore, China and USA. Customers from different industry sectors, ranging from metal processing to medical engineering, benefit from more than 1.000 installations of MPDV‘s MES solutions. These include medium-sized companies to global enterprises. Being part of the TOP 100 businesses MPDV is one of the most innovative medium-sized companies in Germany.

MES HYDRA

Manufacturing Execution Systems (MES) support production companies to improve efficiencies in their production processes, increase productivity and thus to secure or enhance their ability to compete. A state-of-the-art MES puts companies in the position to record and evaluate data along the complete value-added chain in real-time. People in charge can therefore react instantly to unforeseen events in the daily production routine and put in suitable measures.

The MES supports on all levels short-term and far-reaching decisions by providing a reliable data basis.

HYDRA, the modular structured MES by MPDV, features an extensive functional range and meets all requirements stated in the VDI guideline 5600. Individual HYDRA applications based on a central MES database can be combined without the use of interfaces. Thus, HYDRA guarantees a 360-degree view on all resources in production and can incorporate overlapping processes. Powerful tools for configuration and customization ensure that HYDRA can be modified in order to cater for company and industry specific requirements. HYDRA can be integrated into existing IT landscapes and is used as a link between production (shop floor) and the management level (e. g. ERP system). Production companies are particular reactive using an MES system like HYDRA and therefore remain competitive - especially looking at Industry 4.0.

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The MES Experts next to our customers.

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