Engineering Performance – Establishing integrated engineering in plant construction

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The demand for innovation and modernisation is omnipresent in the environment of today's industrial enterprises, also in the context of implementing industry 4.0. Plant construction companies have to blaze new trails in engineering in order to meet these demands. Market requirements and a willingness to rethink existing working methods play an essential role in this regard.

Market requirements

The market requirements for a plant construction company in the environmental sector are very extensive and multifaceted. Customers, most of whom are found in the public sector, expect an individual solution tailored to their needs and meeting their internal standards. The goal is to improve the operational safety of plants and reduce the costs for ongoing operation at the same time. However, an overall optimisation of these factors can only be achieved by applying precisely defined standards. Large sewage boards for example achieve this by developing and establishing specifications for all subsections affected by the implementation. These directives have to be met and implemented with every customer-oriented solution. The effectiveness and efficiency of possible solutions is another important aspect. In view of the current and expected future situation in the energy and water market, the implementation of effective as well as efficient solutions is indispensable.

Cooperation between mechanical engineering and plant construction

Machines exist for all conceivable process steps. A machine can be considered a self-contained unit. Each of them is defined by the manufacturer-specific standard, which begins with the selection of materials and ends with the specifications for regulation and control. Now the challenge is to assemble these individual components and machines into an integrated plant. This is the responsibility of the plant construction company. Here the objective is to transfer the individual standards to a plant or customer-specific standard. Mixing the disciplines of mechanical engineering and plant construction is not productive, since the specific perspectives are not congruent. Cooperation is required instead, making it possible to interconnect the consecutive process steps of mechanical engineering and plant construction. This results in a timely definition of the subsequent plant standard and an exchange of information from the outset that is profitable for both sides.

Strategies and structures in a company

An organisation has structures that can be viewed as a control system. These structures serve to meet the established targets according to the primary objectives of the enterprise. Strategies in a company are closely related to the organisation structures. They define a framework that is valid for a longer period of time and has a significant influence on the subsequent decisions in the enterprise. "Structure follows strategy" and "strategy follows structure" are two different perspectives of the relationship between strategies and structures in a company, going back to A. D. Chandler. But a one-sided interpretation or rating of these strategic orientation principles is not meaningful. Both statements have to be viewed in combination as shown by figure 1.

Deriving a static structure from a previously formulated strategy or deriving a strategy from a structure is too one-sided as an approach. The dependencies have to be viewed dynamically as a self-contained system. Here the benefit and advantage for the enterprise have to come first, and the willingness to adapt the structure or strategy internally is essential.

Industry 4.0

The industrial landscape has gone through three industrial revolutions so far. Mechanisation was the first stage, electrification the second and computerisation the third. Now industry is facing the fourth revolutionary stage, where the physical and virtual worlds converge in what are called cyber-physical systems (CPS).

Consistency in engineering plays a very big role here. Engineering is no longer a purely static process but takes place

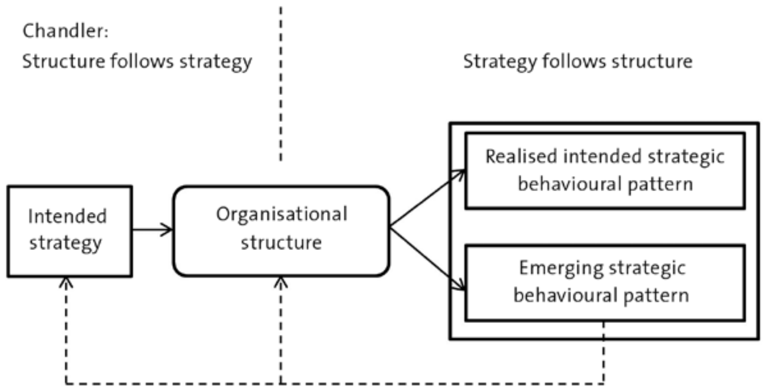

Fig. 1: Organisation structure as a consequence and precursor of the company strategy

dynamically along the entire value chain. A network of connections between the engineering and production situations that have hitherto existed – which has developed over the years, exhibits no consistency and is very inert or sluggish in response to new product requirements – is typical for the existing situation. Now consistency along the entire value chain is to be achieved with the help of cyber-physical systems (CPS).

Just like the path to industry 4.0, which has to be viewed as an evolutionary process, the introduction and implementation of solutions that lead a company to a consistent production process also have to be understood as such growing, evolutionary processes.

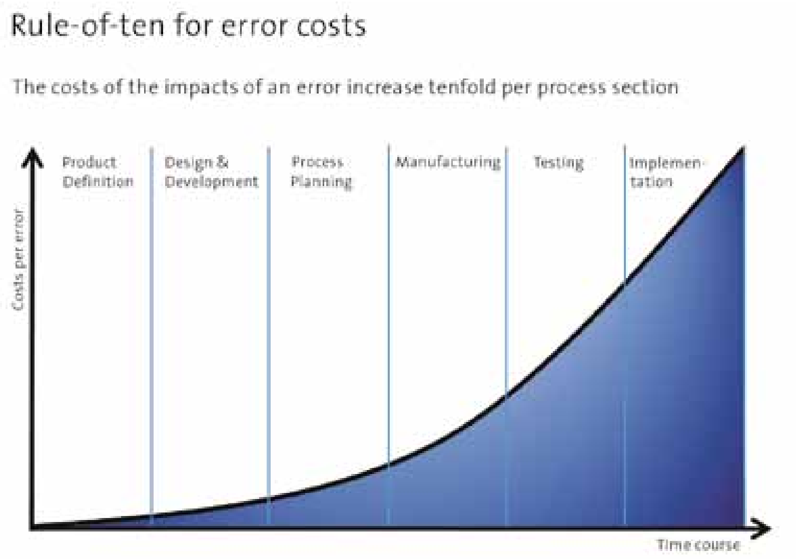

Fig. 3: The rule of 10 for error costs

Cost-time-quality

In the project business there are target parameters that have to be observed while working on a project, especially in engineering. These three decisive factors are the time required for project engineering and the production of a product, the costs incurred for the order and the quality of a finished product when it is delivered to the customer.

The correlation of these three decisive engineering factors is described as the triangle of project objectives or also "magic" project triangle, which is shown in figure 2.

In order to maximise efficiency and production performance with an adequate profit, the factors discussed above have to be optimally adapted and balanced. This means that project engineering has to be realised at the lowest possible cost, in a better than average time and in the best quality.

However, it is the quintessence of the triangle of project objectives that optimising all three factors at the same time is not readily possible. That is why it is also called a "magic" triangle. Lowering the costs and reducing the time for example inevitably causes quality to suffer. Two parameters can be optimised at the expense of the third. Here the challenge is to find solutions that optimise all three engineering factors to best advantage at the same time.

It is interesting to examine the effect that the cost of an error during the project has in reference to the respective process section, which is described with what is known as the rule of 10 for error costs and illustrated in figure 3.

Empirically the error costs increase tenfold for each process section in which the error is later discovered.

Therefore it is desirable that the possibility to utilise consistent quality exists before project engineering starts. Such a quality basis consequently has to be established.

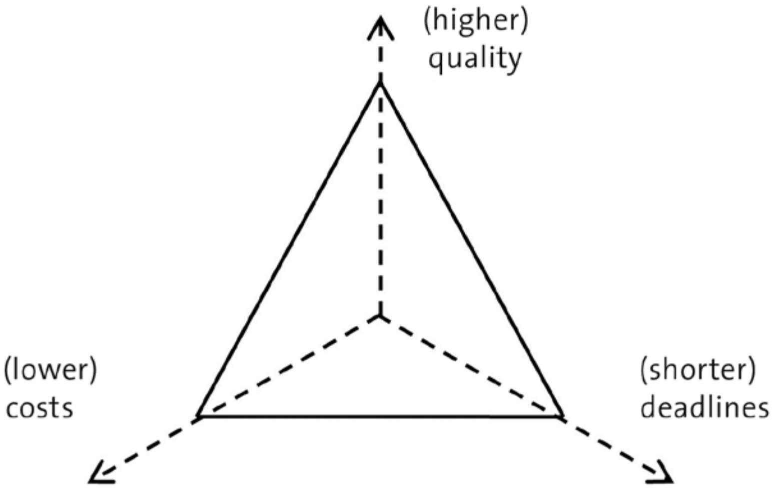

Fig. 2: Triangle of project objectives

Standardisation

Standardisation efforts exist in a wide variety of disciplines. They can for example relate to products or complex processes, for instance in production or engineering. The terms non-variable part and standard part are used in this context. Standard parts are subject to detailed regulations that apply across companies, and non-variable parts can be viewed as internally defined, standardised states. The goal should be to reduce the general diversity of parts and to strive to use standard and non-variable parts.

Especially in engineering however, the term parts is not entirely accurate while the underlying meaning is. Using the same models establishes certainty to the effect that all possible error sources are reduced through the use of routines that have already been tested and proven. Individualism creates potential for errors and should only be applied where it is needed. Working processes and methods on the other hand should be standardised as much as possible, so that the quality of the end products or also services is close to the same.

All standardisation measures have to be implemented based on the premise that the ability to realise individual customer requests is not impaired at any time.

The goal of all standardisation efforts is to save time and costs by reducing the variants and improving customer-specific engineering performance.

Engineer to Order (ETO) and Configure to Order (CTO)

The ETO approach is defined by the elaborate internal planning and design of the plant for a specific order. Here individual engineering plays a very big role in the implementation of the respective customer requirements. Under the CTO approach on the other hand, the plant is configured. That means an entire plant is put together using elements from a set of reusable mechatronic components. Reducing the use of the ETO approach and implementing the CTO concept is the objective.

Requirements for an engineering tool

Plant construction projects are complex, with products that can be highly multifunctional and elaborate. Costs play a very big role, especially for public sector tenders. As a rule the contract is awarded for the cheapest offer that corresponds to the contract specification and is submitted on time before the deadline. Faster engineering and production all the way to acceptance result in a time advantage, thereby making it possible to achieve more in the same time period. Quality is also very important, especially in view of the objective to obtain subsequent orders. Good quality results in good references. And references are playing an ever more important role in plant engineering.

In order to maximise efficiency and production performance with an adequate profit, the factors discussed above have to be optimally adapted and balanced.

This is where standardisation is the key to success. Setting standards establishes qualities, saves time and reduces costs. Such a standardisation process for a plant construction company is illustrated in figure 4. The degree of standardisation is another point that has to be taken into account. It must not be taken too far, since it is the nature of a plant construction company's portfolio to guarantee individuality according to each project. Figure 5 shows that the ability to meet individual customer requests is significantly improved by the standardisation process in the organisation.

The optimum level of standardisation has to be reached with the help of solution concepts as shown in figure 6.

Due to such a reorganisation, a basic level of quality is given by a broad range of reusable standards. More can also be accomplished in the same time since the delivery times are reduced. The resulting lower costs for implementing a project make higher profits possible as well.

The realisation of optimised engineering requires the use of an engineering tool that enables the realisa-

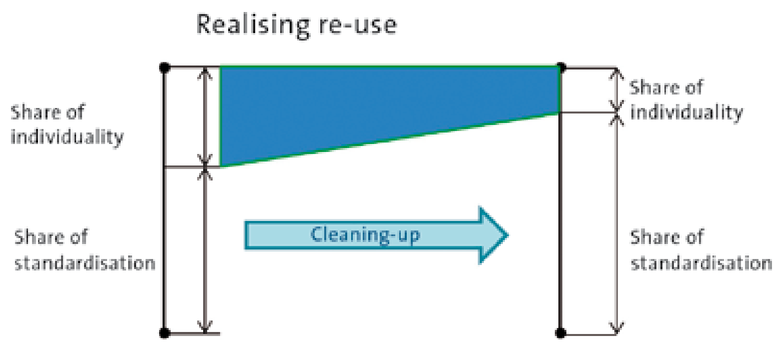

Fig. 4: Standardisation in the organisation by "cleaning up"

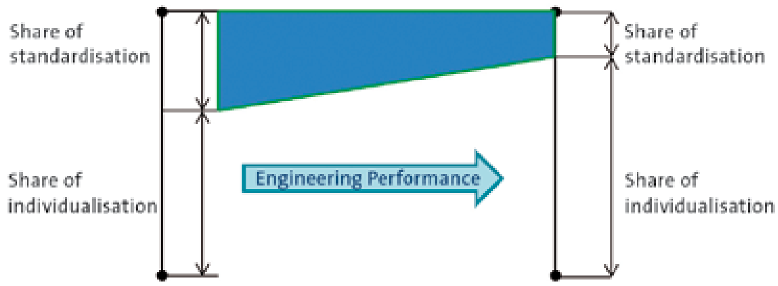

Fig. 5: Standardisation from the customer perspective: Improving the ability to meet individual customer requests

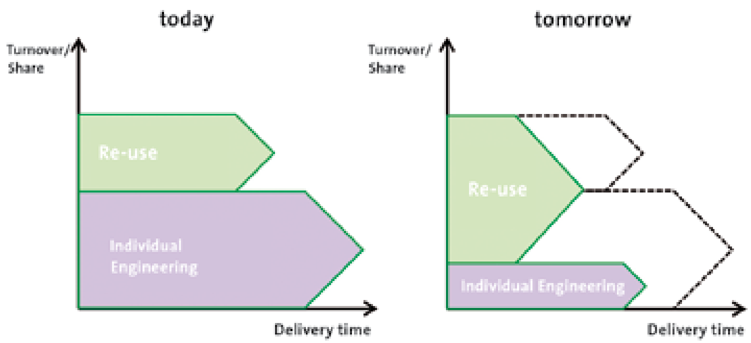

Fig. 6: Standardisation now and in the future

tion of the desired efficiencies. It has to support quality assurance and the consistency of engineering. Consistent engineering reduces errors and eliminates redundancies.

Using an engineering tool

The starting point for the examination that follows is EPLAN Engineering Configuration, a high-end product from the company EPLAN. Insights into its functionality are offered and the possible realisation by a plant construction firm is described in the following.

This engineering tool is intended for comprehensive standardisation and consistency in all engineering disciplines. New developments such as macros are centralised and standardised. This reduces individual engineering and decreases the error potential.

Working with copy and paste is eliminated by EEC. Engineering follows a building block principle. Reusable components are derived from completed projects and ultimately make up the set. Temperature measurement that exists in several versions is used here as an example. The set of components contains a base version "temperature measurement". Three possible specifications are assigned to that, being the type with manufacturer, the measuring method and the layout of the bus head. Now the required machine for specific orders in current projects is derived from the set of components.

In principle, the set of components is a technical database containing items with stored functions that depict their dependencies. EEC does not generate macros together, but creates functional links between them.

A well organised and maintained set of components thereby enables fast, error-free, functional engineering of standardised quality.

EEC has tremendous potential for the generation of technical hardware and software documents. The set of components corresponds to a large set of standards that can also be used to prepare, for instance, design plans, control software and text documents. Generating such production documents is illustrated in figure 7. Corresponding rules therefore have to be defined in the set of components through programming, representing the desired functions. The set of standards is developed under consideration of state-of-the-art technology and with the inclusion of specific customer standards. Configuration is performed through upstream configuration files that can be edited with Microsoft Excel, and is based on the machines and measurements intended for the plant that have to be specified in the tables with their parameters.

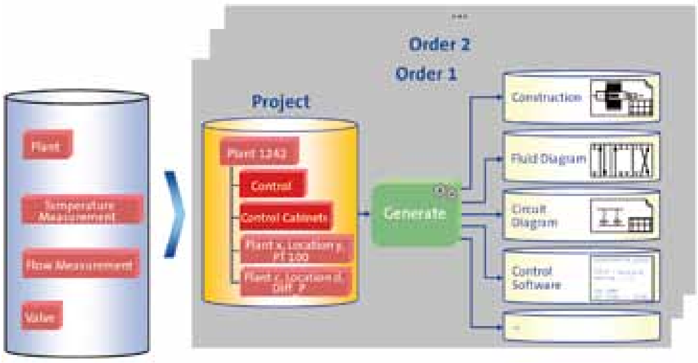

Fig. 7: Generating production documents

Organisation structures

Using the operating methods described above in engineering defines a new strategy in the organisation, so the structures have to be adapted accordingly. The concept of the all-encompassing planning department cannot be applied here any more. One has to differentiate between development in reference to the project-specific engineering process and subsequent design. The development engineer collects, filters and prepares the definite basic information for the mechanical and electrical engineering design as well as the programming of the plant or plant components to be built. He works closely with project management. The designer prepares all documents for production, on-site installation and the customer documentation. He works closely with development engineering and project management.

This ensures that all relevant information required for the subsequent configuration and execution is centrally compiled at the start of the project.

Integrated workflow

Project engineering always starts with the offer from the plant construction company to a customer, or the contract specification and a performance specification if applicable. Having all project-related information on hand before the other steps follow is of essential importance. This also includes reviewing the information provided for correctness and integrity by discussing it with the respective customer. The existence of error-free and complete information at the start of project engineering establishes the quality basis that is needed for all subsequent steps.

The configuration file is defined in the next engineering step. Thanks to the structure, the engineering employee is able to configure all settings according to the information that is on hand. All machines and measurements used for the plant are specified here, with the inclusion of the respective customer standard. These input lists correspond to the form of what are known as plant identification lists and are derived from the pipework and instrumentation flow chart.

The file is read by the engineering tool. Now the implemented functions can be accessed in a menu. After selecting the circuit documentation to be generated, for example, it is generated in a fully automated process. Then it can be opened in CAD software for further processing. Generating PLC code, requirements specifications and documentation is possible as well.

Project-specific individual engineering now follows, encompassing adaptations and details for which standardisation and addition to the set of components is not worthwhile due to the lack of reuse potential.

The result is consistent engineering with much shorter throughput times, very high flexibility and close proximity to the customer. “Engineer to Order” is replaced by “Configure to Order”.

Fig. 8: Example of a finished switching system

Fig. 9: Example of a finished waste water treatment plant

Conclusion

The possible solutions in the preceding examination are extensive, but highly promising in view of introducing integrated engineering. In general the standardisation concept plays a major role. Formerly individual working methods are standardised. In a future-oriented company, the demand for a high level of standardisation has to be viewed as one the top objectives. An engineering tool is suitable for implementing this concept in electrical engineering. The solution chosen for implementation must be aimed at obtaining the maximum possible benefit for the organisation. Accordingly the strategies and structures have to be dynamically harmonised.

The decision to effectively optimise engineering processes and make them consistent has to be made in a timely manner. Today’s competitive environment for a plant construction company in the environmental sector does not forgive errors and demands high quality at the lowest possible price in a reasonable time. The solution lies in obtaining a competitive advantage through consistent engineering with the help of an engineering tool. Proactively improving internal performance in all areas has to be the guiding principle for the future development of an organisation.

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