A generic approach to automated product variant design technology

Dirk Schaefer, Lecturer, School of Engineering, Durham University presents his research into product variant design technology.

One of the most important approaches to enable cost and time reduction with respect to computer-aided design for electrical/electromechanical engineering (ECAD) is to develop, generate and manage various design variants of a product in an efficient manner. This article presents an overview of a new generic approach to product variant design technology that has high potential for efficient reusability of existing designs. It presents the procedure to allow this new approach to be implemented within arbitrary ECAD systems. The approach presented automatically generates a complete technical documentation of an electrical installation on the basis of a placed order specification. The technology behind this involves three major steps.

1. A product variant of an installation is configured on the basis of existing standardised design components.
2. A set of commands is automatically compiled that describe the generation of a typical ECAD project containing the configured components. This is a key novelty, as all these commands are expressed in a non-system specific programming language, which can then be automatically translated into a so-called macro programming language of a specific ECAD system.
3. The targeted ECAD system can import and process these commands in order to create a corresponding project file in its native data format for further processing.

Product variant design

In order to remain competitive in the market, most companies offer their products in a range of different variants. However, new variants of existing products are more and more often composed of existing basic components (product variant configuration) rather than newly designed. A precondition to allow for this is to have modularised product structures. This has become common practice in plant engineering and construction, where the majority of companies developing electrical or electromechanical installations tend to reuse their existing designs, plans and project documentations to develop additional customer specific variants. A typical example of such a design variant would be a product family of similar elevators and their corresponding control cabinets (Figure 1).

Unfortunately, this process of reusing existing designs for the generation of further variants is still predominantly performed manually. This is both inefficient and ineffective, and is prone to errors. Consequently, with the ever increasing pressure of competition in the market it is vital to develop automatisms that facilitate the computer-aided generation of product variants.[1]

The fundamental idea behind a generic approach to variant design technology that may be deployed in future ECAD systems is to automate the natural workflow process of creating ECAD design variants as it is manually performed by most companies today. As such, the approach presented is closely related to industrial best practice and derived from day-to-day operations.

The basic concept in practice

Many companies approach their potential customers by technical field sales and distribution staff. These sales persons usually have selling catalogues, which allow customers to assemble bespoke product variants based on basic components that can be combined. At this stage of the sales process, the number of components that can be chosen from tends to be relatively small. Once such a rough pre-configuration is finished, design engineers usually determine a resultant technical fine configuration. This comprises all parts and components required to make up the complete product variant desired and may consist of thousands of items.[2]

The next step in creating the configured product variant requires a design engineer to start an ECAD system, generate a new (empty) project file, copy the components configured into

Figure 1: A typical example of an electromechanical product variant (elevators, control cabinet).

the project and specify individual customer and order details. Subsequently, alterations necessary to the specific project may be accomplished and the process of generating an updated ECAD project documentation, according to the alterations made, must be initiated.

To make the development of product variants more effective, ECAD system vendors aim towards an automatic computer-aided support of the workflow process outlined above.

Functional principle

The basic functional principle of the generic variant design approach is based on aspects from knowledge-based product configuration,[5] the programming of design variants, as well as parametric product modelling and process automation.[3] The fundamental idea behind the approach is to automatically generate an entire technical documentation of an electrical/electromechanical installation on the basis of a placed order specification. The overall process to achieve this involves five steps:

1. A design variant of an installation is configured by composing standardised modules of existing (previously developed) components.
2. All components identified to compose a specific variant are stored in a data file based on a bespoke data structure that describes ECAD design projects in general.
3. A set of commands describing the generation of a typical ECAD project containing all the components configured together is automatically compiled.
4. The above variant project description expressed in non-system specific commands is automatically translated into commands of a specific macro programming language associated to a particular ECAD system.
5. The specific ECAD system targeted can import and process these commands to create a corresponding project that may be handled or dealt with in any way the ECAD system allows.

Technology approach

Step one requires a software tool to manage, browse, identify and select existing components. Product data management systems (PDM) may be used for this purpose. Alternatively, a variety of commercial product configuration tools are available, and even low cost table-based solutions based on Microsoft-Excel, for example, may be deployed if appropriate in terms of complexity.

As already mentioned, a data structure specifically tailored for representing configuration based variant projects is required. This data structure primarily has to cover components and documents typically used to make up an entire ECAD project documentation. In order to process and automatically

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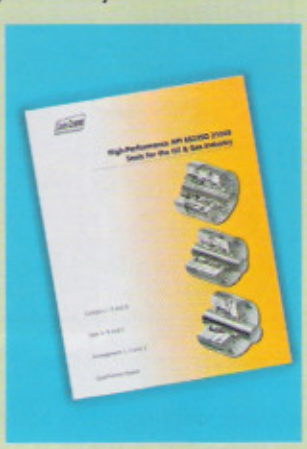
Signed and sealed

The details of various John Crane high-performance seals designed specifically for the oil and gas industry have been included in a new brochure. The ISO 21049 standard, cross referred to as American Petroleum Institute (API)682 third edition, gives recommended seal types, arrangements and flush plans for typical refinery applications.



It also details the three relevant seal types – the Category 1 rotating pusher seal with O-ring and multiple springs; the Category 2 rotating metal bellows seal using O-rings; and the Category 3 high-temperature metal bellows seal which features flexible graphite packings. Detailed drawings illustrate variations on each category of seal.

Other data contained in the new publication includes maximum operating specifications, details on fluid control systems and information on non-contacting gas-lubricated seals.

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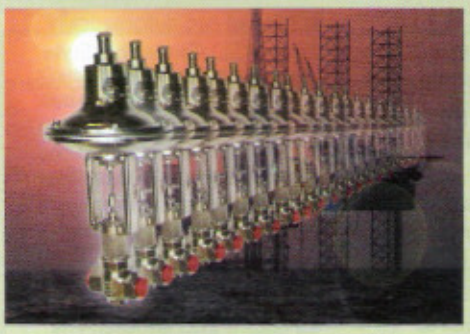

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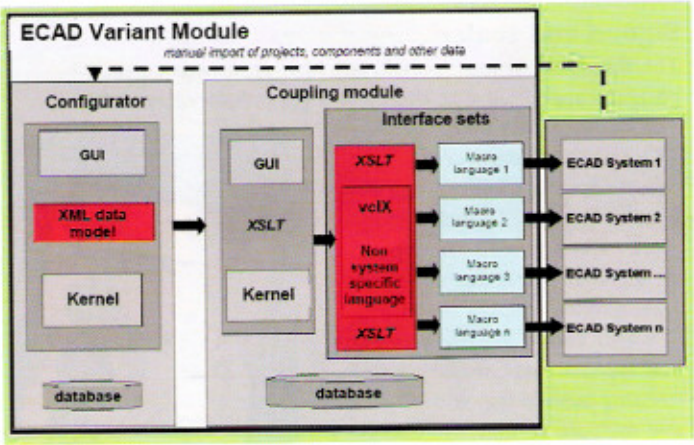

Figure 2: System architecture of the ECAD variant module.

evaluate variant projects based on such a data structure in subsequent processes, a standardised data format has to be used. In the approach described in this article the variant project data structure has been expressed in XML[4] (extensible mark-up language). Simply speaking, XML is a language for describing hierarchically composed objects that distinguishes between the structure of objects and their content and layout.

Realising step three of the functional principle involves formulating commands expressing the generation of a configuration-based ECAD project in a non-system specific form. Hence, a suitable meta-language has been developed and applied. This meta-language covers a variety of system commands similar to those being typical for contemporary ECAD system's macro languages.

Following the functional principle presented, a variant project stored as XML file now can be transferred into a new data format describing the generation of an ECAD project containing the configured components. Technically speaking, this means to enhance the original XML data structure of a configuration-based variant project in such a way that it allows to model and express ECAD system commands in a non-system specific language.

To sum up, the components of a configured ECAD variant project stored as XML file have been picked up and transferred into another, more sophisticated and powerful XML data structure containing non system specific commands to describe the generation of an ECAD project made up of the components configured.

This transformation process is carried out automatically using 'XSL' (Extensible Style sheet Language) and a software tool called 'XSLT' (XSL Transformation).[4] XSL is a language specifically developed to facilitate transformation purposes and allows defining rules describing the transformation from one XML structure into another. The transformation rules necessary to perform the desired transformation are stored within a specific XSL data file. The actual data transformation then is carried out by XSLT.

The procedure described above analogously recurs for step four of the technology approach. However, this time an XSL file describing the transformation from the non-system specific command list structure into another structure encompassing commands of a specific ECAD system's macro language is required. The result of this final transformation is a batch file to be imported and processed by the specific ECAD system chosen. In other words, a real ECAD project in a native data format has been created.

Since the technology approach outlined here is highly sophisticated, further reading is required for an in-depth understanding.[5,6]

Software module conception

The overall variant module architecture comprises of two sub-modules – the 'configuration module' and the 'coupling module'. It is developed as a self-contained unit that may be coupled to one or more ECAD systems rather than directly implemented within a specific system (see Figure 2).[6]

The purpose of the configuration module is to either create new product variant configurations, or adjust existing ones using basic components. Hereby, the various plans of an electrical documentation (for example, schematics, terminal plans, part lists, etc) are drawn on as configuration components. Prior to being able to work with the configuration module, all the components (projects, sub-projects, etc) already existing on ECAD site and available for variant projects must be imported to the configuration module's database. Using the features of a comfortable graphical user interface (GUI), the imported ECAD components can be used to combine new variant projects, to adjust previously created design variants and to add further basic components to the database. The design knowledge, with regard to constraints describing possible combinations and configurations, has to be

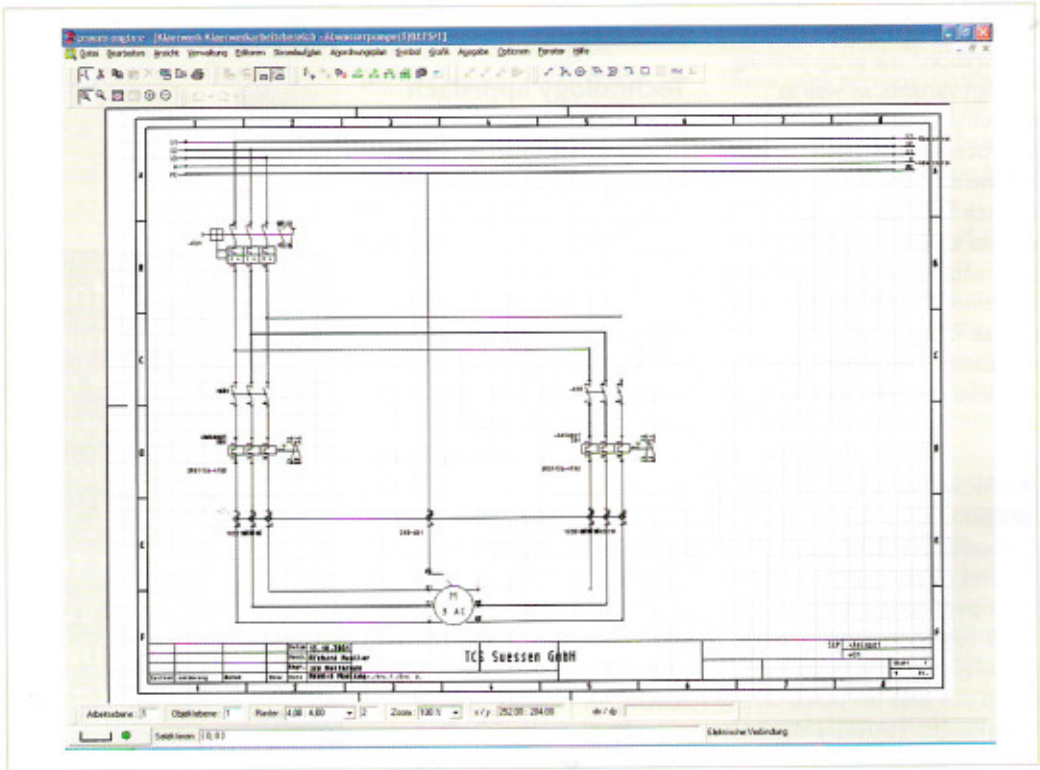

Figure 3: Example of a schematic automatically generated using the variant module.

brought into the database as well. The system kernel of the configuration module therefore has to incorporate an intelligent mechanism to maintain, check and control the compliance of the constraints modelled. Due to the complexity of knowledge based configuration systems the development of proprietary knowledge based configuration tools is not recommended.[2] There are many commercial solutions for almost any configuration task available on the market.

The purpose of the coupling module is to automate the steps of the workflow process that today are usually performed manually by an engineer, once the components for a variant configuration have been determined. A first task for the coupling module is to import a variant configuration from the configuration module. Subsequently, it has to create a file of non-system specific commands describing the relevant steps to open a new ECAD project and to include the configured components. After that, the coupling module has to transfer these non-specific commands into a data file to be imported by a specific ECAD system for further processing.

Conclusion

The generic approach to automated product variant design technology presented in this article has been realised as a software prototype. How it can be applied has been demonstrated using an industrial problem, and has been found to bear a high potential in respect to cost and time reduction in the area of computer-aided product development. Figure 3 shows an example of a schematic automatically generated using the software prototype of the variant module.

Current work with regard to this approach aims at a system integration realisation based on international product data exchange standards such as STEP[7] (Standard for The Exchange of Product model data).

References and further reading

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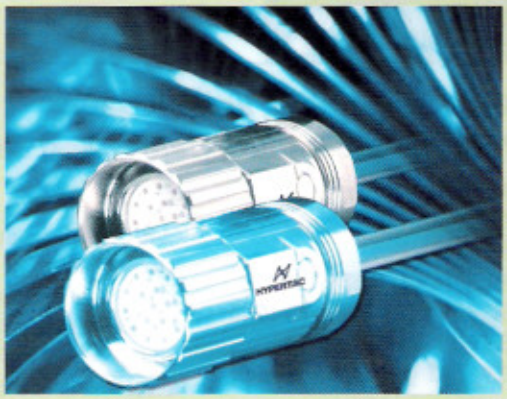
7. *http://cic.nist.gov/plantstep/stepinfo/step_def.htm.*

Full circle

Hypertac has introduced its HyperMotion connectivity solution, a complete product family of circular metallic connectors for the industrial market. The HyperMotion family ranges from M17 to M58 connector sizes. Ideal applications include servodrives, motors, controllers, encoders, connector interfaces for robotics, and feeder/delivery and assembling systems. Custom configurations, complete cable assemblies and prototyping are available on request from



The HyperMotion family is UL approved and designed for customers who wish to introduce a common connector style in their products.

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