PORTFOLIO MANAGEMENT FOR ELECTRIC DRIVES IN POWERTOOLS AT HILTI: CHALLENGES AND SOLUTION APPROACHES

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Abstract

The Hilti product portfolio contains a wide spectrum of electric powertools for construction professionals. The electric drive is an important subsystem within the powertools and a decisive driver for differentiation, but also a source of growing complexity due to its mechatronical character. At the interface between tool and drive development, this leads to increased technical and organizational challenges.
This contribution presents an approach towards portfolio and complexity management at the Hilti Electronics & Drives development based on product platforms. The first aspect includes a recently introduced platform process as a means for an efficient organization of the platform development. A second aspect deals with creating more transparency in the portfolio, based on a structured visualization of the system architecture. Finally a concept is presented towards more conscious decision making in portfolio management, including a classification of decision situations and a guideline for the decision making process. The methodology is applied at Hilti since roughly one year, the feedback and effects are rather positive and the methodology is continuously expanded.

Keywords: Decision Making, Mechatronics, Platform Strategies, Portfolio Management, Visualisation

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

Hilti is one of the leading companies for products, systems and services for construction professionals. The company has specialized itself in providing its customers with system solutions along the whole process chain. The Hilti product portfolio contains a wide spectrum of electric powertools, e.g. rotary drillhammers, circular saws, angle grinders and diamond drilling systems.
The electric drive is an important subsystem within the powertools and a decisive driver for differentiation, but also a source of growing complexity due to its mechatronic character. The Hilti electric drives are characterized by a modular platform architecture which offers considerable benefits such as reducing efforts in product development and increasing economies of scale in the supply chain. However, the corresponding complexity also brings about a number of challenges with respect to technical and organizational aspects.
In the scope of this contribution, portfolio management is considered from two perspectives: the product perspective addressing the portfolio of powertools and the subsystem perspective addressing the portfolio of electric drives. Both portfolios are highly interconnected and undergo constant change and development. Each decision concerning the type of drive for a new tool has an impact on the particular product and its value proposition as well as on the tool and drive portfolio as a whole.
This paper represents a case study from a practitioner's point of view. Chapter 2 depicts the current situation of developing and managing the Hilti product portfolio and derives corresponding challenges with a particular focus on the interface between tool development and drive development. Chapter 3 summarizes the relevant state of the art in research and discusses its applicability to the given company context. Chapter 4 presents currently pursued approaches at Hilti. Chapter 5 concludes this paper with a summary and outlook.

2 OUTSET SITUATION AND CHALLENGES

The outset situation of product portfolio management at Hilti at the interface between tool and drive development is characterized by giving an overview over the product portfolio, the process landscape and the company organization structure.
From a sales and marketing perspective, the **Hilti product portfolio** is structured into product lines, e.g. breakers, combi hammers, rotary hammers or cutting and grinding. From an engineering perspective, the product portfolio can be structured according to drive technology (see figure 1 on the left). Here, the main parameters are type of power supply (AC supply for corded applications vs. DC supply for cordless applications) and type of commutation (brushed drives with mechanical commutation vs. brushless drives with electronical commutation).
The product structure of an electric powertool shows a distinct modular character. Typical modules are e.g. chuck, hammering mechanism, gearbox, motor, electronics, switch and handle (see figure 1 on the right). The system scope of the electric drive covers the motor, the power and control electronics and the switch. In corded tools, the power cord is included, in cordless tools the battery and charger are also part of the drive system.

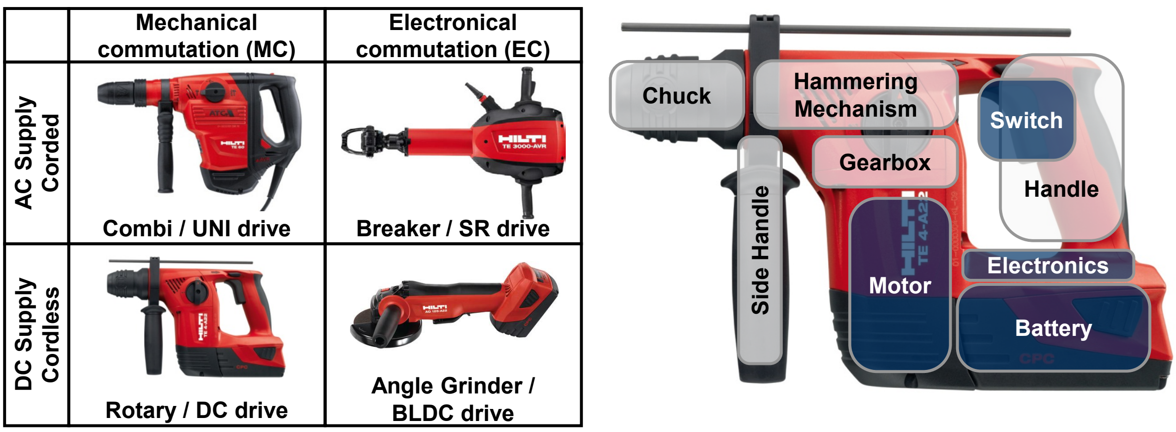

Figure 1. Portfolio structure (left) and product structure (right) of Hilti powertools

The **Hilti process landscape** is structured (in a simplified way) into the areas technology, TTM and product care. The TTM („time to money") is the standard serial implementation process for Hilti products covering five phases from product definition to market introduction. New technologies are developed in the scope of technology projects. Before the start of a TTM project the level of maturity of all relevant technologies is assessed. Only mature technologies are included in the TTM project in order to avoid time and money consuming loops in the TTM project resulting from immature technologies or lack of system understanding. Has a product been introduced into the market and the quality been validated, the responsibility is handed over to product care.
The **Hilti organization structure** features typical matrix character (see figure 2). The responsibility for the products lies within the Business Units (BU), which include the functional units project management, product development, product management (marketing) and supply. The Electronics & Drives department is part of the Technology department, and consists of the functional units motor design, mechanical design, electronics hardware (for corded tools and cordless systems), embedded software, drive technology and drive testing. The competence center Electronics & Drives is responsible for the specification, development and testing of drive technologies and systems and is therefore closely interconnected to the Business Units Power Tools & Accessories and Diamond Systems. Fundamental drive decisions are usually taken in a common dialog with the BU representing the market, customer and application perspective, whereas the Electronics & Drives department represents the technology perspective, including production and supply chain aspects.

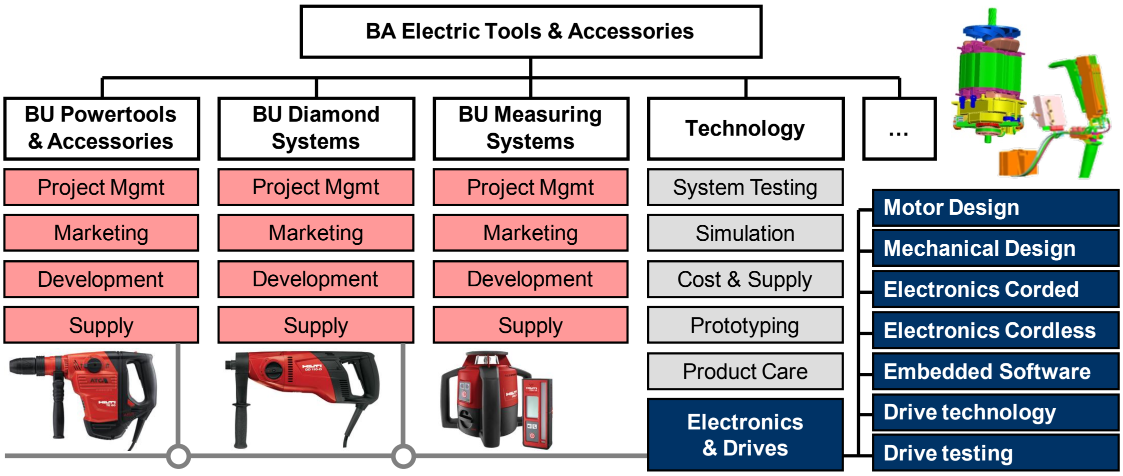

Figure 2. Organization of product development at Hilti

At the interface between tool and drive development at Hilti, there exist a number of hurdles and obstacles. The most essential challenges with relevance to this contribution are structured according to the categories product, process and organization and are briefly outlined:

- **Product:** there is a lack of transparency in the portfolio concerning the correlations between tools and drives. This leads to local optimizations from a single product perspective without utilizing synergies through commonalities (e.g. regarding concepts, components, processes or suppliers). The consequences are an uncontrolled growth of unnecessary variety in the portfolio.
- **Process:** uncertainties and high dynamics impede the synchronization between tool and drive development. System requirements are often still unclear in situations where decisions for the drive concept have to be taken in order to meet the project timeline. Changes in requirements frequently occur in situations where the design has already been defined. The consequences are either suboptimal solutions or iterations and project delays.
- **Organization:** there is a high coordination effort in decision making processes. A multitude of stakeholders with different perspectives and objectives has to be considered in portfolio decisions, especially concerning the drive as a central subsystem. Conflicts of interests occur between the project and the portfolio perspective. The impact of decisions concerning issues related to variety and complexity are often not tangible, resulting in a tendency towards local optimization in favor of the project perspective and creation of additional variety at the disadvantage of the portfolio perspective.

3 STATE OF THE ART IN RESEARCH

In the following, the state of the art in research is considered with relevance to the depicted topics and challenges, first from a technical and secondly from an organizational perspective. The conceptual framework provided by literature is then compared to the specific situation at Hilti, discussing its applicability and deriving requirements towards creating support.

3.1 Technical perspective: product family, product architecture, product platform

In the context of product portfolio management, the concepts of product family, product platform and product architecture play a central role. These highly related concepts have received much attention in literature in the past decades, see e.g. (Jiao et al. 2007) for a comprehensive overview.

A **product family** is defined as a set of products that share common technology and address a related set of market applications (Meyer and Lehnerd 1997). The interpretation of product families depends on the perspective: the marketing and sales view focuses functions and features as common elements, the engineering view defines a product family based on common technology (Jiao et al. 2007). A **product platform** is defined as a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced (Meyer and Lehnerd 1997). A product platform is therefore the technological foundation of product families.

There are two types of approaches for **platform-based product family design**: for scalable platforms, scalable variables are used to "stretch" or "shrink" the product platform in one or more dimensions to satisfy a variety of customer needs (Simpson et al. 2001). For modular product platforms, a configurational approach is applied by adding, substituting and/or removing one or more functional modules in order to derive product family members (Jiao et al. 2007). In order to satisfy performance and economic requirements, the optimal values for common variables and distinctive variables need to be determined.

Product architecture is defined as the scheme by which the function of a product is allocated to its physical components. This includes the arrangement of functional elements, the mapping from functional elements to physical components and the specification of the interfaces among the interacting physical components (Ulrich 1995). Jiao and Tseng extend the view on product architecture from a single product to the consideration of product families. Their **product family architecture** (PFA) concept consists of three perspectives: a functional, behavioral and structural view (Jiao and Tseng 2000). Kissel and Lindemann use the more general term system architecture in their study of the dependencies and interrelations of components and functions across several products and product families within the portfolio (Kissel and Lindemann 2013).

Product family architecture involves two major characteristics: the modularity of the product structure and the commonality among product variants (Jiao and Tseng 2000). The main concern of **modularity** is decomposition, i.e. the task to separate a system into independent parts or modules that can be treated as logical units. Concerning typology, a basic distinction is made in integral and modular architectures. Ulrich argues that most products or systems will embody hybrid modular-integral architectures. He further relates product architecture to product performance (defined as how well the product implements its functions), stating that local performance characteristics can be optimized through a modular architecture, whereas global performance characteristics can be optimized through an integral architecture (Ulrich 1995). The product architecture (modular vs. integral) in combination with the component process flexibility (high vs. low) dictates the economics of producing variety. **Communality** characterizes the grouping of similar module (product) variants of a special module (product) type that is characterized by modularity. The main concern of commonality is clustering (Jiao and Tseng 2000). The relation between modularity and commonality is embodied in class-member relationships. A class of products (product family) is described by modularity and product variants differentiate according to the commonality between module instances.

At Hilti products are classified according to business segments and product lines. There exists a hierarchical **product portfolio taxonomy** that distinguishes product lines, product clusters, product classes, product families, product types and sub-types. A product family in the Hilti understanding therefore covers a narrower scope of product variants. There are various attributes that serve as common denominators for establishing family relations from a customer perspective, such as power / weight class (e.g. 7 kg breakers, 10 kg breakers), type of handle (e.g. D-handle, T-handle) or battery voltage (e.g. 22V, 36V).

The general product architecture of powertools features modular character. Whereas the "business end" of the tools shows high diversity and is mainly specific to the application (drilling, sawing, coring, grinding etc.), commonalities can be created in particular on the drive side, where platform approaches have been established successfully. The platform scope for electric drives covers around 10 different product lines. The architecture of the electric motor follows established rules which are standard in this technology field and are e.g. described by Meyer and Lehnerd in the example of Black & Decker consumer powertools (Meyer and Lehnerd 1997). The common base and therefore the backbone or constituent parameter of the platform for electric motors is the lamination of rotor and stator. A scaling and stretching is realized by adding stack length (see also Simpson et al. 2001). Variant specific parameters such as the winding (wire diameter, number of windings, winding scheme) can be realized economically through a high flexibility in the production process (variation of process parameters).

Jiao and Tseng discuss the challenging task to generate a coherent view on the three seemingly divergent perspectives (functional, behavioral, structural), because the knowledge resides in different organizations (Jiao and Tseng 2000). At Hilti this is also the case, additional changes in perspective occur at the interface between system and subsystem. BU representatives are closer connected to the customer, marketing and application perspective (functional and behavioral view on system level), whereas representatives from the Electronics & Drives department are closer connected to technology, process and supply chain issues (behavioral and structural view on component level). Additional perspectives making it even harder to generate a coherent view result from the mechatronic character (mechanical design, electronics hardware, embedded software).

Besides the multi-perspective issues, the lack of visibility of underlying correlations increases the challenge. Communalities are often realized on a conceptual level (behavioral view) rather than purely on the physical level (structural view). This leads to problems in creating a mutual system understanding between all stakeholders, because commonality is not visible, e.g. when comparing different motors with the same cooling concept or different electronics basing on the same schematics. The result is a general lack of transparency of interrelations between the tools and their drive subsystems across the whole portfolio.

3.2 Organizational Perspective: platform process and decision making

In this section, the question will be addressed how the concepts of platform-based product families respectively product architectures can be embedded and put to practice into the product development process and the organization.

Jiao et al. distinguish four major phases of a **platform design process** (product definition, product design, process design, supply chain design). These phases represent transformations or mappings between the relevant domains (customer, functional, physical, process and logistics domain) (Jiao et al. 2007). The development process for product family architecture (PFA) according to Jiao and Tseng contains the following steps: development of the modularity design space, development of the communality design space, mapping from modularity design space to commonality design space, development of the PFA design space (Jiao and Tseng 2000). Hölttä-Otto describes a process for modular platform architecture design which also deals with modularity and communality and includes the creation of and selection among platform alternatives (Hölttä-Otto 2005).

At Hilti, the stages of transforming customer needs into functional requirements, design parameters, process and logistics variables are carried out for single products in the scope of the TTM process. Each business segment responsible for certain product lines has their own roadmap. In management and strategy processes the individual roadmaps are aligned in order to synchronize activities and projects where the need arises due to planned communalities across the portfolio.

However, high dynamics in the process, frequent changes in requirements, competitor responses, changes in technologies, learnings from development and testing iterations etc. complicate the planning and development of single products and even more the leveraging of communalities across the portfolio. A major prerequisite for synchronizing project activities is a coordinated flow of information. However, the organization of product development at Hilti can be characterized as rather decentralized with many self-responsible and independently acting stakeholder groups (project teams or functional units). The way to approach operational development tasks can be labelled as "informal and experience based". There exist few explicitly documented standards, the proceeding in projects is highly dependent on the involved persons (experience, personal working style etc.).

Summing up, process frameworks for product family architecture respectively platform design affect considerably large parts of an organization. Literature offers a wide range of concepts and guidelines for linking front-end to back-end issues by consistent transformations or mappings between domains and perspectives. For putting these concepts into practice in an organization and guarantee sustainability, appropriate implementation strategies are required. Sometimes, even the success stories contain no entirely happy endings: "Institutionalizing the rules, tools and disciplines of shared architecture is especially difficult as organizations change and new managers come into power" (Meyer and Lehnerd 1997).

Kreimeyer describes a company-specific product architecture design process framework that was introduced at a major German commercial vehicle manufacturer (Kreimeyer 2014). The framework was developed based on the state of the art and industrial practice. It was meant to help ensure that architecture design at the company would be complete, consistent and correct. Another goal was to help communicate the idea of architecture. In order to be practicable, the framework was set up as a table containing topics and tasks of the architecture process. The actual value delivered by the architecture process was summarized by Kreimeyer in four principles: generate transparency, foster communication, prepare decisions and manage complexity.

Thus, one of the main tasks in product portfolio management as well as system architecture design is the support of **decision making**. The high number of entities and dependencies to be considered in combination with the lack of transparency, when dealing not only with a single product, but a product family or the whole product portfolio, causes high complexity (Kissel and Lindemann 2013). A multitude of different types of development decisions can be distinguished that show strong interdependencies. Krishnan and Ulrich discuss a clustering of product development decisions according to traditional functional categories (marketing, engineering design, operations). They propose a different clustering of decisions (in the categories product, portfolio and architecture) with the aim to minimize the interdependencies among clusters (Krishnan and Ulrich 2001).

Decisions in the context of product family architecture need to be made concerning the level of modularity and commonality. Industry requires clear and simple **metrics** that are easy to derive with available information to assess product architectures. A large variety of metrics has been developed as a means for decision support (see e.g. Martin and Ishii 2002, Hölttä-Otto 2005). Heilemann et al. conclude however, that there is a weakness of available metrics concerning their applicability und understandability (Heilemann et al. 2013).

In the context of developing and managing the drive portfolio, many different stakeholders with varying perspectives and objectives need to be involved in decision making processes. For drive development at Hilti, support is needed for platform decisions considering width and depth of the platform approach. For an electronics e.g. frequently the question arises which level of platform should be applied: common schematics only or also common layout and PCB structure?

3.3 Need for action and requirements

Based on the reflection of the state of research, three major requirements with respect to optimizing portfolio management at the interface between tool and drive development at Hilti are derived. These focus topics show a strong resemblance to the principles discussed by (Kreimeyer 2014).

- **Create transparency:** Because of the increased complexity in the context of product platforms and product family architecture, a clear visualization of correlations in the portfolio is of high importance. The benefit of product-related visualizations is also underlined by (Krause et al. 2013) who present the Module Interface Graph (MIG) as a method for visualizing correlations in the product structure. In addition, a visualization is needed going beyond the single product in order to assess the implications of changes e.g. of common parts within the platform on the entire product portfolio (Kissel and Lindemann 2013).
- **Promote synchronization:** Support the synchronization between tool and drive development, foster communication and information flows between relevant stakeholders, reduce unnecessary iterations and project delays.
- **Support decision making:** Reduce the coordination effort in portfolio decision making processes, consider all relevant perspectives and objectives, manage conflicts of interests between the project and the portfolio perspective, create transparency concerning the impact of decisions on the whole portfolio.

4 SOLUTION APPROACH

In order to meet the described challenges, Hilti currently pursues a number of approaches that are based on concepts established in research, focusing on practicability in the given company context. In the following the topics transparency in the portfolio, platform process and conscious drive decisions are presented and discussed.

4.1 Transparency in the Portfolio

Based on existing concepts of platform and architecture design in literature, an approach towards more **transparency in the portfolio** has been developed in the last three years in the Electronics & Drives department at Hilti with the support of partners from academia (Lock 2013, Deimling 2013). The approach includes a model for displaying the system architecture, a guideline for analyzing the system architecture and a graphical representation of relevant sections of the portfolio.

The **system architecture** comprises a vertical dimension (product structure), where the modularity of the system is visualized, and a horizontal dimension (program structure), where communality and variety is visualized. Figure 3 shows the model of the system architecture, where both dimensions are displayed in a matrix, enabling structured views on the multivariant product portfolio.

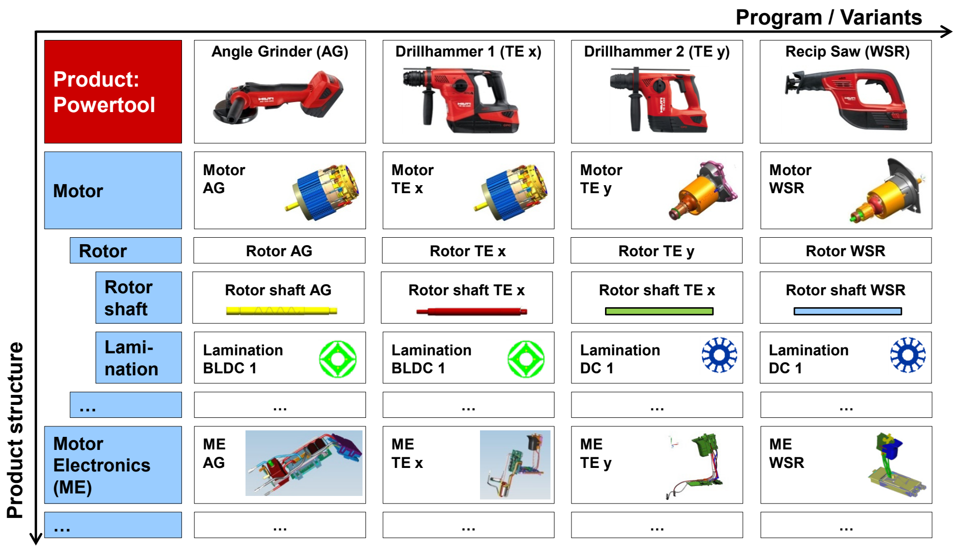

Figure 3. Model for visualizing the system architecture

The **guideline for analyzing the system architecture** (Deimling 2013) consists of 4 steps (see figure 4). In **step 1**, the scope within the entire portfolio is defined, i.e. the relevant components and products are selected for further consideration, depending on project situation and task. Example: Within the product structure, motors are regarded, within the product portfolio, the focus is placed on battery tools. **Step 2** deals with the analysis of variety on the component level. In the example, all parts of the motors in battery tools are compared. This analysis shows that, despite of the platform approach, the variety on component level is still rather high. While the lamination of rotor and stator as constituent part of the platform is common for all variants on the motor platform, the rotor shaft is often unique. Therefore all assemblies on a higher level (rotor assembly, motor assembly) have different material numbers, the commonality is not visible on the physical level.

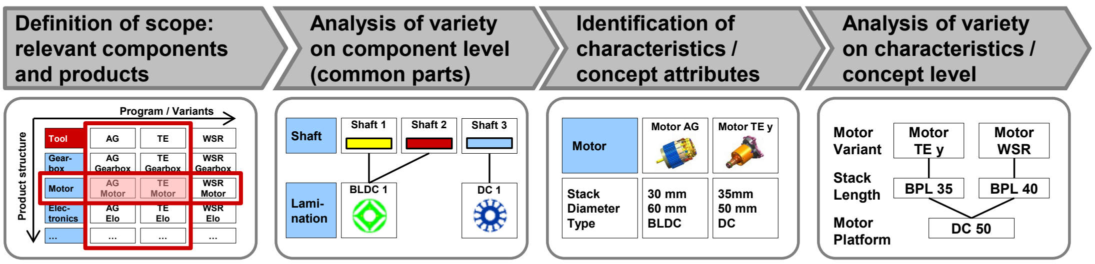

Figure 4. Guideline for analyzing the system architecture

Therefore, in **step 3** an analysis is carried out concerning major characteristics and conceptual attributes that define commonality and variety of variants within the platform, such as motor type, motor lamination, motor stack length etc. **Step 4** contains the analysis of variety on conceptual respectively attribute level. Hereby, the logic of variant generation and correlations within the platform become visible. Invariant and variable parameters can also be distinguished.
The result of the analysis can be displayed in a **graphical visualization** of the focused parts of the portfolio. Figure 5 shows an exemplary visualization for motors (so called "motor poster"). In the lower part the logic of variant generation becomes visible, which is based on the following parameters: 1) motor type, 2) motor lamination, 3) stack length. A motor platform contains all motors within one motor type and a particular lamination (e.g. UNI 1, UNI 2). Within the platform, there exist a number of different stack lengths, which enable a scaling of performance (output power). In the upper half of the poster all powertools are arranged that utilize the corresponding motors. The specific motor e.g. of battery rotary hammer 1 or battery screwdriver 1 contains a certain amount of variable elements, e.g. the winding, which enable an adaptation of the motor to the particular tool requirements.

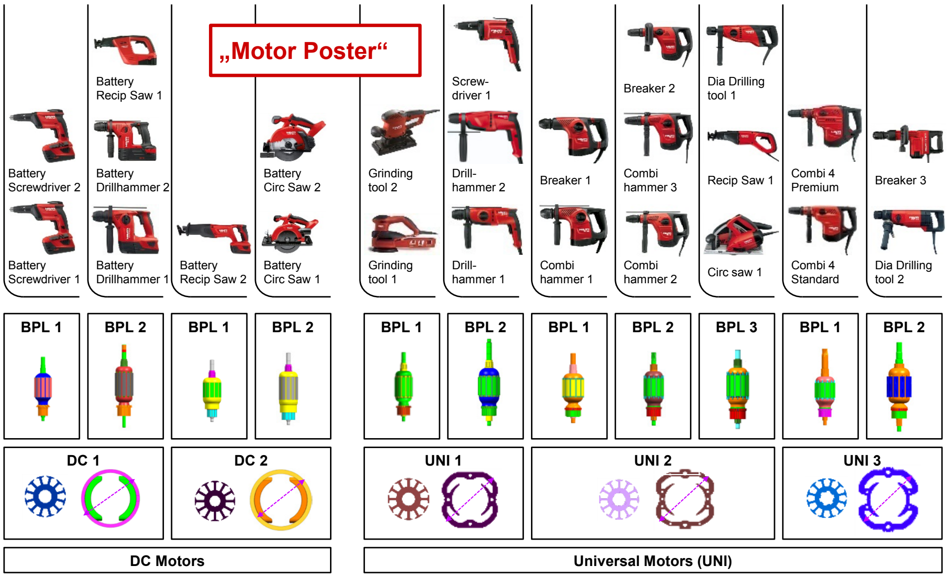

Figure 5. Transparent visualization of portfolio correlations

4.2 Platform Process

Traditionally, the electric drive has been developed in the TTM projects of the corresponding tools. Recently, two major organizational novelties were introduced in the context of developing platform drives: the platform process and the role of the platform project leader. The **platform process** contains similar phases compared to the TTM process, but it refers to the platform component. Until now two major new drive platforms have been developed to serial maturity according to this new process.

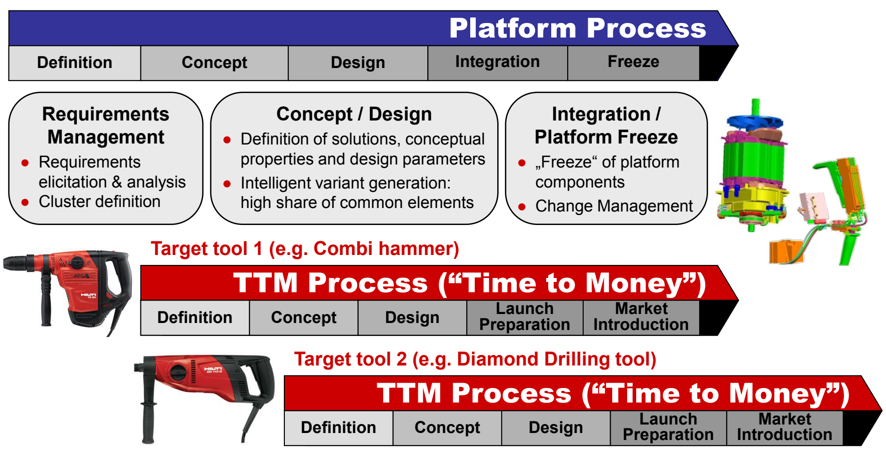

Figure 6. Hilti Platform Process and link to the TTM Process

The platform process is structured into three phases (see figure 6). The first phase deals with **requirements management**. The requirements of possible target products are collected and analyzed. Based on that, clusters of products are derived with a sufficient common base, while assuring that the compromises for individual products are still acceptable. For an electric motor, relevant criteria for cluster definition are among others performance (torque, rpm), design space, robustness (e.g. against dust, debris, humidity, mechanical forces) and dynamic features (e.g. braking time of drive). In the **concept and design phase**, the conceptual properties are defined (e.g. cooling concept, contacting concept, commutation concept, assembly concept) and major design parameters are set (e.g. geometry of the lamination, rotor and stator diameter, stack length, distances between bearings etc.). Here, an intense coordination between platform project and tool projects is necessary. The last phase is the **integration and platform freeze**. After "freezing" platform components, changes are not generally prohibited, but the barriers are increased. From this point on, changes should be considered thoroughly, taking into account the consequences from project as well as portfolio perspective.
The platform setup leads to an increasing technical and organizational complexity. There is at least a "triangular relationship" between platform project and the TTM projects of two (or more) target products. Here, the **project organization** plays a significant role in order to provide the required information flow but remain efficient. The establishment of so-called "bracket functions" (central roles for coordination of technical and organizational issues) has proven beneficial, carried out e.g. by the platform project leader and the technical project leader responsible for the platform drive.

4.3 Conscious Portfolio Decisions

The transparency concerning the correlations in the tool and drive portfolio is an essential factor for a target-oriented further development of the portfolio, e.g. if a drive decision needs to be taken for a new generation of certain tools. In this context, an approach for supporting **conscious portfolio decisions** has been developed, including a classification of decision situations and a guideline for the decision making process (Lock 2013).
On strategic as well as on operational level, frequently decisions are taken with a certain impact on the tool and drive portfolio. The **classification of decision situations** (see figure 7) helps to make the importance of each situation for the portfolio transparent and locate each situation within the process landscape. Basically, a distinction can be made in decisions of choice (Which technology / concept / supplier shall further be considered?) and Go/NoGo decisions (Is the technology TTM ready? Can the serial tools be released?). The **guideline for decision making** contains a general procedure applicable for all decision situations with specifics depending on the particular situation type.

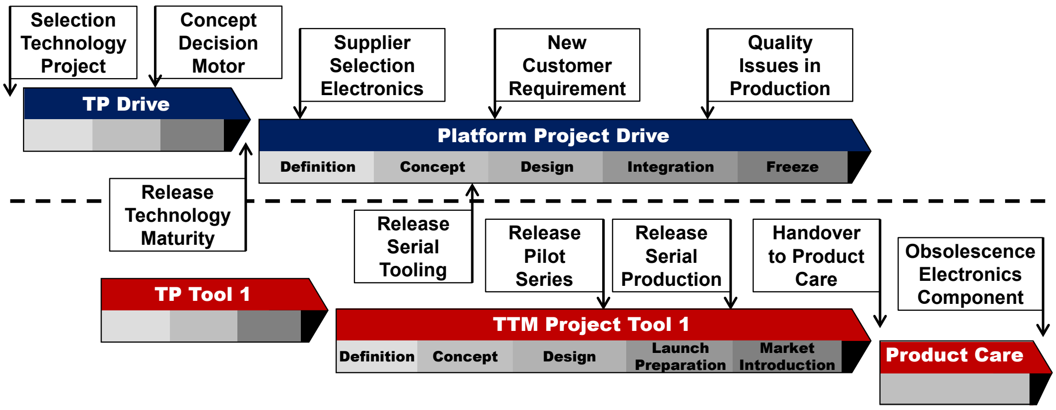

Figure 7. Classification of decision situations

Finally, in the model of the system architecture decisions with an impact on the portfolio structure can be visualized, e.g. referring to options concerning the **modularity** of the product. Example 1: Shall power unit and control unit of the electronics be realized as separate parts or as an integral part? Example 2: Shall the switch be assembled to the electronics with a fix or a separable connection? Closely related to the question of the optimal level of modularity and the design of the interfaces is the question concerning the optimal level of **communality** that can also be illustrated in the model: Which elements shall be standardized or designed differently? A modular design of the electronics may be reasonable if the standardization of the control unit generates high synergies in development.

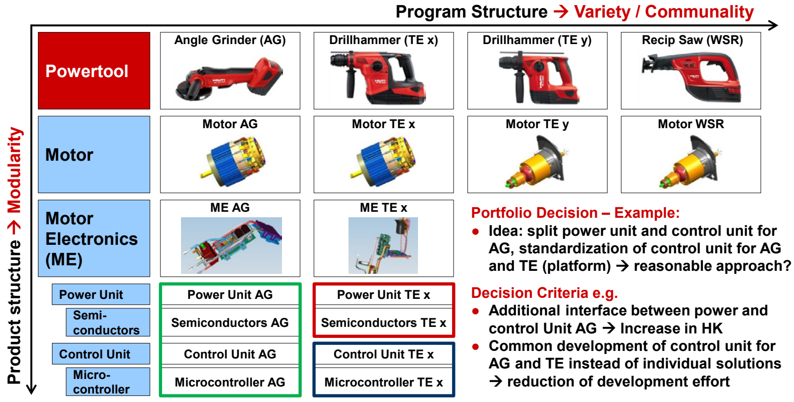

Figure 8. Conscious portfolio decisions: defining modularity and communality of the system

5 CONCLUSION

Based on existing concepts in literature towards product architecture and platform design an approach has been developed aiming at the support of portfolio management for electric drives at Hilti. A major requirement is to create transparency with respect to correlations in the tools and drives portfolio. A graphical visualization has been developed, where selected portfolio details and perspectives can be displayed and analyzed, e.g. according to the logic of variant generation. This instrument serves as enabler for facilitating communication and information exchange among different stakeholder groups involved in product development. In addition with the newly established platform process this helps to synchronize project activities and decision making processes at the interface between tool and drive development. The methodology has been applied at Hilti since roughly one year and has received positive feedback. However, the effects e.g. on the quality of portfolio decisions still have to be verified. Beyond that, the methodology is continuously expanded. Current focus topics are an automated generation of suitable visualizations “at the push of a button” and practicable models for an adequate consideration of complexity costs and design efforts in portfolio and architecture decisions.

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