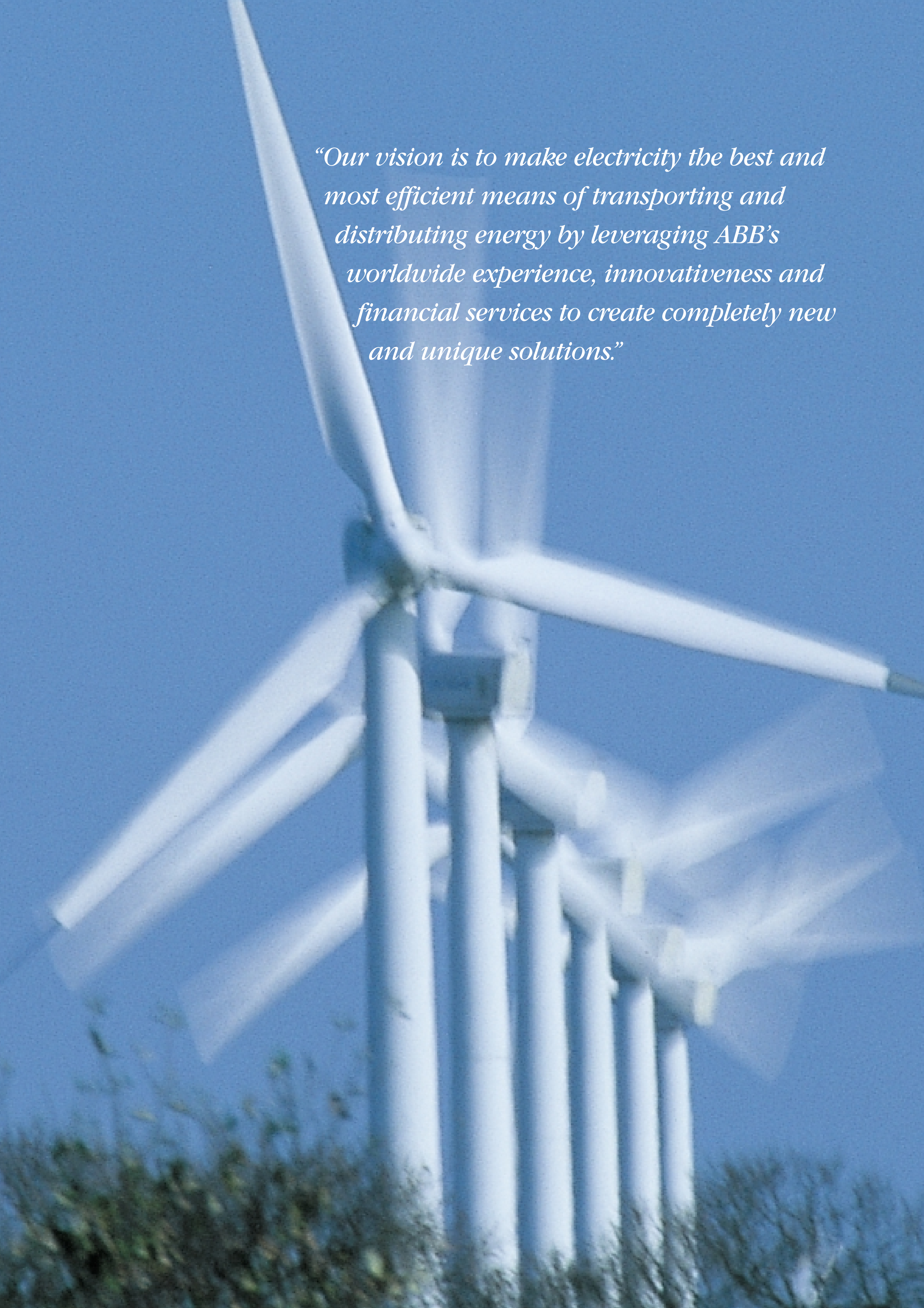


"Our vision is to make electricity the best and most efficient means of transporting and distributing energy by leveraging ABB's worldwide experience, innovativeness and financial services to create completely new and unique solutions."

Power transmission and distribution in the midst of rapid change

Georg Schett,
Senior Vice President for Technology,
Transmission and Distribution Segments

With new Power Transmission and Distribution solutions set to revolutionize the way electricity is supplied in the future, my job is today surely one of the most interesting and exciting at ABB. I believe that nowhere else in the company are things changing so quickly. The destination of our breathtaking journey through the T&D landscape in the years to come is now clearly in sight, and we know what we have to do to get there. The dominating influences on our journey are fast-growing markets, liberalization, cost pressures, increasing environmental awareness, and rapidly evolving technology.

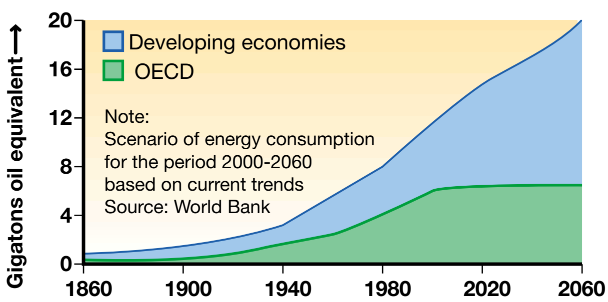
Predicting this T&D technology itinerary and preparing for it is both stimulating and challenging, and I consider myself fortunate to be able to count on the support of a quite considerable team of experts in doing so.

Together, we are attempting to answer a whole host of questions. How *will* new technologies influence the layout and use of electricity transport systems? Which as yet undeveloped technologies will come to the fore in the future? What external issues will drive the direction of our technology?

My task has never been so thrilling, given the fundamental changes in all aspects of our business. In the coming pages I will share with you our vision of how the future *could* look and describe some of our key technology achievements and breakthroughs.

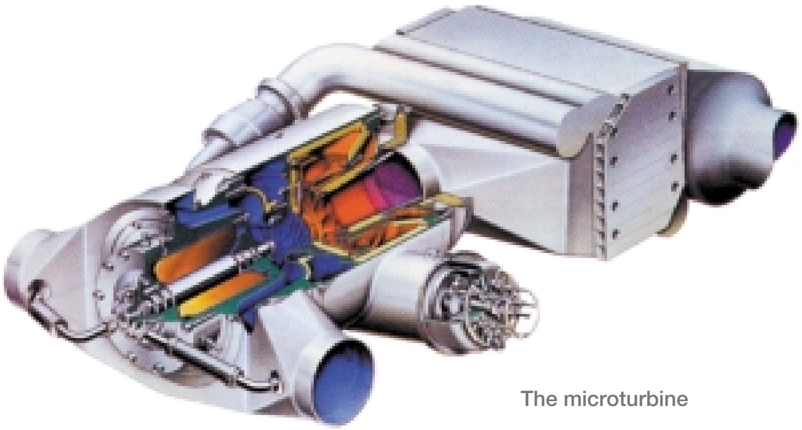
Deregulation as a driving force

Electrical energy is one of the most, perhaps the most, important pillar of our modern society. The undisputed correlation between progress, prosperity and the availability of electrical energy places it high on the political agenda of most countries. Generation, transmission and distribution used to be the preserve



Megatrend: energy consumption

The predicted growth of consumption is dramatic, especially in the developing countries.



The microturbine

of state-owned and controlled enterprises, which were usually vertically integrated monopolies, and there were some good reasons for this to be so.

Will deregulation and privatization now change all this? Is the complex electrical energy system we all take for granted now at the mercy of private investors and lawyers? Will your lights still go on when you flick the switch?

Yes, they will! But the rules and roles will change and energy will become more environmentally friendly, and gradually cheaper. Competition will stimulate the implementation of new technologies to make the grid more reliable, cost-efficient and, in many cases, less visible.

Similar changes in the telecom business were discernible some years ago, after privatization and deregulation, and in that case the changes were beneficial to all. The mobile phones of the electricity world will be the small distributed resources – fuel cells, microturbines, wind generators and others – which are clean, safe and smart.

Getting away from the 50/60 Hz paradigm?

When was electricity discovered? It was always there, regarded as a strange physical phenomena. But it was only latterly that a practical use for electricity was proposed, based on the experiments and basic understanding of scientists like Volta, Ohm, Ampère, Maxwell, Faraday and Edison.

The benefits of electricity became apparent shortly after a series of pioneering inventions. It was also apparent that widespread use could only be guaranteed by approaching generation, transportation and distribution in a rational way. Thus, the 3-phase, 50/60 system was born.

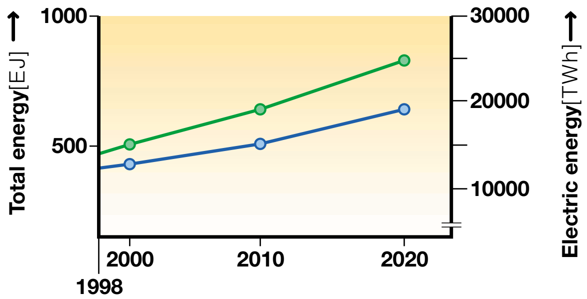
Imagine for a moment a bus which has not one engine, but a separate engine for each wheel. Now imagine that one engine fails and the others have to compensate, but they all start to run at different speeds! The bus would not stay on the road for long!

We have the same situation in the power grid. Many generators (the bus engines) are networked together. If they start to run at different frequencies, large currents would begin to flow between them; oscillations and finally mechanical breakdown would be the consequence.

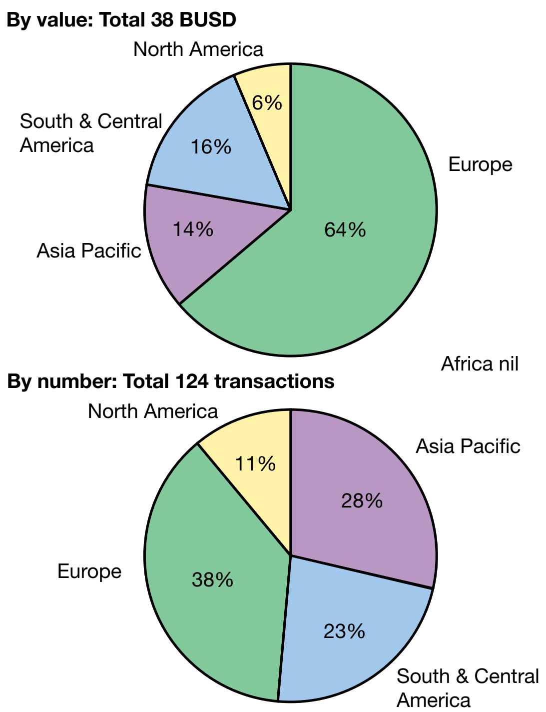
Electrical generation, transmission and distribution systems are now huge synchronous machines whose tentacles – or, in a mechanical analogy, 'elastic driving shafts' – reach into the very hearts of our homes, factories and offices. The larger the system, the more effort is needed to keep this vast oscillating system stable by accurately controlling the frequency.

When you turn the light on at home or, more dramatically, a large load like an aluminum smelter, the speed of rotation of the system would be reduced, sometimes with a jerk, if there were no immediate counteraction.

To avoid instability any load increase should provoke instantaneous compensation in the form of more energy being pumped into the system elsewhere.



Electricity growth (green curve) is outstripping overall energy growth. Forecast by IEA



The frantic activity in utility mergers and acquisitions in 1999 is a very good indicator of the dynamism of the power market. Turnover in Europe totaled more than 20 BUSD as deregulation and privatization spread to more nations.

Switching on of higher loads has to be scheduled well in advance to secure the availability of sufficient generating power. Sufficient standby capacity has to be permanently available in case of unforeseen load changes or failures. Losing the stability of this gargantuan electric machine is a major threat; it can take days to re-synchronize all the power plants and reconnect them to the grid (this has actually happened in recent years).

Maintaining this grid stability is an extremely complex issue for control and protection technologies, and is therefore given a high priority in most countries since regions and countries have contractual obligations to contribute to the stable operation of inter-regional or international grids.

Due to all the technical and procedural rules and regulations which are in place, the electric grid works generally so reliably that we consumers just take it for granted: when we switch a lamp on, it lights up.

Developed regions and countries have interconnected themselves with colossal transcontinental electric systems. Joining such a system is a huge technical challenge for new members and proving that you have the capability to contribute to the stability of the system has become a prestigious political goal. However, technology has now provided us with other, easier ways to do this. Later in this issue of ABB Review, we will look in detail at some of them.

The 50/60 Hz paradigm ensured the wide application of electricity in the last century. Keeping this complex system alive was the task of state-controlled monopolistic organizations; true competition amongst suppliers of electricity was unthinkable.

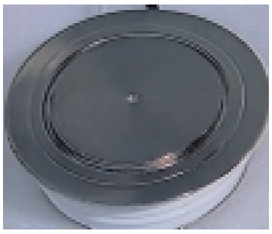
Now deregulation has given business a major role in maintaining this hugely complex infrastructure, so important for our society. This is why we must spare no effort to develop the very best tools possible. One of those tools is power electronics. This technology will influence the structure and the operation of electricity grids and question, step by step, the need for today's gigantic synchronized 50/60-Hz systems.

Power electronics: the key technology in a competitive environment

The grid needs control

In recent years, substantial progress has been made in power electronics for transmission and distribution applications. The use of insulated gate bipolar transistors for HVDC and static var compensation has dramatically reduced the size and costs of such applications.

The main advantage of this technology is its ability to switch currents on and off at high frequencies, thus



Power electronic components can easily switch over 3000 A hundreds of times per second.

reducing the size of transformers and filters, in some cases eliminating the need for such heavy equipment altogether.

In traditional transmission and distribution grids, electric power flows in inverse proportion to the impedance of the grid node separation and is thus not controllable. As a result, maximum power exchange is limited by the weakest connection in the grid, even though sufficient line capacities are, in principle, available. Such a situation is obviously not sustainable once T&D utilities are deregulated and privatized. Proper control of the electrical energy flow enables the transmission and distribution capacity of an existing infrastructure to be increased by 30%, and even up to 100% in specific cases. Deregulation can be difficult to implement without more control of the power flow in existing grids.

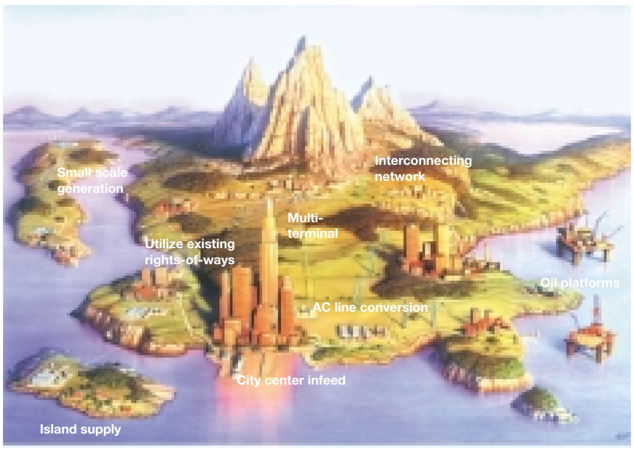
Increased energy trade will boost investment in transmission and distribution, as has already been shown in the United States, where deregulation started earlier. The reach of energy trading will widen and drive a need for more grid flexibility and response to rapid change. In many cases, today's infrastructure does not match up to these new demands.

However, technology to restructure grids and adapt them to the specific needs of deregulation is now available and affordable. Flexible AC transmission systems (FACTS) combined with HVDC Light applications will enable our customers to take a new approach to their transmission business. We will see more mixed AC and DC interconnections to upgrade and enhance the flexibility of the grid. In some cases the justification for huge synchronized multinational electricity systems will come into question, and be challenged by more desynchronized smaller islands interconnected by back-to-back DC-links.

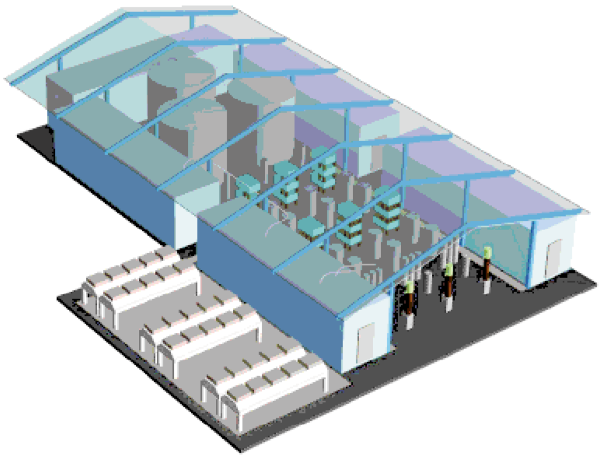
Power quality and flexibility

On the distribution side, power electronics is increasingly used to improve power quality in sensitive areas and to interface to distributed

HVDC Light allows distributed power assets to be connected inexpensively.



Whereas a conventional 130-MW HVDC installation requires 10,000 m^2, the much more compact HVDC Light equivalent needs only 2000 m^2.



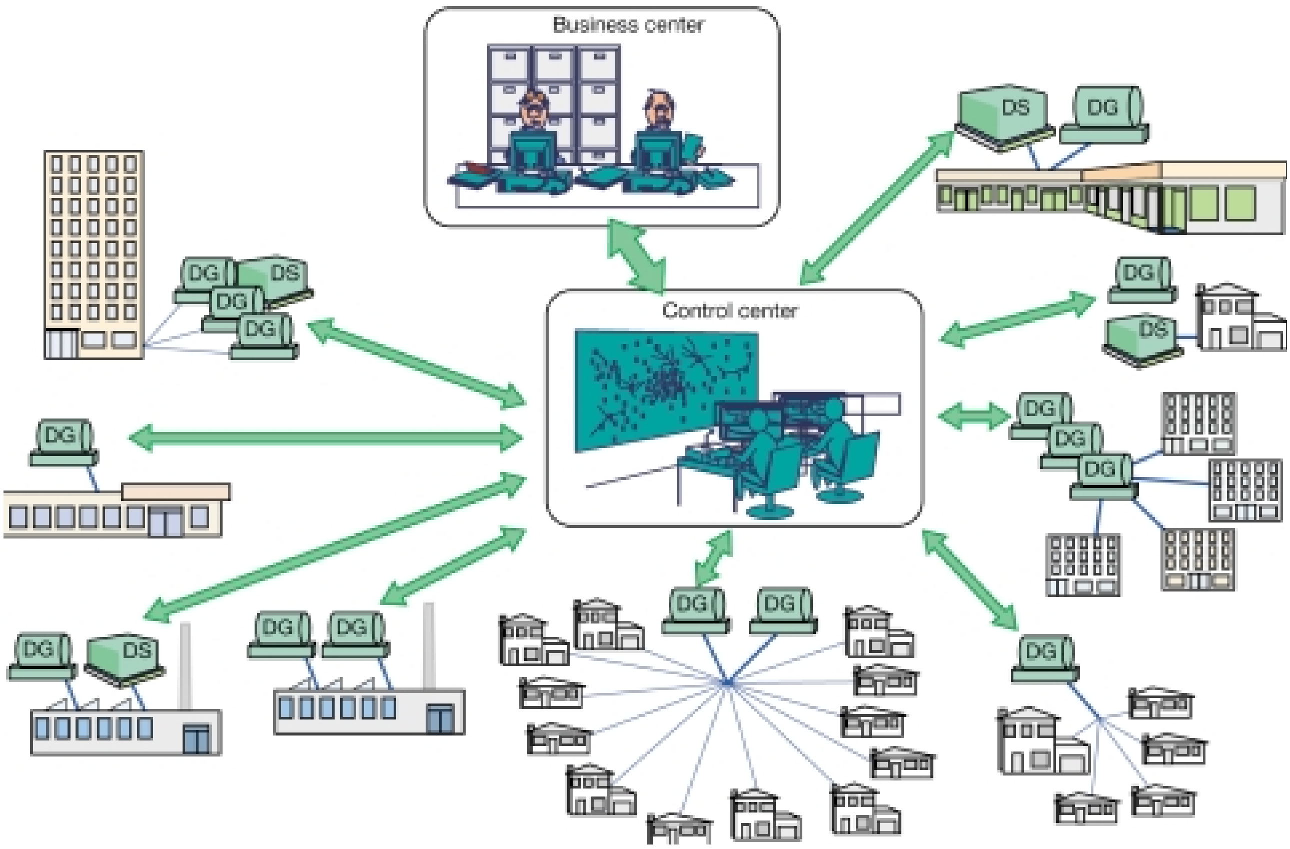
New, faster, cheaper, better power semiconductors are changing the face of the T&D industry. *ABB IPQD (Integrated Power Quality for Distribution Systems), based on platform components and used in control and protection applications to provide reactive power compensation.*

resources, such as microturbines, wind power generators, solar energy and fuel cells. None of these environmentally friendly energy sources produce energy at 50/60 cycles, varying instead from zero to some kHz. Distributed energy resources, combined with heat and chilling, will be interconnected, remotely controlled and operated as highly flexible 'virtual utilities'.

We will see small DC distribution systems used to connect remote loads, such as farms and villages, to the grid without having to install high-voltage AC transmission systems. Such applications will gradually be followed by DC distribution systems as a backbone for high-quality power supply in industrial and office complexes with sensitive electronic loads.

With power electronics becoming increasingly appealing due to deregulation, and much more economic due to improvements in technology, the old paradigm of grid control through frequency stability might gradually fall. Once it is used more widely,

Many different types of distributed generation assets can be combined into a single, seamless, centrally controlled 'virtual utility'.



Windformer™ harnesses wind power at remote coastal sites and offshore.

power electronics will serve to limit short-circuit currents and lead to further economic advantages in the T&D grid.

There will also be enormous investments made in controls and business management systems to satisfy the needs of a competitive environment. Business management systems will be required to manage, for example, risks and continuously changing energy supply contracts, even in the retail business. We can be sure that the Internet will play a key role in all this.

Are we close to realizing the old vision of a fully controllable electrical grid?

Environmentally friendly solutions

So far, the electrical losses of power electronics components and the costs they incur have hindered a wider application of these technologies. The trend is changing in favor of electronics as costs fall fast and new IGBT generations with lower losses become available. It is conceivable that FACTS functions can be combined with reactive compensation of AC underground transmission systems where, so far, dedicated and expensive shunt reactors had to be used. In the future, such combinations could change the economic equation of AC or DC underground systems in areas where rights-of-way for transmission lines are difficult to obtain due to environmental pressure.

Smart power quality devices for distribution which are equipped with fast controls and power electronics will solve the old contradiction of power quality versus cost. Such devices are available now.

Power electronics components will be the key, allowing us to use more of the available renewable energy resources and reduce CO_2 emissions. Most of these resources, such as wind power, microturbines and fuel cells (the latter two can be fueled by biogas), will be connected directly to the distribution system. Lower-cost DC and AC transmission systems will enable remote renewable energy sources to be connected to load centers.

Cables will experience a renaissance due to a surge in demand driven by applications such as underground transmission and distribution, remote offshore wind farms as well as applications in oil-free transformers, high-voltage generators, motors and windmills.

Electricity will be the most environmentally friendly and most economic medium for utilizing renewable energy sources and transportation to the load centers.

Power electronics will finally free us from the 50/60 Hz paradigm.

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