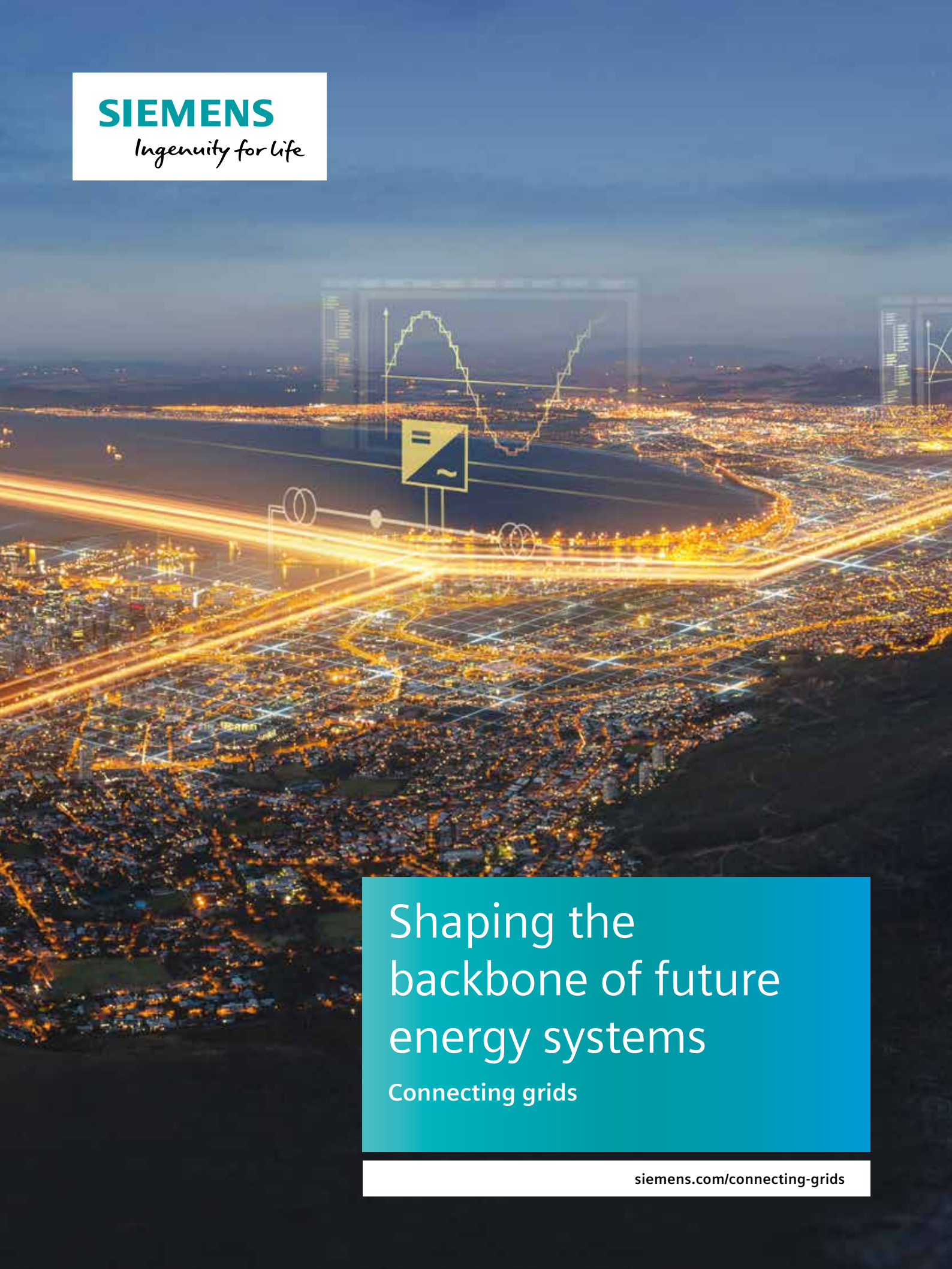


An aerial night view of a city with glowing energy grid lines and digital overlays. The city lights are visible, and the grid lines are highlighted in a bright orange-yellow color. There are also digital overlays, including a line graph and a square icon with a diagonal line and a wavy line, suggesting a focus on energy and technology.

SIEMENS

Ingenuity for life

Shaping the backbone of future energy systems

Connecting grids

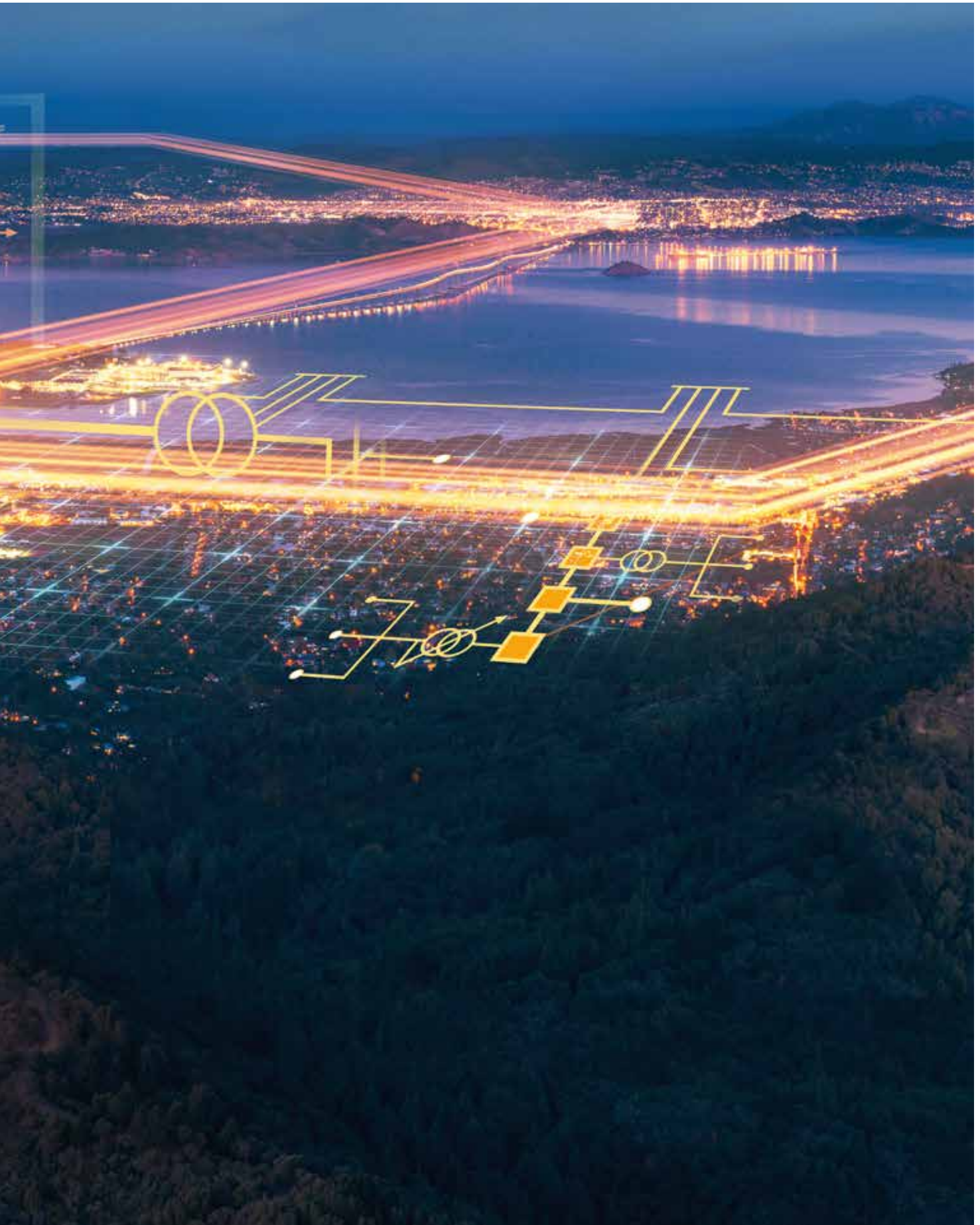
[siemens.com/connecting-grids](https://www.siemens.com/connecting-grids)



Power is only as efficient as the grids it flows through.

Yet as energy systems worldwide undergo transformation, it's becoming increasingly complex and expensive to optimize and stabilize grids.

Connecting grids assists grid operators in shaping the backbone of future energy systems.



Keeping an overview in an increasingly complex energy world

Would the world as we know it today function without power? On the contrary, sufficient power is the foundation of every modern society. That's why a great deal of knowledge, money, and effort is being invested in the generation of cleaner and more reliable power. Yet generation alone is not enough to meet the steadily growing worldwide demand. Power has to be continuously and reliably delivered wherever it is needed – which is why efficient transmission grids will be the backbone of tomorrow's energy systems.

This is a tremendous challenge. The distance between where power is generated and where it's consumed continues to grow, which means that extremely efficient connections are essential. Power generated from renewable sources is still too expensive in comparison to conventionally generated power. The operation of transmission grids is becoming more and more complex along with fluctuating demand and an increasing degree of volatility.

The solution to these problems will determine just how efficient, reliable, and safe power systems will be in the future – and whether power will remain affordable. It requires

Connecting value

Shaping the backbone of future energy systems is an enormous challenge. It takes the right partner in order to lead the competition and to be profitable.

Society



Society has an increasing demand for power and also sets the framework for its generation and transmission.

TSO

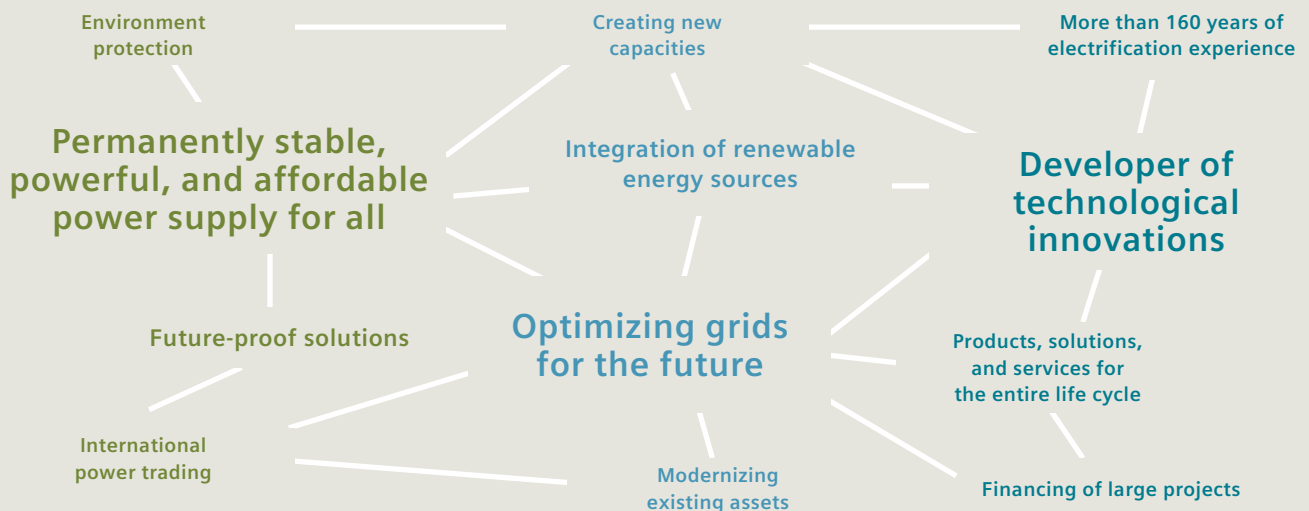


Optimizing the grids for the challenges of today and in the future is a demanding task.

Siemens



Together with a competent partner it becomes easier to master those challenges and to stay successful.



keeping an eye on the big picture while also focusing on the details, thereby ensuring an informed overview and enabling grid operators to make the right decisions that are also acceptable to the public – the right decisions to properly prepare the power systems for the future. This includes the low-loss transmission of large capacities of power over long distances, economic grid access for power from renewable sources, and increased transparency to consistently optimize grid stability – always with the support of the new options created by growing digitalization.

Low loss leads to success

The distances between where energy is generated and where it is consumed are growing. New technologies ensure that increased distances don't result in increased transmission losses.



HVDC technology not only transmits large capacities of power with minimum losses, it also enables international power trading.

Maximum capacity, minimum losses

How long could you run at high speed with a bucket full of water before you drop so much water that it's almost empty?

To reduce the harmful environmental impact of fossil fuels, many countries have turned to renewable power sources such as wind and sun. This, however, results in greater distances between wind turbines, photovoltaic systems, and hydroelectric installations and the cities, industrial plants, and infrastructure facilities where the power is needed. High-voltage direct current (HVDC) transmission is a proven method for transmitting enormous amounts of power over great distances. With the same route width as overhead lines for three-phase high-voltage alternating current and with minimum transmission losses, HVDC systems can transmit substantially more power. It's like a bucket full of water that stays almost full, no matter how far and how fast you run.

HVDC links provide more than targeted, reliable, low-loss power transmission over growing distances. The further development of the technology enables applications in previously unexplored areas.



Converters in onshore stations turn direct current coming in from sea or land into alternating current.

A golden bridge for power

With more than 50 HVDC projects implemented worldwide, Siemens is a leading provider and is further developing the technology in significant ways: HVDC PLUS solutions function as efficient power highways and also help to stabilize power transmission. Because the constant demand for power requires maximum supply security, it is crucial to prevent line faults from causing power failures. In conjunction with full-bridge technology, HVDC PLUS takes over important functions for grid stabilization and can quickly and automatically remedy line faults. This protects connected AC networks from outages and enables reliable transmission over existing overhead lines.

Underground and across borders

HVDC systems can connect asynchronous grids with different frequencies and permit international power trading. Additionally, HVDC PLUS can handle any voltage level. Together with full-bridge technology, HVDC PLUS enables multiterminal DC systems to support and strengthen existing AC transmission systems, and paves the way to the European overlay grid, thus combining the advantages of direct and alternating current grids. As important power grid nodes, high-voltage substations ensure that the power from HVDC solutions can reliably flow into AC grids.

Where overhead lines are not an option – for example due to building restrictions – underground cables and gas-insulated lines (GIL) offer the best alternatives. GILs have proven themselves over decades of use, emit almost no electromagnetic radiation, and are highly versatile in their deployment.

These examples show that the latest generation of HVDC technology makes it possible to balance supply security, rapidly growing demand, public acceptance, and the economical operation of power grids so that all stakeholders benefit.



Gas-insulated lines (GIL) are an excellent alternative to overhead lines and emit almost no electromagnetic radiation.

Making the seemingly impossible possible

In addition to Europe, large countries with rapidly growing power needs such as China, India, and Brazil can also benefit from low-loss HVDC technology. Projects to modernize grids or build new connections often take place under tremendous time pressure: The need for power is growing faster than expected, power generation is outpacing the capacities of grids, and approval procedures are often delayed. All these factors make it even more important for the transmission grids to be completed as quickly as possible and to function reliably after commissioning – all of which is feasible.

Reliability from a single source

Another important component in power transmission is high-voltage substations. They pool the power from different generating sources, transform the voltage, and distribute it to the load points. For example, high-voltage substations feed power from large photovoltaic plants into the AC grid. The components must be especially reliable so that these important power grid nodes never fail.

In many regions of the world, environmental conditions require that substations be extremely robust and, at the same time, efficient. If they're also to be cost-effective, their maintenance must not be too expensive. Compact, gas-insulated substations from Siemens make this possible. Thanks to their small size, simple setup, long service life, and extreme reliability, they guarantee power supply to consumers on an ongoing basis and can be individually adapted to a wide range of requirements.

The reliability of air- and gas-insulated substations depends on the experience and expertise of the manufacturer. The best way to implement projects quickly and successfully is to choose turnkey solutions from a trustworthy partner who is on-site everywhere in the world.

Achieving all this, however, requires a globally active technology partner that is always in close proximity to its customers. A company that has successfully promoted electrification for more than 160 years, and that plays a key role in advancing the technology. A company with a portfolio that contains all the necessary components, including customized services throughout the complete life cycle. One that can arrange for the financing of large projects, and one that can offer all of these things from a single source.

A partner like Siemens.

Power without borders



HVDC project INELFE

One of the goals of the INELFE project was to double the power exchange capacity between France and Spain. Siemens' HVDC PLUS with 320 kV enables high-voltage direct current transmission of 2,000 MW in both directions and power reversal within 150 ms. Underground DC cables connect the power converter stations in France and Spain over a distance of 65 km. Fast control and protection functions and black start capability for rapid grid setup after failures contribute significantly to the supply reliability of both countries and to the stabilization of European grids.

Challenge

Increased capacity for the power exchange between France and Spain

Solution

HVDC PLUS with
320 kV



2,000 MW
bidirectional

65 km
underground cable



150 ms
for power reversal



Black start
capability

Benefits to customers



Greater
supply reliability



Stabilization
of European power grid

Cost-effective access to clean power

Renewable power sources are the power generators of the future – but are not yet economically competitive. Nevertheless, solutions exist that significantly reduce grid infeed costs.

HVDC PLUS technology converts AC current generated in the wind farms into low-loss DC current.



Power from large photovoltaic plants is fed into the AC grid with the help of high-voltage substations.



Helping clean power to become more economical

About 7/8ths of an iceberg is below the water line. What does this have to do with the generation costs of wind and photovoltaic power?

Certainly wind, solar, and hydropower are less harmful to the environment than power generated from fossil fuels. But supplying ecofriendly power to the grid is more complex and expensive. Building rotors and solar panels is only the obvious part of the costs, literally the tip of the iceberg. In addition there are expenses for construction, transport, installation, operation, and maintenance of the platform for the grid connection equipment that account for a large portion of the total generation costs.

This requires new technologies that help making clean power more competitive. End customers will be delighted, but it will work only if power generators and network providers can consistently operate cost-effectively. Reliable, low-maintenance, durable plants make this possible.

Small solution has maximum impact

Here is one example for reducing the less obvious generation costs of offshore wind farms: They're anchored far out to sea and aren't easy to reach. The solution is to shrink the necessary equipment so dramatically that it becomes much smaller and lighter, with much less need for maintenance, while providing the same transmission capacity.

This will soon become reality. Off the coast of Scotland, a wind farm with 84 turbines will produce a total of 588 megawatts and transport the generated AC power to shore via a new type of grid access solution. The offshore transformer module (OTM) is one-third smaller and lighter than conventional AC substation platforms. And it is easy to transport and to install because it requires no special heavy-lift crane ship. All that's needed is a standard and more readily available service operation vessel, which also reduces the installation time by 20 percent.

The Beatrice offshore wind power plant will be the first project equipped with the new offshore transformer module (OTM).



Income return modules for offshore wind farms

For far-shore wind farms HVDC transmission technology is the best choice. In the past several AC substation platforms were needed and a very large and complex HVDC converter platform. Today, Siemens is offering compact HVDC converter platforms, where the wind turbines can be directly connected to. Another further step is a pioneering solution from Siemens using compact and robust diode rectifiers for the AC to DC conversion. Due to the modular approach these can even be installed in a distributed fashion, i.e. several small HVDC platforms are connected in a daisy chain

and then to shore. Compared to the conventional approach, the volume of the platform top sides is reduced by four-fifths and the weight is cut by two-thirds. At the same time, the DRU solution increases the transmission capacity by one-third and reduces transmission losses by one-fifth.

All of this supports the goal to reduce power generation costs to 10 euro cents per kilowatt hour by the year 2020.

Sometimes it's the small solutions that have the biggest impact.

Far out – and still cost-effective



SylWin1 HVDC platform

Since 2015, the offshore platform SylWin1 for the German-Dutch network operator TenneT has been converting alternating current generated by wind farms into direct current. When power is transmitted via the 160 km underwater cables and 45 km underground cables to the second onshore converter station, losses are less than four percent, thus improving cost-efficiency. SylWin1 is one of four North Sea grid connections that Siemens has built for TenneT, with one more currently being built. The links have a total transmission capacity of more than 3.8 gigawatts.

Challenge

Cost-effective connection between offshore wind power plants and the German power grid

Solution

864 MW

capacity (1.1 million households)



2

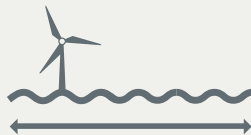
converter stations

Voltage levels

AC: 155 kV / 300 kV / 380 kV, 50 Hz
DC: ± 320 kV

160 km

underwater cable



45 km

underground cable

Benefits to customers



Minimal transmission losses

of less than 4 percent

Transparency creates stability

Stable, secure grids – given increasingly complex power systems, achieving them is a Herculean task. Greater transparency and more powerful tools can help.



Creating new insights based on data helps making the right decisions to stabilize grids.

No fear of complexity

How many balls can an experienced juggler keep in the air? 10? 11?

Network providers know: At some point, they're going to have too many balls in the air. In other words, the influencing factors and requirements are becoming more and more complex and it is increasingly difficult to consistently keep grid stability and power quality at the optimal levels.

The solution is transparency. Through careful monitoring, potential faults can be identified before they occur. With precise information on all the conditions within a widely branched network, it is possible to compensate for fluctuations in power generation and consumption.



SVC PLUS is the ideal solution when space is limited and costly.

Knowledge is power

Stability limits shift continuously during power supply operation, brought about by the changing load on the grid. For operating transmission grids, it remains crucial to be familiar with their defined stability limits. Fundamental load flow changes due to energy market liberalization, an increasing share of intermittent energy sources, and stringent norms and standards raise the bar to achieve lasting stability. Regarding assets, the question often is: How much longer can existing equipment be used before operational or capital investments are due?

Knowing load and consumption in a grid, being able to anticipate fluctuations, and to proactively prevent or remedy dangerous situations is essential. Energy management systems like Spectrum Power from Siemens provide versatile load flow optimization tools, helping to ensure reliable supply, the efficient use of generation resources, and reduced transmission losses in both real-time and operation planning phases.



Storage solutions contribute to stabilizing grids by storing excess power and returning it to the grid when needed.

Less is more

It takes reliably functioning technologies at the field level to regulate voltage and to balance reactive power. Take, for example, flexible AC transmission systems (FACTS). Voltage in widely distributed, vitally important AC grids is fluctuating more and more and its level must be maintained as quickly and effectively as possible. Wear-free static VAR compensators (SVC) that flexibly intervene have long been used for this purpose and can also provide reactive power to stabilize the voltage.

To render this proven technology for SVCs simpler, more compact, and more economic, Siemens developed SVC PLUS. The comparatively low number of components simplifies installation and maintenance, and thus reduces costs. The modular concept features additional benefits and is ideal to cope with challenging conditions in power transmission. SVC PLUS also supports the grid connection of fluctuating power sources such as wind farms and photovoltaic plants. In industrial plants, SVC PLUS is also used for improved flicker reduction.

Increasing grid stability also means being able to quickly restore power supply in case of blackout. Despite all precautions, sometimes power outages are unavoidable due to natural disasters or vandalism. In case of damaged transformers, mobile resilience transformers can be quickly and easily installed. Prefabricated substations ranging from e-houses to mobile substations up to 420 kV are an efficient answer to emergency grid recovery needs or urgent grid connection of power-critical plants. They contribute to improve the grid resilience and allow its agile expansion.

More power in reserve

Above all, the rapidly growing share of renewable power sources in the power mix is adversely affecting grid stability through naturally caused fluctuations in availability. The ideal solution would be to capture large amounts of power while the sun is bright or the wind is strong and store a portion of it, or to store excess power – in case the clouds roll in or the wind dies down.

Storage solutions that permit the short-term balancing of fluctuations and the storage of excess power already exist. SIESTORAGE as an electrical storage system acts as both an energy supplier and consumer. The system feeds in the electricity that isn't currently being consumed and returns it to the grid when it's needed. This serves to stabilize the grids and can help industrial plants and infrastructure facilities to handle peak loads or switch to an alternative power supply in the event of a fault. Excess wind and solar power can also be used by SILYZER systems which, through PEM electrolysis, store it as hydrogen. The hydrogen produced can then be used in industry, as fuel, or for generating power.

It is innovations like these that enable fast reactions to an increasingly complex power system. These innovations were developed by a company that combines a long, successful history of electrification with comprehensive expertise in digitalization. With Siemens, they're based on the experience of a company that's globally active in many areas, a company that treats its customers as partners and wants to collaborate with them to secure the future of power systems.

Grid stability even in the dead of winter



SVC solutions for Hydro-Québec TransÉnergie

To guarantee power supply reliability to some four million residents of the Montreal, Canada area, Hydro-Québec TransÉnergie had to improve network stability. As the substation Bout de l'île is most important to grid stability especially during peak loads in winter, a total of two Static Var Compensators (SVC) were built at the 735-kV level.

Challenge

Stable power supply to four million residents with peak loads in winter

Solution



System voltage

735 kV/60 Hz

2x SVC

with –300 (inductive)
and 300 (capacitive) MVar each



–40°C

Lowest temperature

Benefits to customers



Enhance stability

of the transmission grid by voltage control



Low-loss, publicly acceptable transmission of power over long distances, economically feasible integration of renewable power sources, and fast response capability in an increasingly complex energy system are extremely demanding tasks that are best handled in collaboration. Together, we'll shape the backbone of future energy systems.



Published by
Siemens AG 2016

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Article-No. EMCG-B10035-00-7600

Printed in Germany

Dispo 05402

fb 6990 BR 08161.0

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