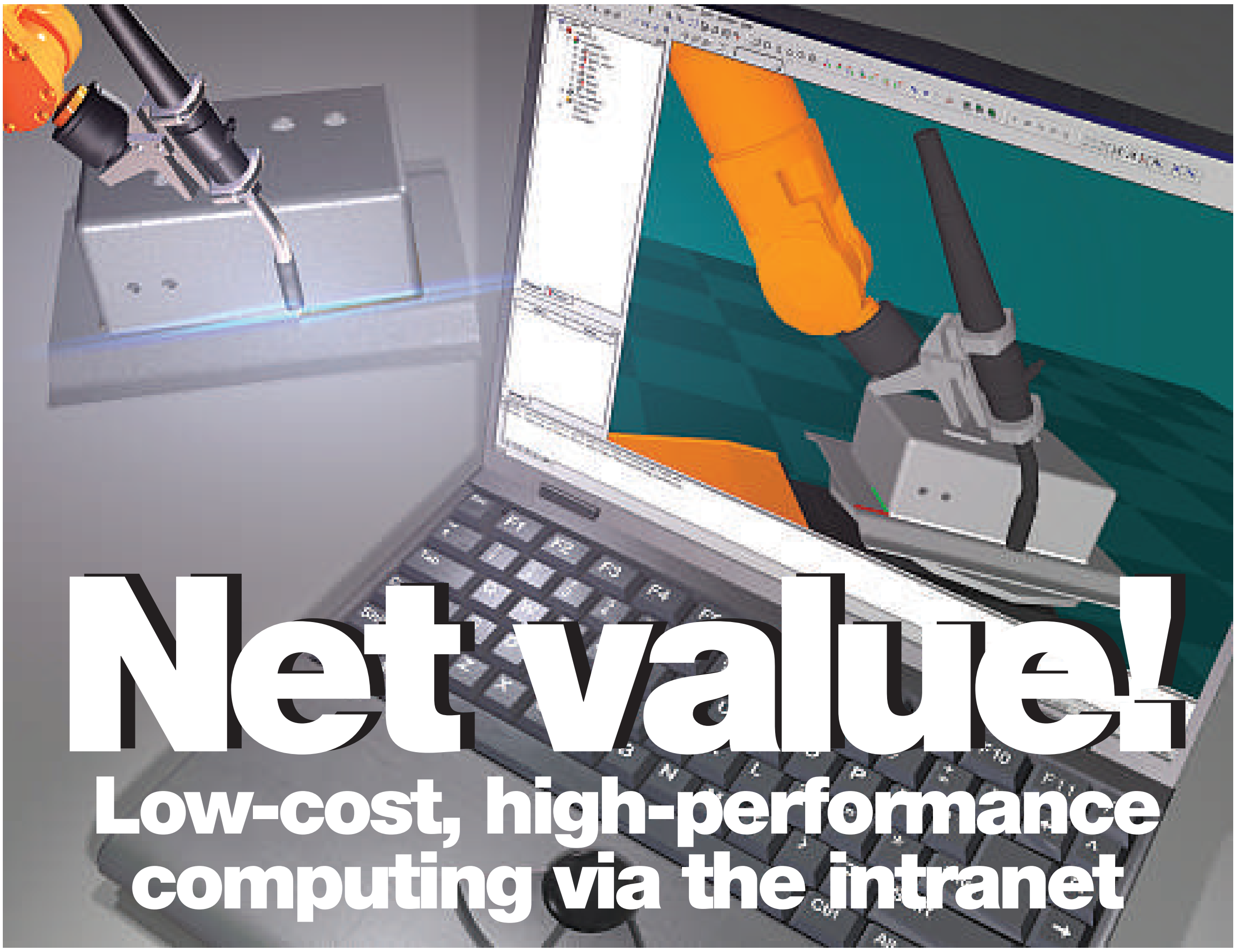
Net value!

Low-cost, high-performance computing via the intranet



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The ability of 3D Computer Aided Design (CAD) systems to quickly generate virtual prototypes has made them a popular tool in product development. However, more complex modeling and simulation tools, such as those dealing with mechanical, thermal and electromagnetic effects, require an infrastructure, hardware and expertise that are beyond the means of many product development departments. As the same tools may be in use elsewhere within ABB, it makes good sense to let these departments access them over the company intranet.
ABB's corporate research centers are now providing just such a service, with benefits for ABB units and ABB's customers alike.

Over the past few years, computer-based numerical computations have become an integral part of the product development process. In particular, there has been a surge of interest in numerical analysis based on 3D product models generated with CAD systems. Using modern CAD systems, designers are able to create a virtual prototype of a new product within a few hours or in just a few days. While the same efficiency may be expected from simulation of mechanical, thermal or electromagnetic effects, this is so only in a limited number of cases. There are several reasons for this:

- The advanced analysis modules are usually not integrated in CAD systems. They are available as stand-alone tools, able to import data from CAD systems, but often requiring their own pre-processing procedures.
- The analysis tools are expensive and need to be run on special high-performance hardware.
- Knowledge of complex, tool-specific procedures is necessary. This knowledge

is not usually readily available, and keeping it updated would hardly be cost-effective for a typical business. Consultative support from external simulation experts is often required.

- Working to tight schedules, designers are often unwilling to invest the considerable time and effort required to perform simulations. Consequently, even if all the necessary resources are available locally, they are not used frequently enough to make local installation and maintenance cost-effective.

Many of these problems can be got around by providing access to remote simulation resources, integrated in the local design tools, via the intranet. ABB have implemented just such a solution as part of its Low Cost Computing (LCC) initiative. The organization of ABB is very suited to this solution.

New Internet technologies make the handling of remote resources easy and efficient. ABB business units can outsource the simulation resources to the ABB corporate research centers, saving tens of thousands of dollars yearly and maintaining access to the latest simulation technologies without having to set up the required infrastructure locally. The corporate research centers (ABB has eight, spread around the world) maintain this kind of expertise anyway, as it is needed for advanced research projects.

This solution also has an impact for ABB's customers, particularly those buying engineered products. Use of the advanced simulation services ensures even greater reliability for ABB products and a faster throughput in the design process, which supports on-time deliveries.

Technology overview

A number of component technologies must be brought together to create an intranet-based simulation environment.

Floating license management

Network-based license management has become the *de facto* standard in the licensing of software products (see: *www.globetrotter.com*). A single company commonly uses engineering analysis software products just a few times in a year, so sharing one license between a few companies makes sense. In ABB, the owners of advanced analysis software licenses are usually the research centers, who export them to the interested business units.

Of particular interest for license sharing are pre-/post-processing systems such as add-on CAD modules (eg, ProEngineer analysis modules like Pro/Mesh and Pro/FEM-POST, or even ProEngineer itself). Simulation tasks can then be performed without having to purchase and maintain the ProE software locally. Software upgrades can be performed in the ABB units in cooperation with research centers and without involving the vendor.

This type of licensing is also possible for many commercial finite element packages (solvers). However, in this case there are some special hardware requirements that companies need to consider.

Real-time distributed collaboration

Designers who perform simulations only occasionally need consultative support from simulation experts located in the research centers. This is normally provided over a telephone hot-line, and has lately also benefited from the use of real-time collaboration tools such as Lotus Notes Sametime and CoCreate OneSpace (see: *www.lotus.com*, *www.cocreate.com*). The former enables

application sharing, which is useful when providing support for interactive analysis modules. The latter is used for collaborative sessions that require co-viewing and co-editing of complete 3D models as well as for discussion of simulation results in VRML format.

Web-access to applications

An interesting technology for accessing all Windows and Unix applications via a Web browser is offered by the Citrix Nfuse and MetaFrame software (see: *www.citrix.com*). It provides a very cost-efficient enhancement of the remote access to all simulation tools that are not Web/Java-based, that do not enable license sharing or that require hardware performance not available on client computers. This technology allows centralized application hosting and publishing via a Web portal. A specially developed ICA (Independent Computing Architecture) protocol enables interactive graphical simulation tools to also be accessed from the Web browser and efficiently used on a client computer.

Linux

In recent years Linux has become a common Unix platform for traditional workstation and supercomputer vendors like SGI, HP and IBM. The computer manufacturers have reduced the development of their own processors and operating systems by using Linux and Intel processors for development of new computer architectures. Linux has become the *de facto* industry standard and a lower-cost alternative to Windows, especially for server applications that require high system stability and availability (see: *www.redhat.com*).

The current disadvantage of Linux is the fact that not all currently available software products are suitable for it. For example, several nonparallel structural mechanics packages as well as CAD systems are available only for traditional Unix systems or Windows.

Linux, being an open source system, has a crucial advantage over Windows: Users and hardware manufacturers can quickly introduce any changes and innovations. It has recently been employed as the operating system for the newest 64-bit Itanium Intel processor. Two Linux Itanium machines, Silicon Graphics 750 and Hewlett Packard i2000, are now available on the market (see: *www.sgi.com, www.hp.com*). Both vendors provide full support for certified Linux distributions. These machines are considered as low-cost, high-performance solutions for engineering analysis applications.

We expect that in the near future a combination of Linux and Windows-based PC-clusters will provide a suitable environment for all numerical applications used in ABB.

Cluster computing

PC clusters have been identified as the most cost-effective platform for high-performance computing since the end of the 1990s (see: *www.beowulf.org*). The strong growth of cluster computing is also reflected in the latest edition of the top-500 list of the world's most powerful computers. The largest cluster installation worldwide, based on Itanium IBM servers with 320 processors and on IBM Netfinity servers with 1024 processors, has a peak performance of 2 TeraFlops (ranks 34 and 41 on the top-500 list in November 2001, see: *www.top500.org*).

The first PC cluster running Linux Red Hat was built in ABB in cooperation with the Technical University of Munich, and currently an 18-processor Linux cluster is being operated to support the LCC initiative. The primary internal network is based on fast Ethernet. Additionally, a high-performance network based on SCI technology (Scalable Coherent Interface) has been installed (www.*scali.com*). A significant cost reduction was achieved for electromagnetic and fluid dynamics applications – up to one order of magnitude compared with the standard multiprocessor workstations.

The Linux clusters are favorite machines for academic and research communities. Universities are developing a variety of parallel numerical applications in such a hardware environment. This gives ABB an excellent opportunity to use the latest achievements of academic research. In a cooperation between ETH Zurich and ABB in the area of numerical mathematics, the scientists from Zurich developed a special preconditioner for the iterative linear GMRES solver applied to eddy current formulations. The software developed could be immediately transferred to the ABB cluster and used to solve the stray loss problem in power transformers.

Load management

Traditionally, load management has been the domain of large computing centers. However, the rapid growth of workstation and PC clusters in the 1990s introduced this technology to the management of distributed heterogeneous systems. In ABB, following on work in the mid-1990s, we are operating at one of our research centers Platform Computing's (*www.platform.com)* Load Sharing Facility (LSF) in a cluster consisting of SGI workstations and Windows-based PCs. In the near future we will implement this technology for the mixed Linux-Windows clusters.

Model-driven simulation environment development

Special software components have to be developed in order to implement customized simulation environments. For example, a component for the client-server interaction between a CAD user and the computer engine strongly depends on simulation procedures applied by designers. The simulation tools, items for evaluation, as well as designer requirements, vary from business to business, and consequently there is a need to adapt the software components to the changing environment. This problem can be effectively managed by implementing these components as UML models in Rational Rose (*www.rational.com*). An interesting extension to Rose is a package called ArcStyler (*www.io-software.com*). Taken together, they provide a future-oriented platform for model-driven simulation environment development; in particular, they allow the following goals to be achieved:

- The developed model can be very quickly extended and reused for other applications. A crucial feature is that the source code (in Java) can be automatically regenerated for a changed model. The parts of code written manually are protected and will be not lost during regeneration.
- The implementation is not dependent on the current technology. Based on the Rose-ArcSyler model one can automatically generate the source code for any given implementation technology. For example, the remote access to simulation resources developed in the research centers is currently based on Java/RMI, but applying other templates/cartridges in ArcStyler can automatically change the implementation to another technology like CORBA. This makes us independent of rapidly changing Internet technologies and lets us focus on the functionality of our simulation environment.

3D visualization

Various commercial post-processing systems, eg, Pro/FEM-POST, offer only a subset of features required for 3D visualization of specific design quantities included in the ABB technical standards. This proves to be a significant limitation when evaluating simulation results and presenting them to ABB customers. Therefore, we have investigated technology based on the Virtual Reality Modeling Language (VRML, see: *www.vrml.org*). VRML models can be created from simulation results and visualized in standard Web browsers. VRML provides an excellent opportunity to present the physical behavior and other characteristics of ABB products on the Internet.

Low Cost Computing (LCC) initiative

The LCC initiative started in the corporate research centers has the following goals:

- Implement Web-based portals to selected simulation tools and make them available via standard Internet browsers.

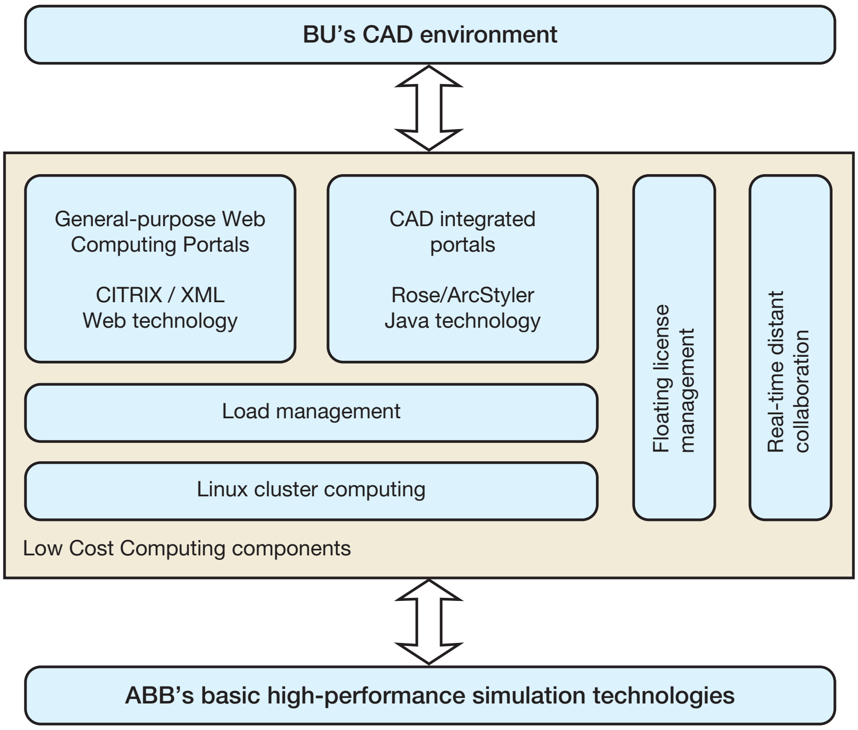
■ Integrate complete simulation procedures into the CAD environment of selected business units (BUs), based on remote access to computing resources and experts.

The first goal has been achieved using the Citrix Web portals technology. The engineering analysis applications are integrated, personalized and published in an interactive XML-based format with no need for additional coding. The applications currently implemented are mentioned in the next section.

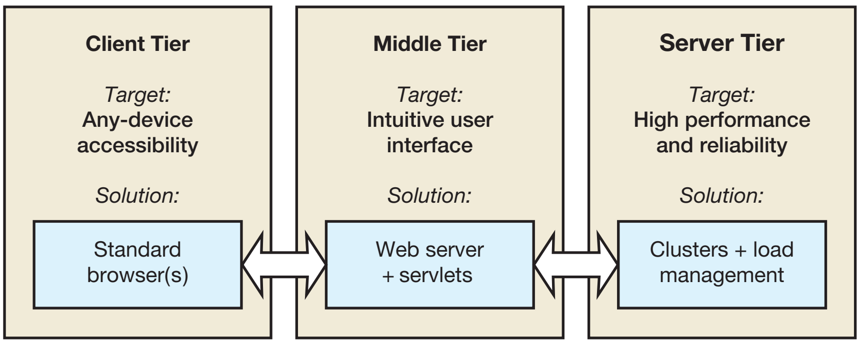
The second goal was achieved with highly customized portals integrated in the CAD environment. They are based on specially developed software models that comprise ABB specific components like design criteria evaluation or VRML visualizations and are implemented using Java technology. A pilot implementation for the Power Transformers business is presented in the following.

In both cases we use the same underlying technology on the server side: PC clusters controlled by job management systems. The architecture of the intranet-based simulation environment that has been developed is shown in 1. It provides a link between the engineering design environment and the world of simulation. The main goal is to bring the newest advances in simulation technologies to the fingertips of engineers while outsourcing the overhead of high-performance computing and maintenance of the numerical analysis solvers.

1 Architecture of the Low Cost Computing environment



2 Architecture of the Web Computing Portal



Pilot application 1: Web Computing Portal (WCP)

A pilot Web Computing Portal has been created at the research center in Milan, Italy. It provides access to engineering applications via a Web browser. There is no need to install any software on the client computer except browser plug-ins to fully enable the GUI (Graphical User Interface). The available services are 'published' on WCP through XML service descriptors. Only authorized users can access these services. The basic components of WCP are shown in 2.

3 Example of a Web Computing Portal application: polymer processing simulation tools based on CadMould, using remote sources from the corporate research center in Milan, Italy

The portal is being continually enhanced. The current focus on the server side is on implementing load management and data storage in a cluster environment, while on the client side the WCP efforts are focused on customizing the access for different applications.

The core feature of WCP is Web-enabling of the desktop applications (even if these are not Web-based). Furthermore, the WCP provides any service available on high-performance clusters to the desktop or mobile users. The WCP can be regarded as a low-cost platform for integration of the corporate engineering analysis tools.

The software accessed via WCP can be divided into the following groups:

- General-purpose engineering analysis packages that support the designers' work but are not used in ABB units frequently enough to justify local installation and maintenance. Typical examples now available in the pilot WCP implementation are MatLab 5.3 and Maxwell2D 7.0.
- Advanced 3D FEM (Finite Element Methodology) packages that are used for simulation projects performed usually by research centers. The current WCP implementation includes: Ansys 5.6, Fluent 5.4.8 and Maxwell3D 7.0. Designers need to access this kind of software for collaboration purposes like viewing and evaluating results. However, the BU users can also define and submit jobs via WCP, if required. In this case, the whole WCP infrastructure, including floating licensing, high performance clusters and job management, is utilized.
- Business unit specific engineering tools based on in-house codes created for dimensioning or evaluation of design criteria. The main purpose of bringing these tools to WCP is centralized maintenance.

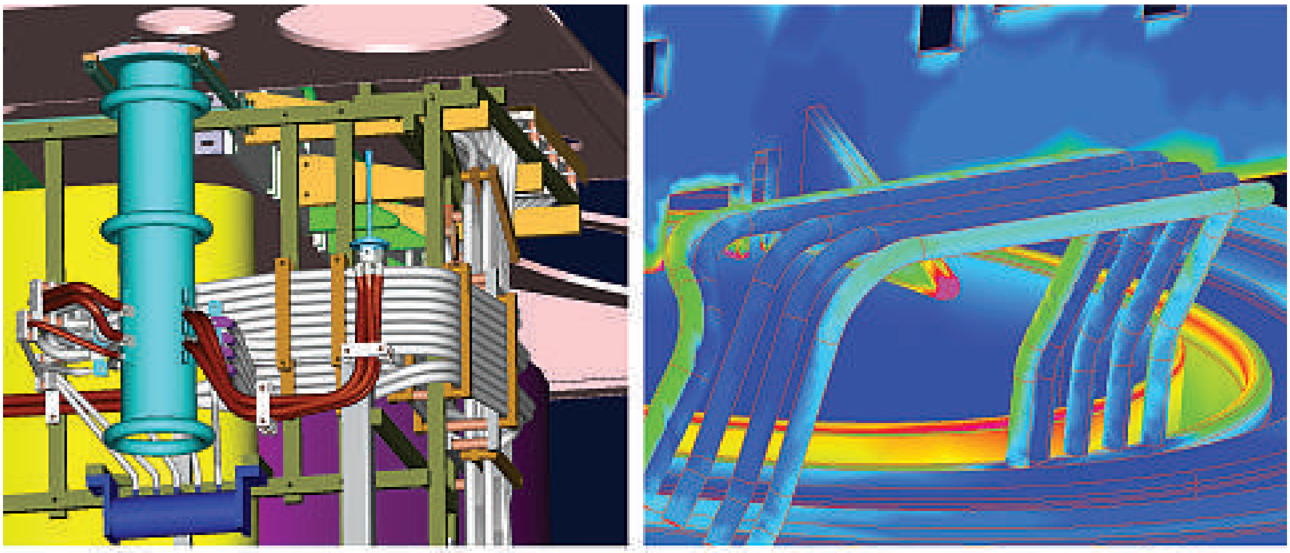
The main users of applications mentioned above are the Italian business units that are setting up their new, Web-based simulation environment in cooperation with the corporate research center in Milan. The businesses involved in this initiative include sensors, servomotors, transformers, and high- and low-voltage switchgear.

The WCP applications can be customized according to the requirements of the business unit users. In **3** WCP-based implementation of a User Friendly Interface (UFI) for a polymer processing simulation tool based on the CadMould package is shown. It allows non-expert users to run numerical simulation of an injection molding process. The basic characteristics of the process, like filling behavior, clamping force and deformation, can be presented in a single snapshot. This application is used by ABB businesses related to low-voltage control products not only in Italy but also in France, Finland, Sweden, Germany and Switzerland.

Pilot application 2: Dielectric design of power transformers

The ABB business area 'Power Transformers' is introducing 3D dielectric simulation into its order-related design

4 Example of a power transformer model (a) and corresponding results of dielectric computation (b). This example was calculated at the Power Transformers business unit in Bad Honnef, Germany, using remote resources from the corporate research center in Ladenburg, Germany.



a b

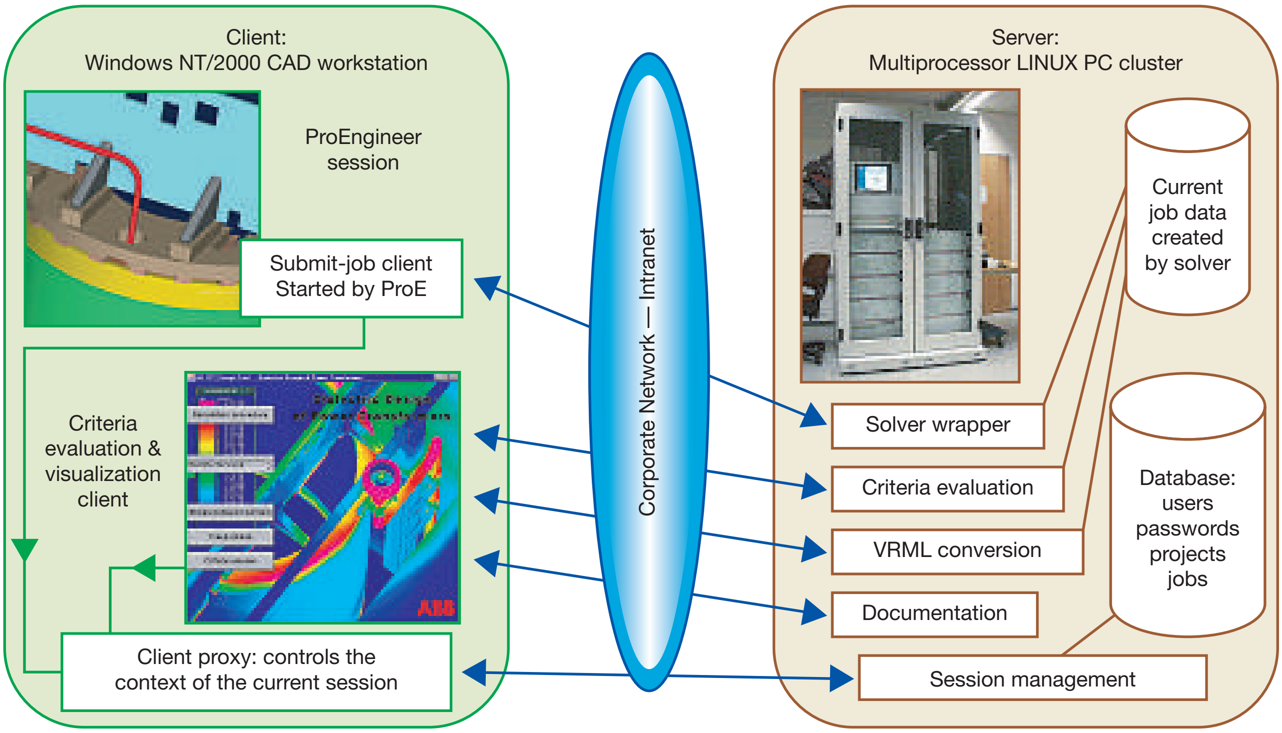
process. The 3D CAD model of a transformer unit is created on the basis of a customer order (see example in 4a). Since the product is taken directly from design into production, the designers must ensure that the final high-voltage tests will be passed first time. The 3D dielectric simulation enables identification of and evaluation of critical spots (see example in 4b). Based on simulations, the engineers can make a quantitative assessment of the failure risk and compare it with the business area's design guidelines. Without simulation the design procedure is 'experience-based' and the quality of the final product depends strongly on personal knowledge of the responsible designer.

Attempts to integrate 3D simulation in power transformer design are not new. During the 1990s a lot of effort went into developing an efficient simulation procedure that included improvements to ABB's in-house boundary element code Polopt and its integration in ProEngineer. However, direct practical use of the new procedure by designers could not be achieved. This gap is now closed by the LCC initiative; in particular, the following requirements have been defined by the Power Transformers business area:

- A CAD expert based on clear and permanently updated documentation can perform the analysis pre- and post-processing in ProEngineer; simulation expertise is not required (eventually, interactive hot-line support from a remote expert will be provided).
- The solver as well as the corresponding hardware should be accessed remotely in a research center. There is no simulation software or hardware installed in business units. The remote solver is activated directly from ProEngineer.
- Designers should be able to evaluate and visualize specific design criteria on their CAD workstations based on the solver data stored on a remote computer.
- The complete simulation procedure is easy to use, and transparent for a designer not experienced in simulation; it should be possible to compute even complex arrangements within a few days.

Based on these requirements, a client-server model 5 has been implemented. An important feature is the integration with a CAD system. With this model, a special 'submit-job' client is required that transfers data from/to the CAD session, starts the solver on the server and monitors the progress of the computations. Access to the user data on the server is controlled by a client proxy that communicates with the 'submit-job' client as well as with the 'evaluation & visualization' client. The latter provides services like design criteria evaluation, based on

5 Client-server architecture for accessing the remote resources integrated with CAD environment and design criteria evaluation



remote data, VRML conversion and access to the latest documentation.

The architecture shown in **5** has been implemented as a UML model based on the RationalRose/ArcStyler technology. The source code has been generated for Java/RMI. A significant advantage of this approach is the re-usability of the model; ABB will use this model not only for power transformers but also for dielectric design throughout the Group (including medium- and high-voltage switchgear businesses). The pilot implementation for power transformers is already underway.

Outlook

Remote access to computing resources creates a new dimension in the ABB design environment. It makes the use of engineering analysis tools cost-effective. Expensive software and hardware do not need to be purchased and maintained separately by each unit, but can be centrally hosted and offered to ABB engineers via the intranet.

The Low Cost Computing initiative assigns a new task to corporate research centers in the ABB R&D process: to explore and adapt the newest simulation technologies and to put them at designers' fingertips. The new role includes not only developing and implementing Internet-based access techniques but also integrating simulation procedures in the CAD environment and making them easy to use by designers.

Most important of all, the new environment creates a strong customer advantage as the ABB products are designed from the start to be user-friendly and easy to install, operate, and maintain.

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