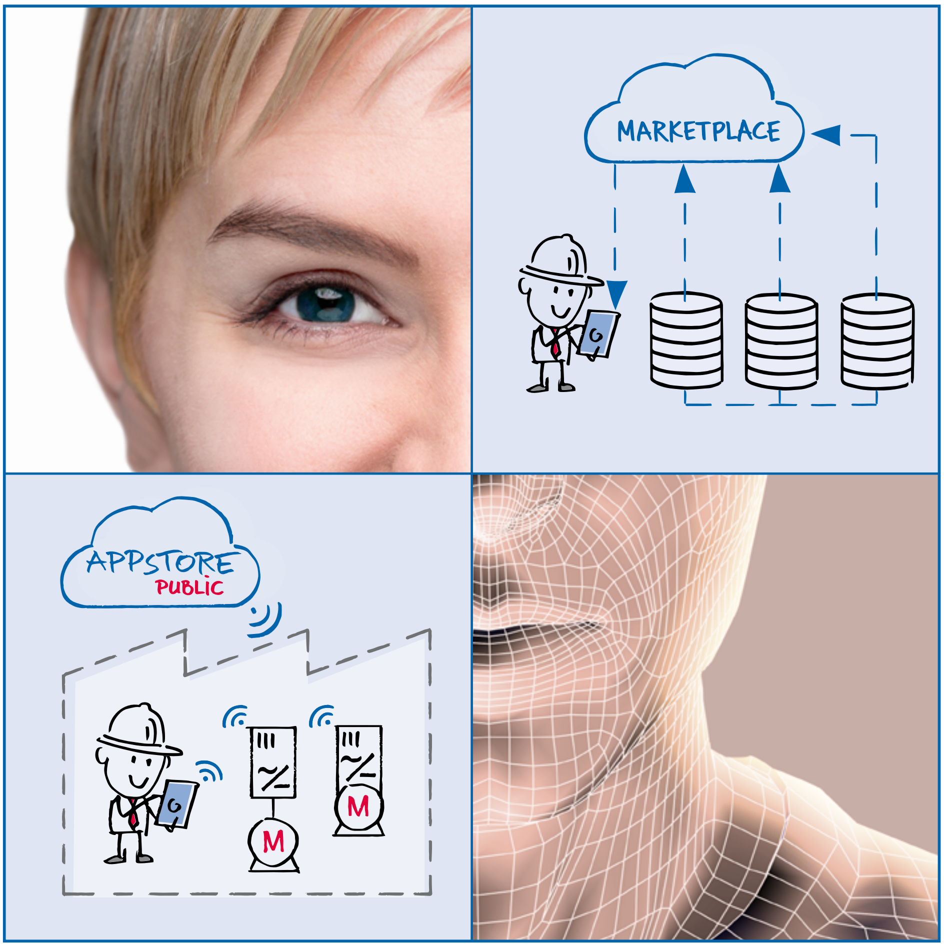
White Paper

Drive System 2030



German Electrical and Electronic Manufacturers' Association

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1 Management Summary

In the working group Industrie 4.0 for Electrical Drive Systems, a temporary project group, Drive System 2030, was set up in 2019. The aim of the project group was to propose future-oriented theses relating to the electric drive system for a period of 10 years. These 12 theses are described in the Drive System 2030 white paper. Although electric drive technology will develop, there will be incremental rather than disruptive change on the power electronics side or in the rotating part. These incremental changes could include, for example, miniaturisation, cost reduction and an increase in efficiency.

The interplay between digitalisation and resulting business models will therefore become more important, for example the interaction between business partners in the horizontal and vertical value chain.

The Drive System 2030 will primarily develop in terms of sensors and connectivity in the Industrial Internet of Things (IIoT) environment and become embedded in the user's value chain. Future business models are thus addressed that appear economically feasible as a result of progress in technological possibilities. Standardisation will also play an important role here.

Conversely, these theses generate demands for the Drive System 2030 with regard to its future capabilities.

2 Motivation und Methodology

In a faster digital world, new ways of collaborating and communicating etc. impact the value chains. The behaviour of market participants is also influenced by digital technologies and platforms. Business models, value creation and even value chains may change.

The Plattform Industrie 4.0 as a reference describes a 2030 vision for digital transformation in production www.plattform-i40.de:

"Industrie 4.0 describes a fundamental process of innovation and transformation in industrial production. This transformation is driven by new forms of economic activity and work in global, digital ecosystems: today's rigid and strictly defined value chains are replaced by flexible, highly dynamic and globally connected value networks with new forms of cooperation. Data-driven business models prioritise customer benefits and solution orientation, replacing the focus on the product as the prevailing paradigm of industrial value creation. Availability, transparency and access to data are key factors for success in the connected economy and largely determine competitiveness."

The possibilities of new technologies will also influence drive technology along its value chain.

In this context, the white paper proposes theses that are described using "EPICs[1]".

Core questions and problems

- How is digitalisation influencing business with drive systems?
- How are new trends, such as "smart production", influencing drive technology and business?
- Is there a disruptive approach for reorganising the traditional value chain?
- Are there already trends in various markets/sectors/customer segments?
- What are competitive attributes in 2030 and how will competition be influenced from the point of view of manufacturers of motors/drives?

This white paper will not focus on issues relating to macroscopic market developments, for example:

- What role will substantially growing electrification sectors, such as energy (climate change) and electromobility play?
- How will emerging markets/applications develop, for example robotics, medical applications?
- Cyber security is of the utmost importance in a digitally linked world.

[1] EPIC: a term in the context of requirements management describing an application case. The description method comes from agile software development.

3 Starting Point: Drive 4.0 – Vision Becomes Reality

Drive 4.0 [1] and Plattform Industrie4.0 [2] form the starting point for this white paper. [1] addresses the Industrie 4.0 platform concept [2], in particular from the drive technology point of view. This relates to automated data exchange between the market participants (manufacturers, machine builders and operators) through the entire value chain, based on classified features, functions and other data.

Every delivered product forms an instance. As a real material or physical object, it has a unique identity, which is described in classified features. In the stricter sense, it can be rating plate data, in the wider sense all conceivable features that a participant needs to operate in the value chain. The physical object thus becomes an "Industrie 4.0 component".

Standardisation is of central importance for all those involved in the value chain: Communication between the instances takes place via digital exchange protocols which contain semantic information. This information must be classified in a standardised manner so that market participants can participate in the market in accordance with the announced definitions. Data exchange takes place via standardised communication protocols. The reference architecture model Industrie 4.0 (RAMI 4.0) is used here.

The use cases cover the entire value chain from planning through to recycling. One sample use case is the automated commissioning of networked drive systems. Data is exchanged here between the instances that are involved in the current asset events. Other sample use cases are in asset management itself, in which the life cycle of an instance is tracked. With the data of the classified I4.0 semantics, it is therefore possible to fill a digital twin in an Asset Management database or operate a smart factory.

The asset administration shell has a particular importance with regard to the mapping of classified features of an Industrie 4.0 component within RAMI 4.0. Within this asset administration shell, the classified features of the respective instance are published to other instances with their own asset administration shell. To create a uniform data structure, the classification system ECLASS was chosen. This is based on and harmonises international standards.

Environment technologies, digital platform technologies, interfaces and other connection points therefore understand the information because it is standardised. The ability of assets to cooperate can be described by the degree of compatibility in accordance with IEC 61804-2: The highest level is the exchangeability of an Industrie 4.0 component which can be structured with two levels:

- The data level with its instantiated data, the communication interface and the communication protocol in which the data is stored in a classified manner
- The performance level, which contains parameters, application functions and dynamic functionality

Compatibility achieved through standardisation is an absolute prerequisite for the theses and EPICs described below.

[2] **References:**

[1] Drive 4.0 – Vision Becomes Reality, ZVEI, April 2018 www.zvei.org/presse-medien/publikationen/antrieb-40-vision-wird-realitaet/

[2] Plattform I4.0 www.plattform-i40.de

4 Theses and EPICs 2030

Twelve theses were drawn up and presented in the form of EPICs. Theses 1-4 relate to software, theses 5-7 to business models and theses 8-12 to technological aspects.

With regard to technical characteristics, morphological analysis in the form of a matrix is used. The technical characteristics are very generalised in terms of the defining features, e.g. attributes, factors, parameters, dimensions (ordinates) and the strength of the technical characteristics is depicted in the form of performance classes (abscissa).

Each thesis is backed up by a morphological matrix which splits the features into performance classes. The features are divided into the following general properties:

- "Connectivity" describes the "outward" connection
- "Data processing" makes a statement about where data processing takes place, possibly with additional calculations such as simulation or only the availability of data models
- "Process execution" indicates where/from where control and optimisation are carried out
- "Traceability" identifies the asset based on data and accuracy of localisation of the asset
- "Serviceability" describes the sensor characteristics for providing data for control/optimisation and the sub-process of the value chain in which the feature plays a role

The morphological matrix has the same content in each thesis and the relevant features are highlighted in light blue (example below).

<table>
<tr><th></th><th>Feature</th><th colspan="30">Performance classes</th></tr>
<tr><td rowspan="3">Connectivity</td><td>Resolution</td><td colspan="10">As required</td><td colspan="10">Batch</td><td colspan="10">Real time</td></tr>
<tr><td>Interlinking</td><td colspan="10">one2one</td><td colspan="10">one2many</td><td colspan="10">many2many</td></tr>
<tr><td>Data rate</td><td colspan="10">Low kB/s</td><td colspan="10">Medium MB/s</td><td colspan="10">High GB/s</td></tr>
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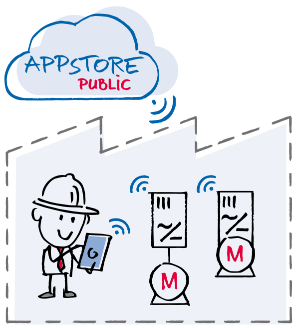
</table>

The combination of highlighted features thus results in a conceivable technical demand made on a solution. The highlighting was chosen intuitively based on the experiences of the authors in a group discussion.

Thesis 1:
Application software is available for standard drive applications as an app in the cloud



Vision

A library for standard drive applications is available as an app store in the cloud. Each app can be used for each drive system, regardless of manufacturer. The cloud also performs all administrative tasks needed for authorisation, user management and billing.

Short description

Today, all software is available locally in a drive control, shipped ex works, possibly enclosed as a CD. With the option of central provision, on the other hand, drive controls can be delivered on an application-case-independent basis via local coupling to libraries and the controls get their functionality from apps in the cloud. The business model can be made user-dependent (app fee, license fee, pay-per-use) and the payment is made via the cloud environment. Third-party providers can offer other apps.

Challenges for R&D

- Compatibility of software regardless of manufacturer, compatibility with hardware
- Market acceptance, end customer becomes system integrator or a third-party provider is responsible for functionality and security
- Billing/controlling, system integration with existing ERP, interfaces
- Legal liability
- Providers for app store

Morphological matrix

	Feature	Performance classes				
Connectivity	Resolution	As required	Batch	Real time		
	Interlinking	one2one	one2many	many2many		
	Data rate	Low kB/s	Medium MB/s	High GB/s		
Data Processing	Computing power	On the object	At the location (edge)	In the Cloud		
	Digitalisation	Modelling	Simulation			
Process execution	Control	Information	Event	Self-controlling		
	Optimisation	From outside	Self			
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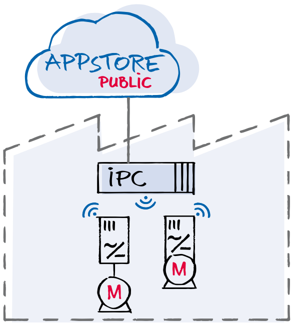
Thesis 2:
An edge device performs drive controlling for one or more drives



Vision

An edge device takes over application controlling of the variable speed drive(s). A library for standard drive applications is available as an app store in the cloud. Each app can be used for each drive, regardless of manufacturer, but the edge device performs administrative tasks and offers computing power locally.

Short description

Today, the application software is located locally in a PLC on-top on the drive control, shipped ex works. Because of the power of today's PLCs, it is conceivable to build edge devices that take over the complete application management and are connected to cloud libraries. Downwards, the variable speed drive contains only the firmware of the power semiconductor controller. The edge device takes over management, authorisation and user management and serves as a communication frontend. High data rates are then needed when the edge device connects to the cloud.

Challenges for R&D

- "Manufacturer-independent", compatibility, HW/SW
- Market acceptance, end customer becomes system integrator or a third-party provider is responsible
- Billing/controlling
- Legal liability
- Providers for app store
- High data rates and real-time capability

Morphological matrix

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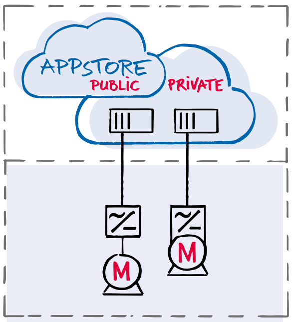
</table>

Thesis 3:
Computing power for drive controlling is provided in the cloud



Vision

A library for standard drive applications is available as an app store in the cloud. Each app can be used for each drive, regardless of manufacturer. The cloud takes over the computing power of the local PLC and possibly for the variable speed drive FW.

Short description

Today, the power semiconductor control and application software are located locally in a drive control, shipped with the hardware. Thanks to the possibility of providing computing power centrally, control signals for torque and speed control can be provided directly from the cloud. The business model can be made user-dependent (app fee, license fee, pay-per-use) and the payment is made via the cloud environment. Third-party providers can offer other apps. The application SW (apps) are drive-manufacturer-independent. Memory and computing power are minimised locally and the cloud takes over tasks in a scaled manner. The highest demands are made on communication with regard to reliability and data rate.

Challenges for R&D

- "Manufacturer-independent", compatibility, HW/SW
- Market acceptance, end customer becomes system integrator or a third-party provider is responsible
- Billing/controlling
- Legal liability
- Providers for app store
- High data rate, low latency time, short cycle times of the ICT cloud device

Morphological matrix

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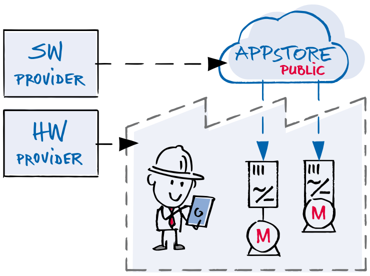
</table>

Thesis 4:
Separation of HW and SW – software enterprise for drive technology



Vision

Some drive manufacturers will develop their model to become a software provider. Others will focus on hardware value creation. HW will become a standard product manufactured in large quantities by a few manufacturers.

Short description

As the software becomes more differentiated (analysis and control, applications), the hardware will become less of a factor in creating USPs. Customers' willingness to pay for pure hardware will therefore fall. As a result of the higher cost pressure in the area of hardware, a few manufacturers will serve large parts of the market, because scaling effects can be achieved through high standard quantities. As a result of expertise, practically pure software enterprises will launch products that differ only by their software. As specialist software enterprises, they achieve scaling effects over larger segments of the market as a result of the use of digital platforms. As a result of specialisation and concentration in both areas, the customer has a lower cost item.

Challenges for R&D

- "Manufacturer-independent", compatibility of software/hardware
- New companies – disruptive business models are possible
- Legal liability

Morphological Matrix

	Feature	Performance classes				
Connectivity	Resolution	As required	Batch	Real time		
	Interlinking	one2one	one2many	many2many		
	Data rate	Low kB/s	Medium MB/s	High GB/s		
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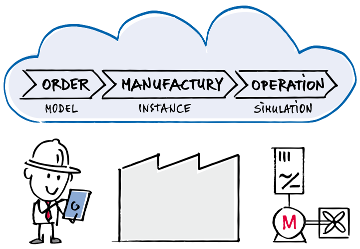
Thesis 5:
Horizontal integration: Participants in the value chain interact seamlessly



Vision

Horizontal integration across company and system boundaries is a key element of Industrie 4.0. Thanks to the holistic approach, horizontal integration relates not only to the linking up of individual machines, plants or production units, it also includes suppliers and customers. Data from the drive is thus available over the entire value chain. New, data-driven and in some cases also disruptive business models are therefore possible.

Short description

Today, there is a high engineering effort in the design of a drive task. During operation of a drive component, other asset engineering tasks also arise. Thanks to horizontal integration, this effort can be massively reduced. As a result of the available data and future artificial intelligence (AI) applications, the drive can simulate itself and during operation learns to adapt itself. Energy consumption, marginal or maximum performance, torque or planned/predictive maintenance can thus be optimised. The drive independently calculates its remaining life and proposes measures and optimisation steps or carries these out itself continuously. By correlating the data of individual local drives, it is also possible - via self-learning algorithms - to automatically provide data-driven and dynamic services adapted to the system. This is done over the entire value chain without system boundaries.

Challenges for R&D

- Create acceptance for sharing data with other stakeholders
- Technical and legal framework conditions to ensure protection of sensitive data and intellectual property
- Overcome system boundaries – create end-to-end interoperability
- Data and features must be standardised and machine-readable

Morphological matrix

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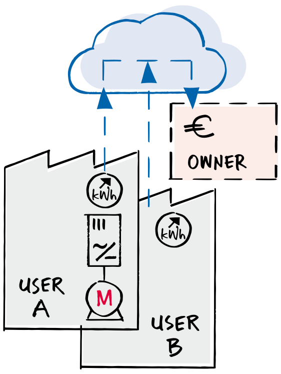
</table>

Thesis 6:
Micropayments: Data points or information implemented in business models



Vision

Smart drives are a part of increasingly complex plants and are operated in a particular context. In view of this, smart services relating to the smart drive must also integrate data from smart environments. Micropayments permit new smart, digital business models that compensate for the reduction in classic drive business.

Short description

Today, industry is dominated by classic business models involving clear ownership structures. Companies sell products, goods and services which are usually transferred to the buyer following a one-time payment.

However, a reduction in income from classic offline products and services and the new opportunities provided by data-driven business models are increasingly forcing classic industrial companies to adopt new, sometimes disruptive, business models. With the opportunities offered by digital services, companies face the challenge of generating new income through micropayments to compensate for the decline of the classic business model.

In the future, ownership and the possession of a product will have to be looked at differently. As a result of the available data, the possessor will have new ways of implementing business models and micropayment models. The product will not necessarily have to be owned by the micropayment provider. For the owner, it will therefore become increasingly relevant to describe and delimit the use of data and to generate new business models through micropayments. In the future, this can compensate for the downturn in classic sales. One example here is "pay-per-X", which is already being tested in initial pilot projects in the industrial environment.

Challenges for R&D

- Employee and customer mindset for micropayments and business models
- Cutting the tie between ownership and possession requires new ideas and approaches to implement and establish new, profitable and market-oriented business models
- Required billing and controlling processes
- Technical system adjustments to avoid system discontinuities
- Who is liable for which part of the product?

Morphological matrix

	Feature	Performance classes				
Connectivity	Resolution	As required	Batch	Real time		
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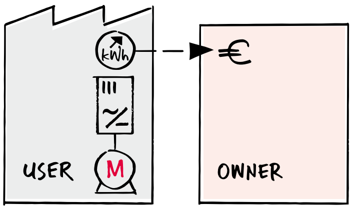
Thesis 7:
Business models: Pay-per-use, billing per unit XaaS



Vision

Thanks to the exchange of data, digitalisation across company and system boundaries enables an end-to-end business model for services – from the supplier to the end customer.

Classic "sell and forget" business models are coming under increasing pressure as a result of digitalisation. Flexible usage and price models increase end customers' flexibility. Payment for products and services is based on use. The business models of the drive manufacturers will therefore change so that the focus is no longer on the sale of products and components, and instead, use and ultimately customer benefit are monetarily assessed.

Short description

Today, produced goods are sold or leased. In the future, this will shift to the selling of services and benefit, rather than purely physical products. The end customers of the plant and machine builders purchase services and the plant and machine builders or OEMs buy and sell services. Drive manufacturers must therefore also adapt to these new business models and, in the future, focus more on business generated by services in which a greater focus is on the benefit to the customer.

In the area of drive technology, these services will be a focal point in the context of pay-per-use. The offered service includes, for example, payment only if the motor is used, or is calculated based on used torque or speed. The most simple and stable connectivity possible is therefore a prerequisite for the products. Processing of data by the drive manufacturers is also necessary to prevent unscheduled downtimes and make the economic risk manageable.

Challenges for R&D

- Digital business and service models and usability of the digital systems
- New, flexible billing systems without system discontinuities
- Liability issues in the event of downtimes, and legal issues relating to billing and traceability of the provided services (measurement and instrumentation law)
- Detailed information for using the plant
- Preventive maintenance, because downtime means loss of income
- Mindset of customers and operators – advantages for the market participants?

Morphological matrix

<table>
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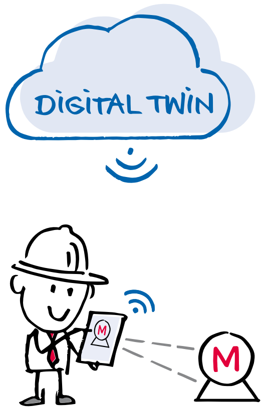
</table>

Thesis 8:
Role of virtuality – AR, VR, mixed reality



Vision

As a result of virtual reality (VR) and augmented reality (AR), interaction with drive systems will become faster and more interactive in the entire value creation process.

Short description

VR and AR devices are capturing the mass market and are another large computing platform alongside PCs and mobile devices. As a result of VR, drive systems can already be experienced in interactive, virtual environments during design and planning. AR supplements the real picture of the drive system by adding information and accelerates manual logistics, commissioning and maintenance processes. Drive systems and the information they contain over the entire product life can be examined right through to the innermost components.

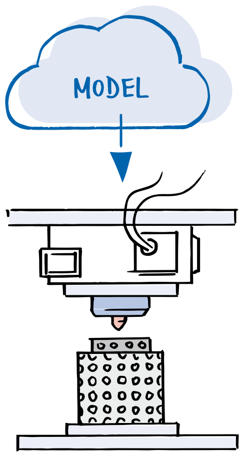
Challenges for R&D

- Simple identification of the system through “visual contact” or geo information
- Role-based authentication and the associated use of information
- Robust business models developed based on the benefit of VR/AR technologies
- Integrated 3D model information for all components

Morphological matrix

	Feature	Performance classes				
Connectivity	Resolution	As required	Batch	Real time		
	Interlinking	one2one	one2many	many2many		
	Data rate	Low kB/s	Medium MB/s	High GB/s		
Data Processing	Computing power	On the object	At the location (edge)	In the Cloud		
	Digitalisation	Modelling	Simulation			
Process execution	Control	Information	Event	Self-controlling		
	Optimisation	From outside	Self			
Traceability	Identification	Product	Module	Component		
	Localisation	Global	Area	Building	Room	Work station
Serviceability	Sensors	Single sensors	Sensor cluster	Interlinked sensors		
	Sub-process	Development	Production	Distribution	Use	Recycling

Thesis 9:
3D Printing of Drives



Vision

Fast and cost-effective creation of individual drive systems using 3D printing.

Short description

The speed and material availability for 3D printing are increasing, while costs are falling. It is now possible to produce not only prototypes, but also produce customer specific drive systems and spare parts, quickly and at low cost. 3D printing makes it possible to reduce weight for special use cases and achieve a high degree of component individualisation. Logistics, production and assembly steps can be reduced and relocated to the value creation network. The expertise of the drive manufacturer lies in the design and creation of a 3D print model, to which firmware and other software components can be added after additive production..

Challenges for R&D

- Printing of different materials such as Cu, Fe, insulation material etc.
- Development of workable business models
- Increase in quality and longevity of the printed drive

Morphological matrix

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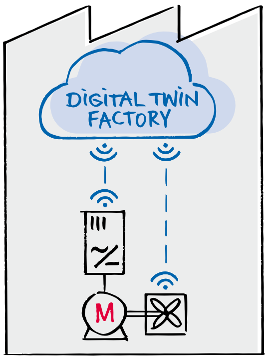
Thesis 10:
Plug, Work & Optimization by the Drive



Vision

Commissioning and optimisation of the drive system are automated.

Short description

The parameterisation of individual components and the prototype phase of a complete system are carried out automatically (and virtually). Required parameters are configured in advance during the installation of components and adapt to the actual behaviour and requirements of the production system. The application expertise (expert knowledge) required for commissioning and optimisation is located on the individual components, which are constantly improved as a result of self-learning algorithms and the data from operation of the components. The productivity and energy efficiency of a production system will thus increase over the usage phase and the information obtained here can be used for the optimisation of new production system generations.

Challenges for R&D

- Interoperability between the components in the life cycle
- Participation in the productivity gains and energy savings leveraged by the optimisation algorithm
- Expert knowledge transfer to design and simulation models
- Protection of IP rights and sufficient data sovereignty
- Legal liability (possible lack of expert knowledge during commissioning)

Morphological matrix

	Feature	Performance classes				
Connectivity	Resolution	As required	Batch	Real time		
	Interlinking	one2one	one2many	many2many		
	Data rate	Low kB/s	Medium MB/s	High GB/s		
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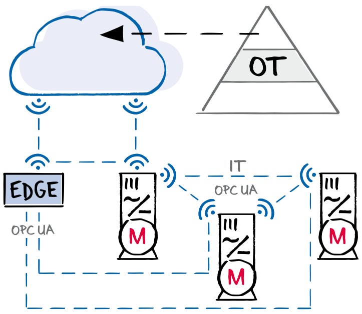
Service-ability	Sensors	Single sensors	Sensor cluster	Interlinked sensors		
	Sub-process	Development	Production	Distribution	Use	Recycling

Thesis 11:
"ONE" fieldbus for OT and IT requirements and I4.0 language



Vision

Thanks to a manufacturer-neutral and interoperable communication interface, the drive system can be flexibly used and is transparently accessible right up to high-level business processes.

Short description

With penetration of the market by a manufacturer-neutral and interoperable communication ecosystem, which meets the requirements of both operation technology (OT) and IT, flexible and scaled use of drive systems and their software solutions is possible. Application developers can develop new control concepts in numerous high-level languages and for various platforms. Theses 1-4 enable an unhindered flow of information from the field to the cloud.

The drive system itself will be able to abstract its communication at various levels in order to enter into control-relevant, capability-based or business-oriented cooperation with other systems.

Challenges for R&D

- Manufacturer-neutral interfaces and information models (e.g. Field Level Communication (FLC) initiative of the OPC Foundation)
- Migration strategy for existing systems in the field
- New security mechanisms from IT to OT level
- Freedom of design for manufacturer-specific functions

Morphological matrix

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</table>

Thesis 12:
Design of drives – experience-based design, from engineering to pricing

Vision

For a load and movement profile, a drive system which can be immediately ordered is automatically configured from the individual components available on the market.

Short description

Today, manufacturers of drive components offer separate design tools to generate a suitable configuration with order information based on the required load and movement parameters. The prices relating to this order information are then inquired about from the respective manufacturer.

The isolated design tools become a design ecosystem in which components from various manufacturers can be selected based not only on technical parameters but also on delivery times and prices. This means users can immediately order the best possible solution both technically and economically and can access the manufacturers' global design knowledge.

Providers can align their portfolio in a better way based on customer requests and increase efficiency with regard to the Configure-Price-Quote (QPC) process.

Challenges for R&D

- Dynamic price information must be available to the customer in a transparent manner
- Design algorithms must determine the technically best solution for the customer problem manufacturer-neutrally
- Platform effects should be utilised but without the platform restricting direct contact between user and manufacturer (consulting expertise, formation of monopolies)
- Data security and sovereignty must be ensured

Morphological matrix

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</table>

5 Features and Capabilities of the Drive System 2030

When determining the future requirements placed on the manufacturers of drive technology, we must differentiate between the following: On the one hand, the electric drive system affects other technologies and sectors (outbound), on the other hand, "external" technologies influence the electric drive technology (inbound). The latter is to be regarded as a bottom-up approach from a technological perspective, e.g. in terms of module development, or top-down as a result of the impact of new approaches, e.g. platform technologies.

The following issues (not all of which can be discussed here) can serve as a line of thought for determining the requirements placed on "Drive System 2030".

"Drive System 2030" interactions between the sectors
- Bottom-up technology: What is the effect of innovation in the drive technology itself (outbound)?
- Top-down technology: What other technologies from the outside influence the "Drive System 2030" (inbound) and what capabilities are therefore required from the drive side?
- How is drive technology influenced by third-party stakeholders?
- How do market participants build a network?
- What are the options and effects for operators/owners of digital platforms?
- What role does the IIoT play?
- What are the benefits of data and information exchange for scrapping, recycling, circular economy, environmental and climate protection?
- …

Technology innovations that have an impact
- What is the role of technologies that generate information from data, such as blockchain, deep learning and AI?
- 3D printing, augmented/mixed/virtual reality
- How can cyber-security be ensured?
- …

Interaction of "Drive System 2030" with the sectors:

Today, electric drive technology already performs the majority of drive tasks in the industrial environment. By 2030, drive tasks in practically all areas will be performed by electric drive systems, 80 to 90% by controllable electric drives actuated by a variable speed drive or servo amplifier. This reduces the emission of CO2 (decarbonisation of production) and thus also provides a further driver for providing electrical energy with a low CO2 footprint (kg CO2 per kWh). The drive industry can therefore make a significant contribution to achieving the ambitious climate targets set by the federal government and society's demand for climate-neutral production.

The best possible design of the drive systems in terms of energy – i.e. the system approach – must come further to the fore to ensure maximum benefit is extracted from energy-efficient motors and their controllers: Drive systems must be designed such that the system performance is optimised for the drive task taking account of life cycle factors.

A careful examination of the process and optimum design of the drive system for the machine/plant are crucial to success. The use of corresponding design tools, including the simulation of the application, is a prerequisite, as is the use of internationally recognised standards for the design of an efficient drive system (IEC 61800-9-1).

Generally speaking, drive manufacturers must be more involved in the design of the machine/plant. The trend towards digital production entitled Industrie 4.0 and the standardised data available as a result will lead to the success of these processes.

In addition, electric drives will increasingly be used as sensors in process and production technology, as these by nature contain high-resolution information (from both a time and quality perspective) about the particular drive task. This will enable other technologies to obtain additional information about the production process through the fusion of data from many drives.

How is drive technology influenced by third-party stakeholders? What are the options and effects for operators/owners of digital platforms?

In future, there will be a shift towards the sale of drive performance in the sense of performance contracting. This provides the possibility for third parties to take action between the manufacturer of the drive system and the system integrator.

On the other hand, there will be efforts to establish "data dealers" for the handling and evaluation of data. On the one hand for technical reasons, because the data dealers have the relevant AI knowledge, but also for reasons of protection of trust, because the data dealer acts as a notary and keeps the initial data under lock and key.

Role of the IIoT

The dream is a completely virtual world, which digitally maps the complete drive system as well as the complete machines and the production process with a multi-domain approach (energy, design, movement control, IT wear and ageing). Realistically, we are still far from this and cannot expect it in a complete and reliable form before 2050.

For the Drive System 2030, there will be largely reliable part twins, which are able to digitally model, for example, the movement control of a machine with the energy consumption in a reliable manner including all error states. There will of course also be tools for sales, development etc.

Which other technology innovations from the outside influence the Drive System 2030, and what capabilities are therefore required from the drive side?

First, increasing electromobility will impact industrial drive systems. This affects the competition for resources such as components, e.g. electrical steel, power semiconductors etc., as well as skills and abilities such as engineers, technicians and skilled workers.

In the form of a modular system, the design methodology of drive systems can be further automated, and the drive components based thereon can be flexibly exchanged. This enables the customer to procure components from different suppliers and, for example, react flexibly to new products or discontinuations. This helps with later recycling. This trend towards greater flexibility will largely replace the trend still prevailing today of higher efficiency and performance density – except in the case of special applications.

On the material development side, 3D printing technologies must be mentioned. In 2030, it will not yet be possible to completely additively produce series products, but 3D printing methods will accelerate prototype construction and possibly also change spare parts business.

In the area of wide bandgap semiconductors, in particular SiC, there will be further cost reductions. We can assume that the prices for SiC-MOSFETs will fall by around 30 to 40% by 2030. SiC-MOSFETs will thus also become attractive for generally cost-driven industrial drive systems, because advantages of the installation size can be achieved through smaller coolers or smaller intermediate circuit capacitors. However, as a result, there will be greater pressure for the insulation and bearings of the electrical machines to cope with the high slew rates of up to 50 kV/μs.

In addition, research work will be carried out in the field of dielectrics for capacitors with rel. permittivity > 40. There is a good chance that by 2030, new kinds of capacitors with double the energy density will be available, permitting a more compact design of the power electronics.

The increasing computing power and the design of processors that specialise in machine learning will enable the drives to perform "higher-quality" analyses of the data available in the drive, thus enabling independent commissioning, for example. In addition, these methods also provide the opportunity of analysing in real time large volumes of data supplied by a large number of drives, for example within a machine tool. This will be made possible thanks to the increasing connectivity of the drive components at field and automation level.

However, we must at this point warn against a certain overstatement: Where traditional methods based on drive technology knowledge work satisfactorily, the use of AI is simply superfluous.

With regard to cybersecurity, cost-effective and faster processors, new encryption methods and high bandwidth will positively impact communication.

6 Business models, value chains

In the coming years, business models for drive systems could see a fundamental change. Today's largely product-oriented models will become usage-based. And usage-based models will in turn become result-oriented. Result-oriented business models will, sooner or later, turn into platform-oriented models. These four largely consecutive development steps are described briefly below in terms of value proposition, value creation architecture, network and finance. The chapter concludes with a vision for 2030.

Step 1: In production-oriented business models, the value lies in the product itself. The drive system is purchased as an investment good, the customer relationship ends with the sale of the product. Value creation is organised in traditional value chains. Suppliers supply to the drive manufacturer, the manufacturer assembles and supplies to the customer. A one-time fixed price is set for the product. In some cases, simple additional services such as repairs and the supply of spare parts are offered.

Step 2: With the usage-oriented model, service becomes more important. The value now lies not only in the product itself, but also in accompanying, more complex services such as maintenance, repair, overhaul and so on. Supply chains become more complex. Service networks are built up alongside the product-oriented supply chains. The product is offered for example in the form of a rental or leasing model. Relationships between the manufacturer of the drive system and the customer are more intensive across the entire product life cycle.

Step 3: Result-oriented models are characterised in that the product itself shifts to the background. The result of application of the product is of value to the customer. The customer doesn't want to buy the drill or the drive system, but rather the hole in the wall or the movement. Originally product-oriented supply chains have become service systems. The different roles in a complex business ecosystem contribute to the value creation process. At the end of the day, the customer no longer pays for a product or service, but for the result.

Step 4: In the fourth step, drive power is traded on service platforms. The platform is no longer used to develop and implement products or services, and instead is used to reconcile demand with the supply of drive performance and to support the corresponding transactions. The value now lies not in the product and service but in the network. There is an ecosystem behind the platform. The customer pays the platform for the mediation service and the provider of drive performance for the movement.

Examples from other sectors show that it can make sense to follow this development path. For example, the company ALD Vacuum Technologies implements a mixture of steps 1 and 2 with its "Own and Operate" model. Kaeser Compressors and Rolls-Royce use "product-as-a-service" models to market compressors and aircraft turbines. The step from the result-oriented business model to the platform is particularly challenging. Platforms can disruptively change the power structure in value creation systems. In the area of wind power plants, for example, the US company Sentient Science has established itself in the value chain between the suppliers and operators of turbines, and has thus significantly changed the established value creation systems and the power structures in them.

The above-mentioned examples are discussed in the following four case studies based on the literature[3]:

1. Case Study: Sentient Science [1] [4] [7]

In cooperation with a mathematics and statistics software manufacturer and a cloud provider, the start-up Sentient Science developed the "DigitalClone" platform to visualise wind power plants and monitor their states. The data for forecasting the future operating states of wind power plants is provided by material science analyses for example about the actual material quality of individual components of the plants. With the "software-as-a-service" offering from Sentient Science, the customer can determine the risk of the plant failing, launch measures to extend the life of individual parts at an early stage, and achieve more favourable conditions for maintenance agreements. The start-up benefits from revenue generated by a monthly usage fee, other customer-specific billing options and valuable industry knowledge.

2. Case Study: Rolls-Royce [3] [8]

The traditional business model of UK aircraft turbine manufacturer Rolls-Royce is based on selling aircraft turbines to airlines. This classic product business is changing with the introduction of the performance-based contract approach, i.e. result-oriented payment. Rolls-Royce is innovating its business model with the introduction of the "Power-by-the-Hour" concept. In this "non-ownership business model" (NOBM), the turbine is not transferred into the airline's possession, and instead billing is based on hours of operation. Therefore, the value of the turbine now lies in the service offering and no longer primarily in the product usage. Responsibility for the operating state of the turbines, including cost factors such as maintenance and repair, is covered by the price per hour of operation. The airline benefits from lower capital commitment, more variable fixed costs and certainty with respect to the availability of the turbines. With the new business model, Rolls-Royce has continuous streams of revenue, which increase profit and enable long-term customer retention.

3. Case Study: Kaeser Compressors [5] [2]

Kaeser Compressors SE is a German manufacturer of air compressors for industrial use. The traditional Kaeser business model was based solely on the sale of the plants. As part of the digital transformation, the company asked itself what its customers actually needed (possession of compressors or needs-based availability of compressed air), and this has led to an incremental change in the company's business model. With the "Air-as-a-Service" offered by Kaeser, the company no longer sells the plant to the customer. Instead, it ensures the availability of compressed air as needed. As a result, Kaeser generates revenue not from the sale of plants but from the fee per cubic metre of compressed air used. Customers benefit from a higher availability of the plant, lower capital commitment and thus a reduction in risk and higher flexibility. Maintenance air repair, which can be carried out particularly efficiently with the use of IoT technologies, is carried out by Kaeser and is included in the service fees. A further advantage for Kaeser is the retention of customers over the long term.

[3] References:

[1] Alvarez, E. & Ribaric, A. (2017). "An improved-accuracy method for fatigue load analysis of wind turbine gearbox based on SCADA". Renewable Energy. Vol. 115, pp. 391-399.

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[3] Emprechtinger, F. (2018). "3 berühmte Geschäftsmodellinnovationen und was man davon lernen kann" [3 famous business model innovations and what can be learned from them], accessible at:

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[5] Hewlett Packard Enterprise Development LP (2020). "Ein Schwermaschinenhersteller nutzt das industrielle IoT, um Systemausfallzeiten bei Kunden um 60 Prozent zu verringern" [A heavy machinery manufacturer uses the industrial IoT to reduce system downtimes at customers by 60 percent] accessible at: h20195.www2.hpe.com/V2/GetDocument.aspx?docname=A00001469DEE.

[6] Robers et al. (2010). "Geschäftsmodellinnovationen – Neue Wege am Markt beschreiten" [Business model innovations – forging new paths on the market], accessible at:

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[7] Sentient Science (2020), accessible at: www.sentientscience.com/company/

[8] Smith, J. D. (2013). "Power-by-the-hour: the role of technology in reshaping business strategy at Rolls-Royce". Technology Analysis & Strategic Management, Vol. 25, No. 8, pp. 987-1007.

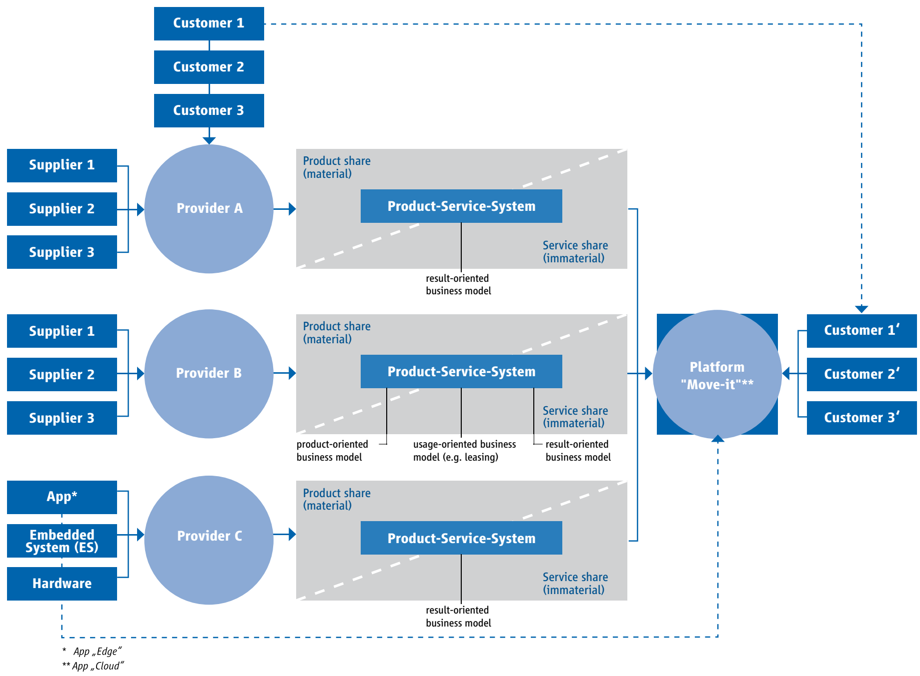
4. Case Study: ALD Vacuum Technologies [6]

Machine and plant builder ALD Vacuum Technologies GmbH is one of the world's leading providers of plants and services in the field of vacuum process technology. The company innovated its traditional product business with the sale of plants in the direction of an "Own & Operate" offer. Here, in contrast to the non-ownership business models (see the example of Rolls-Royce and Kaeser), the product is still sold to the customer. What is different about this business model innovation is that the ongoing service of optimum machine operation is also sold. The customer thus benefits from the manufacturer's comprehensive expertise. With the new business model, ALD Vacuum obtains valuable industry knowledge, continuous access to real application data, a higher degree of plant usage and higher sales thanks to the "Operate" contracts.

Figure 1 below describes a vision for the future. The core element is a platform for the sale of drive power. Providers can offer drive systems as a product or a service and market them via the platform. The same applies for added-value services and bought-in parts. The drive system of the future requires not only the machine itself but also the embedded microelectronics, software and data. The bought-in parts themselves can also be traded via the platform. Platform operators, drive manufacturers and suppliers of bought-in parts form the basis for the development of a complex ecosystem. The role a traditional drive manufacturer plays or wants to play in this ecosystem must be decided by each company in a comprehensive strategy determination process.

Fig. 1: Product/service system

(from Weißfloch, 2013 based on Tukker, 2004)[4]



Source: ZVEI

In addition to the manufacturers of drive systems, other stakeholders of the value chain are involved. New elements of the value chain will also emerge, and thus also new stakeholders. Examples include specific providers for ICT, such as cybersecurity or blockchain technology as a further platform, which complement the drive value chain with software licence models.

In particular the horizontal integration of existing enterprise resource planning systems of companies in the value chain will require the aforementioned specific providers for IT. Not least, this will result in the digital incorporation of logistics in a complete value chain process right through to the end customer, such as the plant operator.

7 Summary

This Drive System 2030 white paper is intended to contribute to the discussions to ensure successful implementation of Industrie 4.0 and addresses the subjects of technology development, digital infrastructure and interoperability in digitally run economic systems. The approach addresses requirements that norms and standards still need to meet. There are also considerable legal hurdles to overcome before many of the proposed theses can be implemented. This applies in particular to the difference between possession and ownership and warranty claims derived from this between the participants in the value chains.

Whether some of the theses can be implemented is also not least a question of change management and the behaviour of the market participants. In any case, the theses involve opportunities and risks for the market participants, particularly because data, platforms, innovative technologies and new customer expectations will change the creation of value for manufacturing companies.

[4] References:

Tukker, A. (2004): “Eight types of product-service system – Eight ways to sustainability, Experiences from SusProNet”. In: Business Strategy and the Environment, Vol. 13, No. 4. P. 246-260:

Weißfloch, U., Schlummer, M., Jäger, A., Merk, S. (2013): “Chancen für die nachhaltige Entwicklung durch neue hybride Wertschöpfungskonzepte” [Opportunities for sustainable development through new hybrid value creation concepts], closing report of the “HyWert” project, Stuttgart.

Abbreviation

CPQ	Configure-Price-Quote
ERP	Enterprise Resource Planning software
FLC	Field Level Communication
FW	Firmware
HW	Hardware
IoT	Internet of Things
IIoT	Industrial Internet of Things
IT	Information Technology
ICT	Information and Communications Technology
AI	Artificial Intelligence
OT	Operation Technology
PLC	Programmable Logic Controller
RAMI 4.0	Reference Architecture Model Industrie 4.0
SaaS	Software-as-a-Service
SW	Software
USP	Unique Selling Point
Xaas	"Anything-as-a-Service" or "Everything-as-a-Service"

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