Design^IT

A tool for efficient transmission system design

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Transmission System Configurator

Transmission capacity is a key profit factor in today's largely deregulated utility business, and network operators are continually investing in infrastructure to maximize it. Investment decisions of this order need to be based on a thorough technical and economic evaluation of the network's condition as well as an analysis of all the alternatives. Besides the sheer complexity of this there is the problem of market volatility, which makes everything from investment planning to commissioning and operation very time-critical.

What is needed, once an opportunity to improve the profitability of a transmission system has been identified, is a tool for streamlining the evaluation. The Design^IT Transmission System Configurator (TSC) was developed to do just that. Built upon ABB's Industrial^IT software framework, it shortens the time to create and evaluate different system solutions from months to just hours.

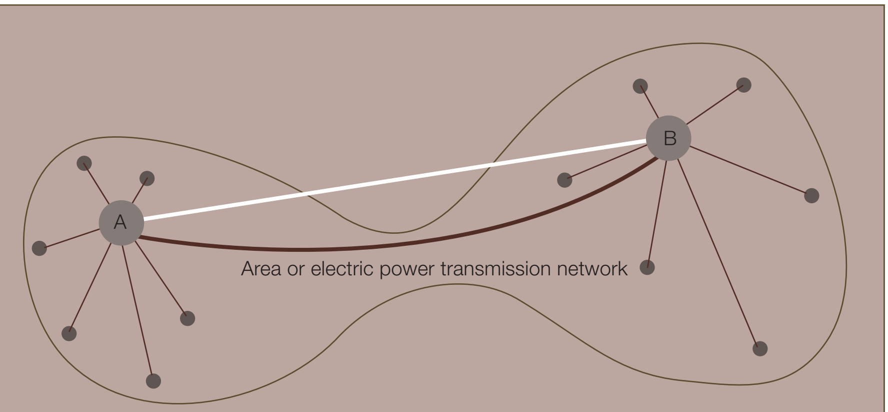
Before committing to a major investment in electrical power transmission, network operators collect masses of data and facts for evaluation. Many different scenarios are possible – so many in fact that the success of the evaluation often depends on how effectively an operator's knowledge of the electricity markets can be linked with the functional capability and support provided by the advanced technical solutions at his disposal.

Transmission capacity translates into profit

New electrical power transmission lines, constructed to eliminate bottlenecks and congestion or as merchant transmission lines 1, can generate profit for all the market participants. However, assessing the value of such new infrastructure can be difficult, as it depends to a large extent on the network situation in a given market environment. This situation is, in fact, the principal factor driving business development and the identification of business opportunities. As the project chain in 2 shows, any tool for streamlining such an evaluation has to address a whole host of other issues, too. For example, certain basic specifications can be defined for each project, such as: 'Which points have to be connected?' and 'What is the expected power flow to be handled?'

The next step is to translate these basic specifications into feasible alternative solutions at a more detailed, but still conceptual design level. This involves defining the different solutions technically such that the cost to the customer can be determined and used as input for a subsequent economic evaluation. The specification resulting from this is used as input for the detailed design during the EPC[1] phase.

1	Major investments are being made in power transmission systems to eliminate bottlenecks and congestion as well as to provide merchant transmission lines.



Speeding up the process

Mapping the basic specification to technically feasible, but different solutions, and their subsequent economic evaluation, is a very time-consuming process. Product and market knowledge has to be combined in extensive studies case-by-case. Even experienced power system engineers may need a month or longer to design an alternative solution – selecting, configuring, and harmonizing the necessary subsystems, then calculating the cost and the price to quote to the customer. What the Design[IT] Transmission System Configurator does is combine all this knowledge and data in a way that allows faster processing. Alternative solutions can be generated and evaluated in a much shorter time.

> Use of the Design[IT] Transmission System Configurator starts with the customer's idea and ends when the customer is convinced that the best solution has been found.

Modeling with black boxes

As implied, the function of the Design[IT] Transmission System Configurator is to generate conceptual solutions for transmission system configurations. Unlike a sales configurator, which simply handles (well-defined) variations of existing products, the design configurator calculates complex dependencies already at the beginning of the design process. In the case of a power transmission line, for example, there are dependencies to consider – and balance – between the voltage level, the wire and the tower type as well as the reactive power (var) compensation.

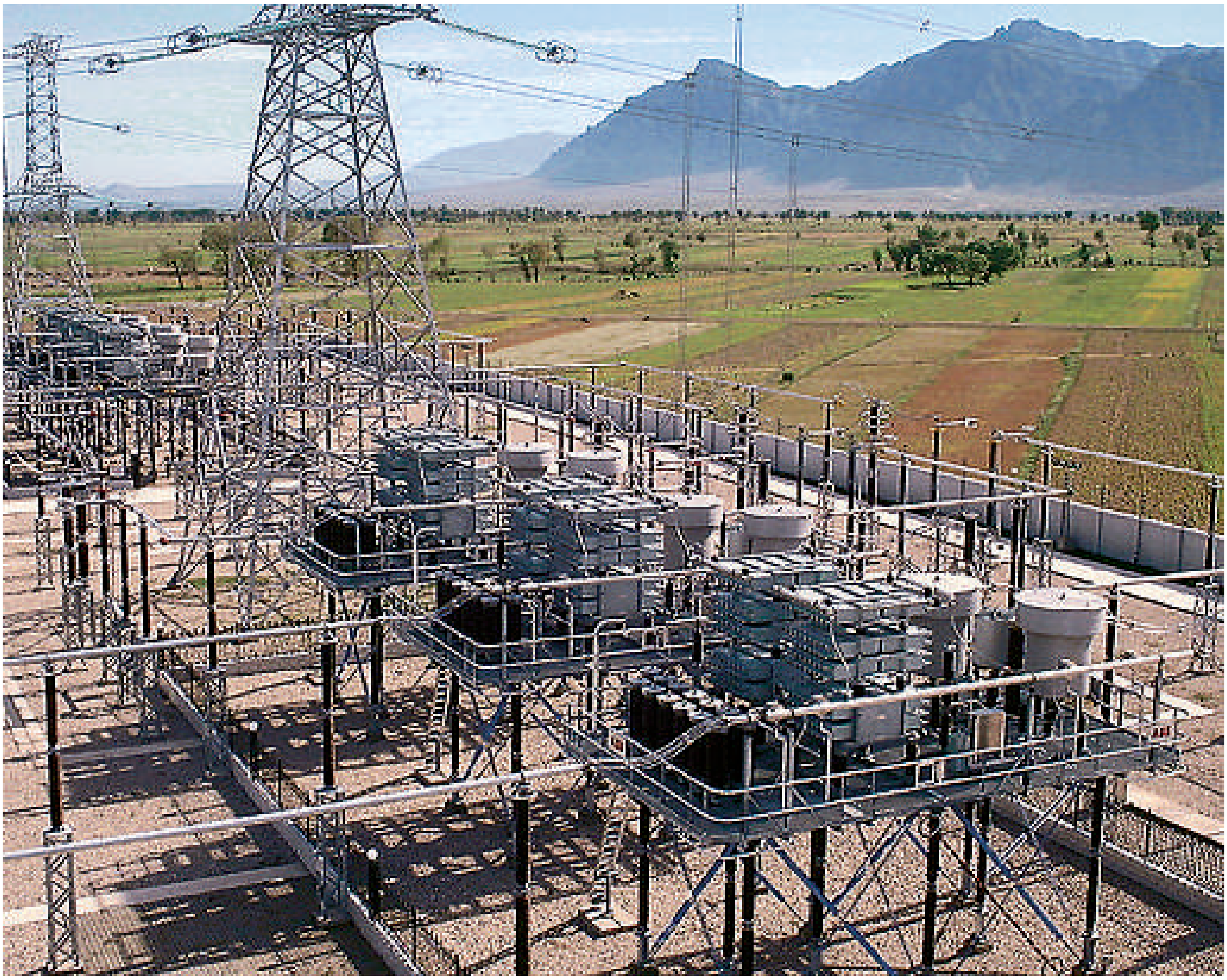
The individual components of the transmission line are modeled using a completely new approach, patented by ABB [1], that makes full use of our technical, product and human expert knowledge and experience base. It breaks the transmission system down into parts, each of which is modeled as a black box 3. A black box can, for example, represent a substation, line element, var compensator, transformer or control device. Using the black boxes as building blocks, customers and sales engineer can progressively test the specification and solutions. The high level of detail enables the price and technical feasibility of a solution to be determined with high accuracy already at this early stage of a project. By optimizing the technical and economic parameters in this way, ABB can assure customers of an optimal result.

Economic evaluation

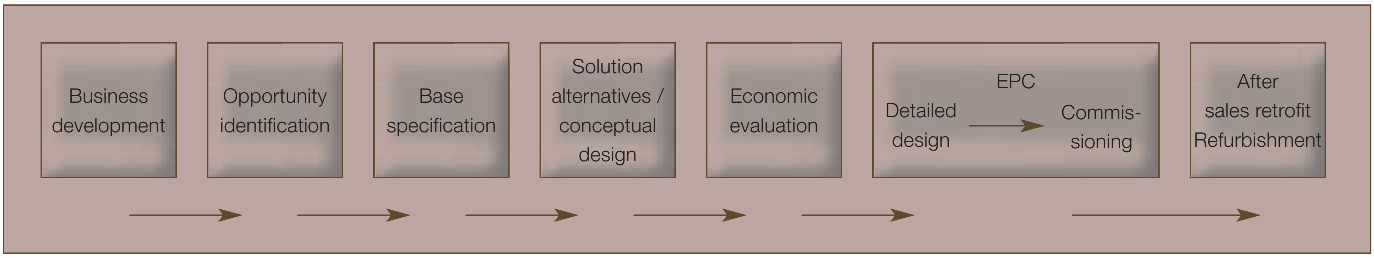
To be really beneficial, an economic evaluation has to consider all possible uncertainties over the total investment period. These uncertainties are mainly the result of the volatile behavior of today's energy markets, but technical risks, such as maintenance and outages, also have to be included.

The basis for the economic evaluation is the investor's own business model for the energy market situation considered. 'Uncertain' parameters can be modeled using probability distribution functions, combined with a Monte-Carlo simulation. A number of variations are then calculated to determine the distribution and the uncertainty of standard investment parameters, such as return on in-

[1] Engineer, Procure and Construct



2 The Design[IT] Transmission System Configurator supports the entire project chain for power transmission lines.



vestment or net present value. These values are decisive in the selection of an appropriate technical solution.

ABB's entire solutions portfolio can be accessed

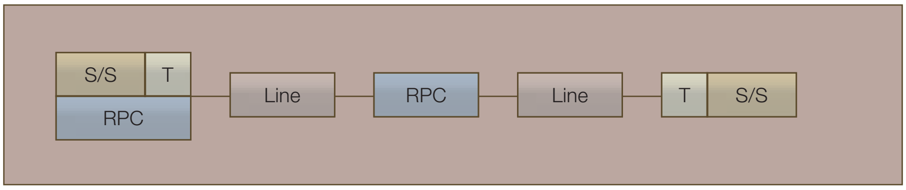
The DesignIT tool provides key support at all stages of a project, from early discussions with potential investors right through to the offer phase. This has special benefits during the initial project discussions, as possible solutions – and alternatives – can be generated and evaluated quickly, allowing the value of potential investments to be estimated without any need for extensive network studies.

As mentioned, the main benefit of DesignIT lies in the speed with which several different solutions can be generated. This accelerates the decision-making process considerably and avoids unnecessary delays. Results are obtained in days, even hours – a dramatic reduction over the months that are often needed with conventional methods. Being able to generate several alternative solutions makes the entire portfolio of ABB solutions accessible for any given application. The flexibility and simplicity with which different solutions can be generated even allows very advanced or uncommon solutions to be evaluated and discussed with ease. The black box approach ensures a quick and detailed response. And it has the additional advantage that the design and technical teams are not needed until the final stages of a quotation. All parties, and the customer in particular, can vary the parameters and then quickly see their technical and economic impact.

Although it may be less specific than conventional systems, the black box technique has the key advantage that it overcomes the need for premature, costly detailed design. Use of the DesignIT Transmission System Configurator starts with the customer's idea and ends when the customer is convinced that the best solution has been found.

The DesignIT Transmission System Configurator combines knowledge and data in a way that allows alternative system solutions to be generated and evaluated much faster.

3 Internal representation of transmission system elements as black boxes for the conceptual design
(S/S = substation, T = transformer, RPC = reactive power compensation)



Validation of the configuration process

Transmission projects in Brazil were chosen for trial application of the black box modeling approach. The solutions that were developed for these projects have been validated by comparing them with solutions designed in the conventional way. The comparisons showed the precision to lie within ±5% [2]. A thorough economic evaluation based on the business model for the Brazilian market showed that, for this country's particular regulation framework, the optimal solution is strongly dependent on the reliability of the alternative solutions [3]. In order to obtain sound economic results, it is therefore essential to model the reliability as a probability distribution.

ABB Brazil has already started using the DesignIT Transmission System Configurator algorithms as a tool in its AC systems solution development. As a result, far less effort is required to develop feasible solutions than before. The main advantage has proved to be the responsiveness achieved in the business development and solution engineering phases of a project. The configurator is now being used to optimize transmission system solutions for the newly planned 11,000-MVA Belo Monte hydropower plant. By using and optimizing leading-edge information technology in the field of power system configuration, such projects are proving the ability of the ABB IndustrialIT approach to leverage important benefits in business areas beyond industrial automation technology.

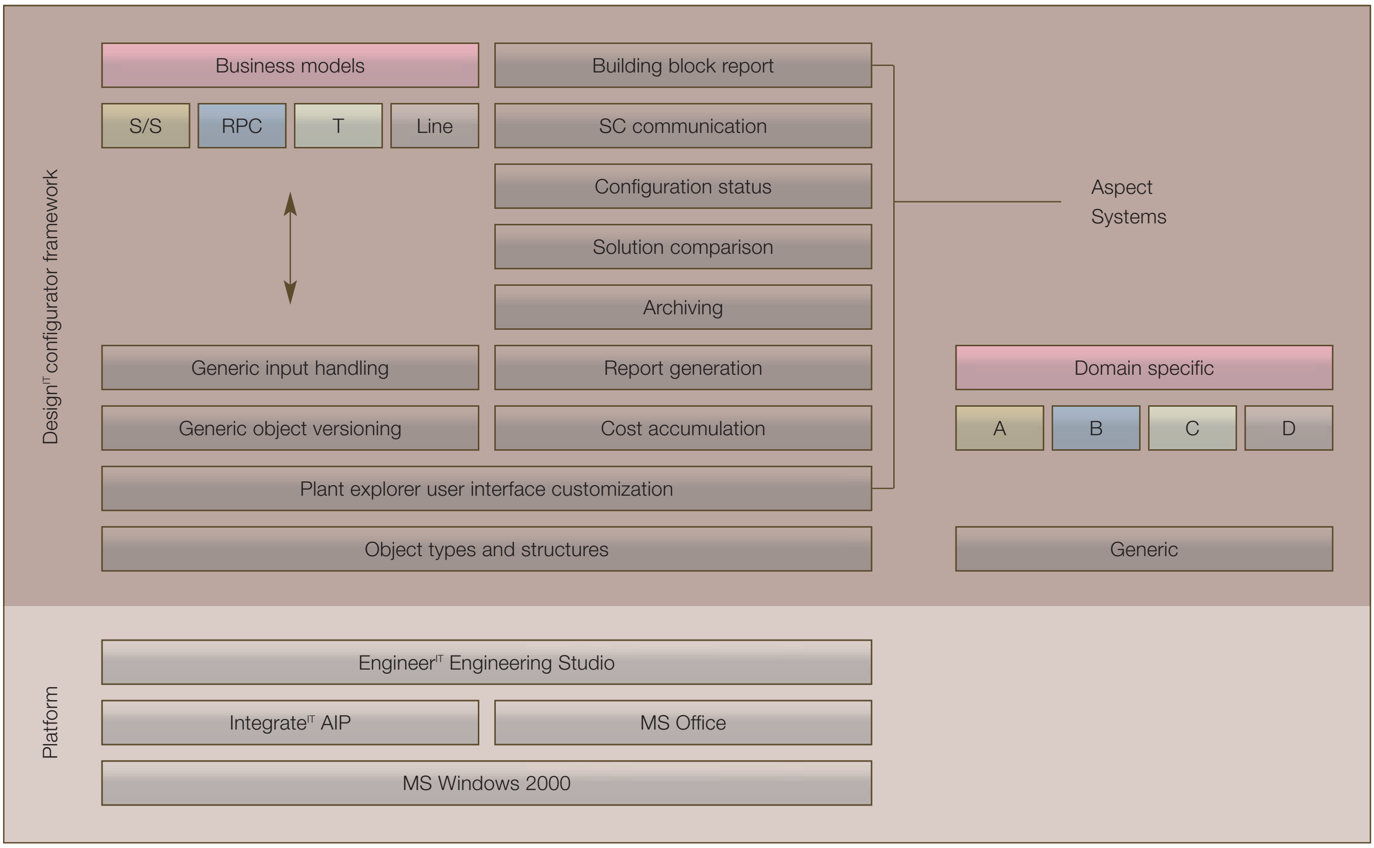
The DesignIT solution

What requirements have to be met?

HV transmission systems are complex entities, both with regard to their configuration and their operation. A computerized tool designed to help sales engineers draw up detailed offers for such systems, specifying both the electrical behavior and the expected cost/price of the solution, therefore has to fulfill a number of special requirements.

For example, it must have access to the (stored) cost-related data of the system components – in this case, transformers, substations, HV lines and var compensation equipment. What is more, as most of the subsystems are not off-the-shelf products, but engineered to order, the tool must be able to derive a relatively accurate cost estimate from general specifications. The tool must also incorporate knowledge concerning the electrical behavior of the system components, and it must be able to derive from this knowledge information about the more complex electrical behavior of the combined system. At the same time the 'configuration' process – the creation and evaluation of different options and alternatives – should be as user-friendly as possible, ie mostly using 'point & click' or 'copy & paste'.

4 Design[IT] configurator framework for system solutions



Moreover, the tool has to be fully functional in stand-alone mode, as the sales engineer might not always have convenient and secure access to ABB's corporate network. For this reason, and because the knowledge contained in the system evolves over time (costs and prices change, new products become available, etc), the tool also has to be capable of being updated in the field, and by a user who may not be a software expert.

Just having the latest version of the information for every available system component, however, is not enough; what is also needed is a 'versioning' mechanism that helps the user understand why a certain configuration for a previous project was chosen in the first place. After all, the products and costs at the time might have led to a design that is less than optimal for the current project. Also, as the subsystem configuration algorithms might be specific to certain boundary constraints, such as country regulations, there are, in reality, always a number of equally valid current versions, and the tool has to select the right one at run-time.

With these requirements in mind, and driven by a desire to create a re-usable, generic solution to the problem, the decision was made to base the tool on ABB's Industrial[IT] architecture.

Advantages of the Industrial[IT] architecture

Designing and configuring HV transmission lines, which are engineered to order and are often one-of-a-kind, is a highly complex process requiring special expertise in many areas.

Standard configurator software is well suited for designing systems where the options are limited and the interdependencies are known. However, it soon shows its limitations when it comes to solving the complex numerical calculations used to configure more sophisticated systems. This, and the fact that several different analytical tools could be needed to evaluate alternative solutions, pointed to the

[2] This paradigm replaces the conventional object known from object-oriented programming, which carries all the data and behavior (methods) associated with a real-world entity, by an 'Aspect Object' carrying a number of 'Aspects'. The Aspect Object represents the real-world entity as such, without its (externally visible) data or behavior. Each Aspect, which is more like an object in object-oriented programming, implements and exposes the subset of the real-world entity's data and behavior that refers to a certain facet of the entity's total functionality/behavior. Decoupling behavioral Aspects that are not entity-specific from the Aspect Object representing the entity ensures a high degree of reusability for the Aspects as well as extensibility for the Aspect Objects.

need for a special kind of configuration tool. ABB's response was to develop the DesignIT configuration framework, which has both generic and domain-specific parts 4.

The early evaluations showed that the IndustrialIT architecture is very well suited for implementing the subsystem (object) centered configuration approach described in [1]. The Aspect Integrator Platform (AIP) supports this with its tree browser based front-end and the underlying Aspect Object paradigm[2)], which allows all kinds of data and applications, even external ones, to be linked to a conceptual object.

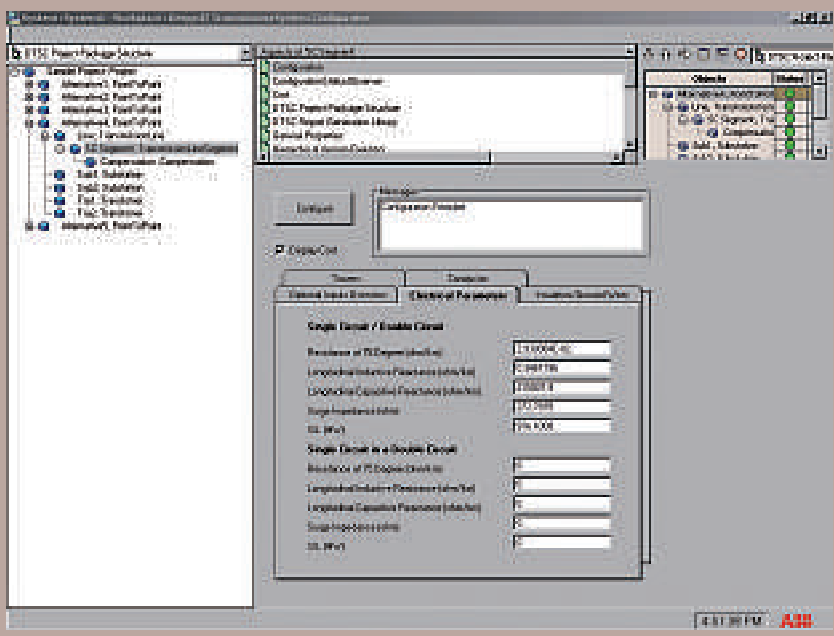
Mapping the problem to the Aspect Object paradigm

In the resulting software architecture, each subsystem of the HV transmission system is represented by two types of Aspect Object. The first type represents the subsystem – for example, a transformer – as a domain object in the user interface used to assemble and evaluate alternative solutions 5. One instance of this Aspect Object type is stored in the system (eg, for the transformer) in each alternative solution and in each project.

The second type represents the configuration algorithm and data for the transmission system component in question. Again, the system stores one instance of this Aspect Object for each version of the configuration algorithm. However, the existence of this second type of Aspect Object, and the complex version management mechanism used to dynamically link the two types at run-time, is completely hidden from the user.

Both types of Aspect Object carry one set of Aspects which are specific to the HV transmission system domain and another set which, like the user interface, is completely generic for this kind of configurator application, providing functions such as parameter entry, versioning, cost and price calculation, automatic tender document generation, etc 4.

5 Screenshot showing details of a line subsystem configured with the DesignIT TSC



Framework for the future

Basing the configurator architecture on the Aspect Object paradigm makes it easy to exchange, redesign or add new black box components. Among other things, this allows more detail, realism and accuracy to be added, for example by breaking down the substation subsystem into primary and secondary equipment subsystems.

The separation of generic and application-specific parts of the software tool also facilitates quick adaptation of the framework to completely different domains. This is important, as system solutions in different areas can have similar configuration problems. The potential of the DesignIT configuration framework is underscored by the interest being shown within the ABB Group in applying it in areas as varied as wind parks, subsea oil fields and oil drilling rigs.

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