# Modern knowledge management enhances turbogenerator design tools

**The power generation market has come to expect extremely short delivery times for all power plant components. As a result, lead times for ABB ALSTOM POWER turbogenerators are today less than 34 weeks for 200-MVA air-cooled units and 12 months for 500-MVA indirectly hydrogen-cooled machines. Such short times call for optimization of the development, engineering and production processes. By investing in R&D in these areas, ABB ALSTOM POWER has been able to speed up both product development and the integration of innovations in the product lines. Engineering design tools play a key role in this process. The know-how contained in these highly flexible tools needs to be continuously upgraded and adapted to changing market conditions. ABB ALSTOM POWER has developed an evolutionary method, based on modern knowledge management, that breaks down the monolithic engineering software into modules which can be individually modified and upgraded.**

Today, almost all of the expert know-how required for a project is contained in the engineering software. Such software, however, is generally monolithic and contains enormous amounts of source code, making it difficult to adapt for new development work. At ABB ALSTOM POWER a methodology has been developed which enables the existing, large-scale monolithic engineering software to be broken down into individual modules. The systematic, evolutionary approach that has been adopted allows very early application of new or modified engineering tool components. This also has special benefits when using the software for service and retrofit projects.

## Background

Computer programs have been used in electrical machine development at ABB ALSTOM POWER for more than three decades. During this time both the hardware and software have progressed enormously. Whereas program storage and running time received most of the attention earlier, today's market requires software systems which are user-friendly, open-ended and portable.

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In 1980 ABB ALSTOM POWER began developing an interactive software system especially for turbogenerator design which brings together all the individual programs in one unified design system. As a result, it has been possible in recent years to reduce the cost of design calculations for orders and enquiries by a factor of 10. However, over the same period of time, these monolithic systems have grown massively and now commonly feature more than 100,000 lines of source code.

Global competition is forcing generator suppliers to develop and produce units of the highest quality while at the same time reducing costs. Driven by these market forces, ABB ALSTOM POWER developed in recent years two 'firsts' – the world's largest air-cooled generator, 'Topair' **1**, and the world's largest indirectly hydrogen-cooled generator rated to 500 MVA, 'Topgas'. These units had to be integrated in the company's development and engineering programmes.

## The engineering process

Traditionally, the technical know-how needed to design turbogenerators has been developed, updated and passed down from engineer to engineer. This is no longer possible on account of the enormous amount of data involved and the increasing complexity of the design methods used. More and more know-how is being stored in the systems themselves. Management of the knowledge contained at the different levels within such a system has therefore become a central factor in the success of every innovative company.

Turbogenerator design is based mainly on electromagnetic, thermal and mechanical calculations, performed with the help of specially developed computer software.

The programming language most commonly used is FORTRAN.

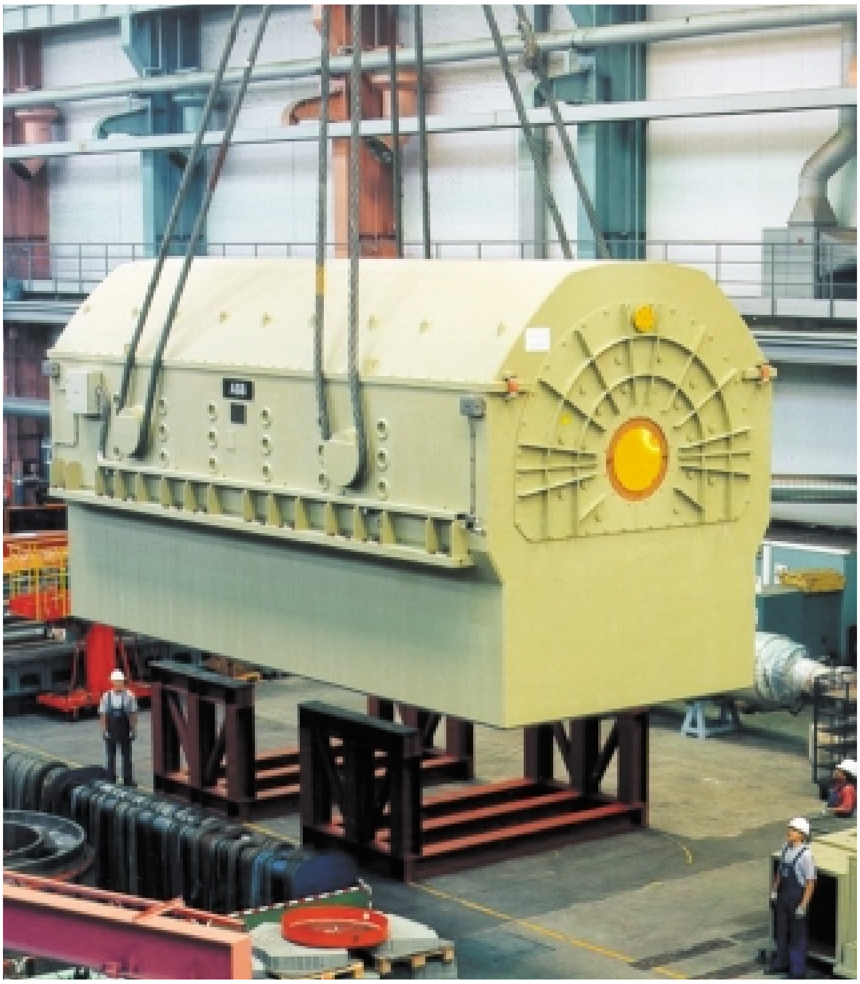
The software can be divided into two kinds of program: basic and design **2**:

- *Basic programs*; the platform for these programs is provided by three-dimensional mathematical models which make use of numerical methods to find solutions. The running time for calculations can be as long as several hours, depending on the complexity of the models.
- *Design programs*; these programs take into account standards, design criteria and the existing design, etc. The results, which become available in just 1 to 5 minutes, are used in tenders, to answer customers' enquiries, and to check the calculations for generators already delivered and installed. These programs ensure that standard components are used, which in turn guarantees fast, cost-efficient and reliable production. The programs also ensure that the pertinent standards and guidelines are adhered to, and so make sure that all quality requirements can be fulfilled.

To design a complete machine several design program stages have to be executed. The correct program sequence and data consistency, as well as an efficient design process, are ensured by bringing the design programs together in a unified 'design system' **3**.

When the design system has completed the calculations, all the main characteristics of the generator are defined, ie the electromagnetic, fluid-mechanical and mechanical design as well as the cooling and main geometrical dimensions.

The calculated data are then automatically transferred to a Product Data Management System (PDMS), where further processing takes place. The PDMS is also where the generator components are defined for production on a contract-by-contract basis.



***'Topair' air-cooled turbogenerator in the 300-MVA power class, for Beijing no 1 power plant in China*** **1**

## System requirements

### Objectives

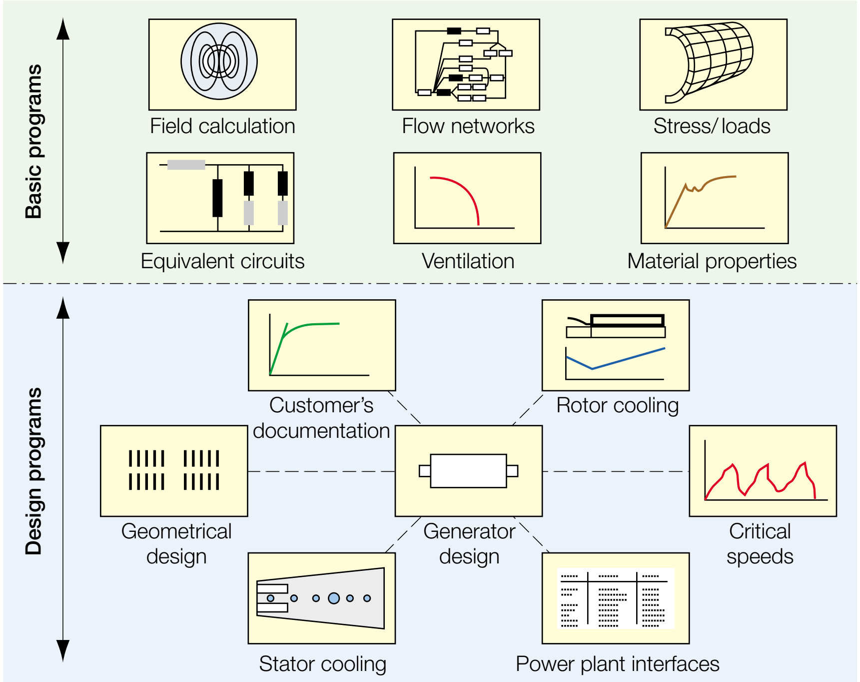
The importance of being able to quickly and individually adapt the basic and design programs applies as early as the product development phase. One to two months are needed to integrate new or modified design programs in the design system.

When developing any new engineering tool it is important to ensure that the calculations performed for the existing and the newly developed turbogenerators are of the same quality. This means that components (programs and data) from the old system have to be included in the new engineering tool.

Any new design system for turbogenerators needs to be maintenance- and user-friendly, ie it must be flexible, extendable and suitable for use by third parties. Furthermore, it must be capable of development and order-related engineering tasks that involve existing as well as future products. And it must be possible to perform calculations for products from non-ABB ALSTOM POWER vendors.

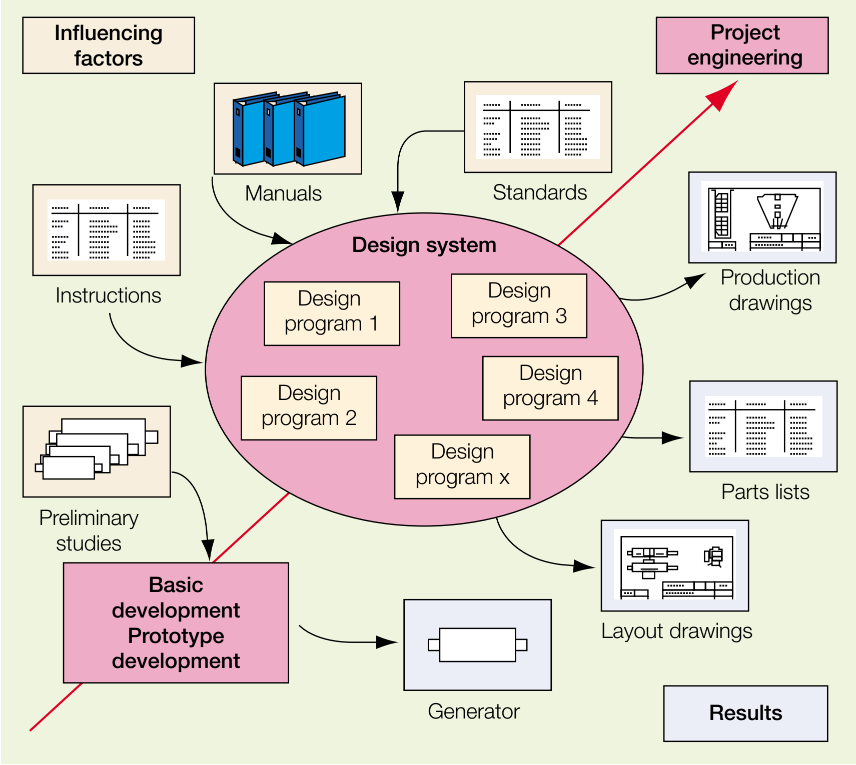
### Developing a 'greenfield' solution

An estimation of the cost of developing a completely new engineering tool – a so-called 'greenfield' solution – showed that developing all the physical and mathemat-



*Software for calculations used in the design and development of turbogenerators* **2**

*Design system in which all the machine design programs are united* **3**



ical models needed for the turbogenerator calculations alone would be so costly that it could not be justified. Also, a problem with 'greenfield' solutions is that it is difficult to check the calculations for generators built earlier.

As an alternative to this 'big-bang' solution, in which the existing design system is replaced in one go, ABB ALSTOM POWER decided to adopt an evolutionary approach.

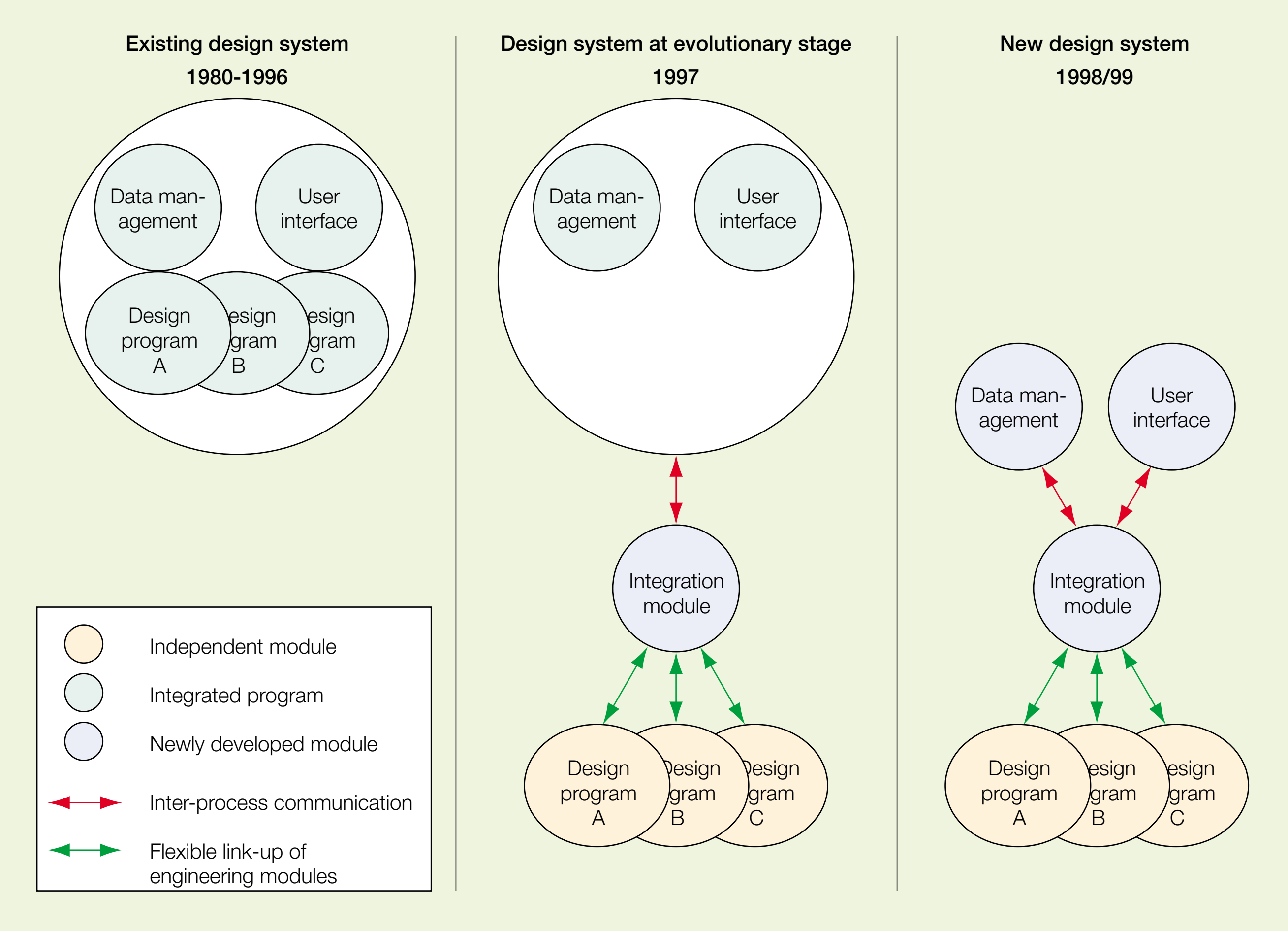
### The evolutionary method

The evolutionary solution is based on the idea of splitting up the fully integrated design programs of the existing monolithic design systems into independent modules and coupling them to a flexible integration module.

The replacement is carried out in four steps:

1. Creation of a new integration module for the continued communication with the existing design system.
2. Realization of a standardized I/O for simple coupling of design modules to the integration module.
3. Step-by-step detachment of the individual design programs from the design system to form independent design modules **4**. This is done by linking them to the standardized program I/O.
4. Total replacement of the existing design system by a new data management system and new graphics user-interface.

Using this approach it is possible to progressively detach all the design programs individually from the old design system and afterwards link them again as independent design modules via the integration module. Since the basic functionality of the design modules can then be reused, the calculations for the existing generators can be checked.



*Evolutionary approach to the detachment of modules from an existing design system* **4**

The detached design modules can be modified and further developed on an individual basis. The modularity of the new design system ensures high flexibility and ease of maintenance.

Such a design system can be used continuously for development and engineering work during the complete evolutionary development phase.

The data management system and the graphics user-interface have to be developed in parallel with the detachment of the individual design modules.

## Link-up of design modules during the evolutionary phase

The link-up between the individual design modules and the integration module should be as flexible and open-ended as possible. Besides the user-program design modules, commercially available programs also have to be coupled.

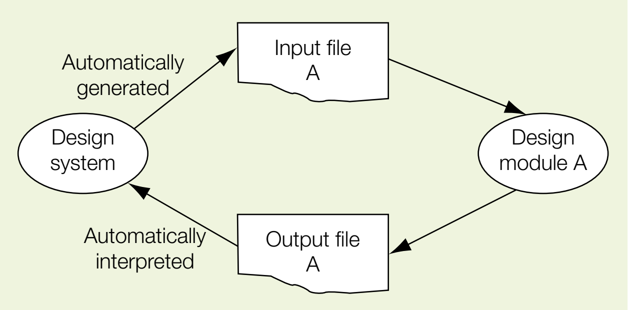
All the input and output data belonging to a calculation are managed and stored in a data vector in the existing design system, as before. The input of values takes place exclusively via the user-interface of the existing design system.

A general link-up of the design modules can be achieved with the help of datasets, over which the input and output data are transferred. The integration module makes a system call to the design module, after which the input file is read and the calculated results are written back into the output file.

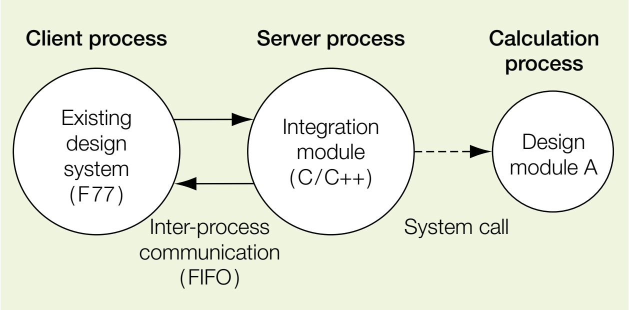
To be able to automate this mechanism the data present in the storage unit of the existing design system have to be read and an input file in module-dependent format generated from them. Similarly, the results generated by the design module have to be interpreted in the output file to enable them to be written again into the data memory of the existing design system.

**5** shows the principle upon which the design module link-up is based.

Input data lists (IDL) and output data lists (ODL) are used for the automatic generation and interpretation of the input and output files. These lists contain the descriptions of the input and output file of a design module and ensure that a value is read (or stored again) in the right data vector element of the design system.



***Simplified diagram showing how the design modules are linked*** **5**



***Unix processes involved in the evolutionary phase*** **6**

### System architecture in the development phase

Users rely on the design system remaining stable throughout the development phase. A Unix system was therefore chosen as the platform for the engineering environment. Two independent Unix processes (a server and a client) were set up and linked together by an inter-process communication system. The individual design modules are started by system calls.

Each of these processes has its own error-handling functions for exceptions (signals) and internal program errors (logic errors). Internal program errors originating in the design module or the integration module are reported to the existing design system and can be displayed to the user.

The set-up of the two independent Unix processes during the evolutionary phase is shown in **6**.

### Extension capability

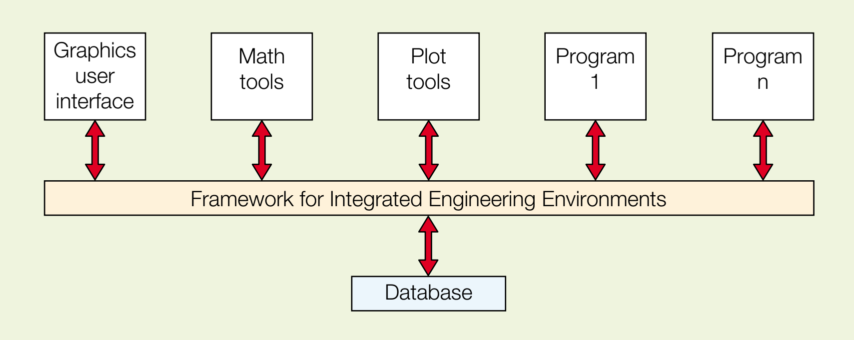
Modifications to the data management system and the user-interface are carried out at the same time and in parallel with the detachment of the design programs. The user-programmed, file-oriented data management is replaced by a commercial, relational database. This new data management system supports today's growing need for flexible data evaluation during the development and engineering phases.

A graphics user-interface also replaces the character-oriented user-interface of the existing design system. The new interface is also linked to the new design system.

An increasing number of commercial mathematical tools, such as Mathlab, and auxiliary programs (eg, 3D plot software) are also being integrated in the system. A standard interface (eg, CORBA) is used for this. Highly flexible communication is therefore possible between a wide range of different services.

The overall integration of the modules (user-interface, database, tools, programs) is implemented with the help of 'middleware'. Development departments now use this level of integration as a toolbox (Framework for Integrated Engineering Environments, or FEE **7**).

***System architecture: Framework for Integrated Engineering Environments (FEE)*** **7**



### Results

The new engineering tool proved its worth already in its first application – integration of the new engineering modules in the development of the Topgas turbogenerator **8**. During this project, it was investigated how the success of making large program systems flexible can be verified.

The cost of adapting the system for the new Topgas turbogenerators is given in **9**, which compares the old and the new system.

The evaluations confirm that the chosen approach was the right one. The measuring points show that engineering modules with simple interfaces allow a saving well in excess of 50%. In extreme cases (providing no changes have to be made to the interface) the cost of adapting the system is zero, since the only changes needed are to the engineering module itself.

In the case of engineering modules with very complex interfaces the saving was

***Indirect hydrogen-cooled 'Topgas' generator in the 500-MVA power class*** **8**

found to lie in the region of 30 %, which was fully in line with expectations.

**Summary**

The decision to adopt an evolutionary approach to re-engineering the software used in the design of large turbogenerators has some important and far-reaching advantages over a 'greenfield' solution:

- Know-how built up in the software over decades is not lost.
- Engineering work on generators is unaffected during the development phase.
- The generated system is modular and user-friendly.
- Development engineers soon become familiar with the new environment.
- Step-by-step replacement of the old system translates into a short pay-back time.
- Operating and maintenance costs are reduced since there is no need to run two systems in parallel.

The project showed that, by breaking the software up into modules, work packages can be quickly put together and simply and efficiently prepared for use. This step-by-step approach enables users to be progressively introduced to the system.

Experience gained with the new design system so far shows that re-engineering allows major savings in operation and maintenance as well as a marked improvement in the development processes.

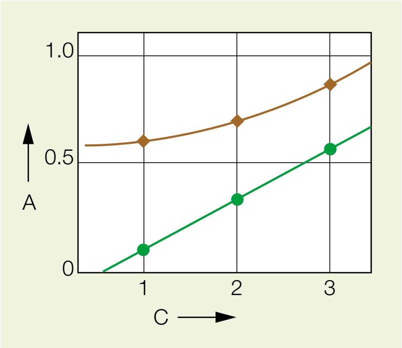
The success of the project underscores the importance of modern knowledge management and its application to the modernization of engineering systems through evolutionary development. This systematic and consistent approach represents a further step towards even faster market introduction of new products, with advantages for customers and suppliers alike.

***Evaluation of the cost of adapting the system for new 'Topgas' turbogenerators*** **9**

◆—◆ *Old system*
●—● *New system*

A *Cost of adapting system*
C *Complexity of module interface*

1 *Low*
2 *Medium*
3 *High*



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