Transformer insights
A journey through the fascinating world of Siemens Transformers

Sensformer – Born connected.

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Siemens Transformers play a decisive role in the digital revolution. The energy superhighways of the future consist of high-voltage direct-current transmission. Masterful performance at network hubs is crucial for reliable power distribution. The transformer is at the start of it all, indicating the importance of transformers in power generation. Up close to the consumer, transformers play a critical role in ensuring accessible and efficient energy distribution.
The Sensformer® revolutionizes the role of transformers in the grid

The trailblazing connectivity feature of Siemens’ new Sensformer product class puts an end to transformers being considered as a voltage shifting black box. The new transformer units completely change the way power transmission and distribution systems are planned, operated, and optimized. And that’s for good reason.
Connectivity makes all the difference

Data are the currency of the digital age. And just like in the world of money, there are currencies that are generally held in high regard and others which are not. In the field of power generation, transmission and distribution, the most valuable data are those that come straight from the heart of the system. That’s what Siemens’s new Sensformer® provides thanks to its connectivity feature. In a nutshell, these next-generation products link transformers to the digital grid, which offers considerable benefits. With Sensformer, Siemens is actively shifting the perception of transformer digitalization from a pure maintenance focus towards grid information.

A growing need for transparency and flexibility

The changing energy system requires an unprecedented degree of flexibility and efficiency from all actors. At the same time, excellent reliability and security of supply are a must in a world that is increasingly dependent on electricity. A main driver of this increasing dependence is digitalization. According to statistics by the International Telecommunication Union, almost half of the world’s population uses the Internet. And by 2020 a whopping 50 billion machines and devices will be connected to the Internet of Things.

However, digitalization also provides the key to mastering challenges such as managing the increasing power infeed from renewable sources, e-mobility, global industrial competition, and the quest for the most efficient and reliable power supply. Reliable and comprehensive real-time data provide a degree of transparency that makes it possible to operate, analyze and optimize electrical power systems and their components more flexibly and more efficiently than ever before.

The birth of the connected transformer

Enter the Siemens Sensformer transformer class that was been introduced in spring 2018. Their connectivity feature benefits all grid operations. The connectivity unit, which is installed either inside the control cabinet of a transformer or externally in a special outdoor-casing, is connected to a standard set of sensors for GPS positioning, oil level alarm, top oil or winding temperature, and low-voltage winding current. All data are transmitted via common data communication channels such as Modbus, Ethernet, or GSM and stored securely in the operator’s data warehouse or, alternatively, using Amazon Web Services (AWS) as is the case with Siemens MindSphere®.
The security framework used for this purpose complies with industry standards IEC 62443 and ISO/IEC 2700 as well as with governmental recommendations for data handling using cloud infrastructure. This way merging physics and information, the Siemens Sensformer® turns the black box transformer into a transparent info-hub.

“Born connected”: the added value of Sensformer units

Sensformer units make transformer and grid data easily accessible. Visualization and analytics tools provide operators with a concise overview of all assets. The corresponding data platform is an open ecosystem using data from the installed Sensformer units, which holds tremendous opportunities for operators to create and use applications for optimized grid operation, faster action, and predictive maintenance. On top of that, a mobile app provides secure mobile connectivity for an instant overview of real-time data. Key KPIs push messages in case of alarms. There’s no cause for concern anymore when transformers need to be operated under overload conditions for a certain time and when maintenance works need to be planned precisely. A great contribution to simplified asset management, enhanced operations and increased availability. It also represents a big step towards the Internet of Energy.

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Siemens continues its long-standing history of trendsetting transformer solutions

Reliable electricity for the digital revolution

A study by a large, international environmental organization suggests that, if the Internet were a country, its electricity consumption would be the world’s 11th largest. Major data centers such as those of online stores, search engine operators, and cloud storage providers, have a massive thirst for electricity, and the energy requirements in this particular sector continue to grow at a tremendous rate.
Greater efficiency for offshore wind power

For experts like Michael Liebreich, chairman of the advisory board of the research and information service Bloomberg New Energy Finance, it has long been clear that the cost-efficiency, and ultimately the long-term marketability, of power generation from renewable sources is determined by system costs alone. The calculation includes all investment, operating, and financing costs over the entire service life of a generating system. This total is then divided by the electricity revenues. The result is the system costs, expressed in euros per megawatt hour.

**Transformers to reduce system costs**

Important levers to reduce system costs, besides potential effects of scale, are reduced investment expenditure and increased efficiency of power generation and transmission. With the latest generation of the FITformer REN, an innovative 66-kV transformer developed especially for offshore wind farms, Siemens is introducing a further efficiency boost in the area of offshore wind power.

The new, extremely powerful transformer, with a capacity of 8.7 MW, is an important contribution to the transmission of electricity from increasingly powerful wind turbines with minimum losses: With the higher transmission voltage of 66 kV, it reduces the amount of cable needed for connection of a wind farm plus the losses in the process – making wind power even more cost-efficient. But that’s not all. Despite its power level, the virtually maintenance-free FITformer REN, designed especially for the tough conditions of offshore use, weighs less than 20 metric tons and has a particularly compact structure. That means it can be installed directly in the nacelle of the wind turbine.

**Smart technology for easy serviceability**

In the unlikely case of any service requirement, all components of the new transformer are arranged in such a way that they are easily accessible and replaceable without having to drain the insulating fluid. Siemens offers special in-house trainings during which independent offshore installers are taught to service the transformers on-site. In addition, Siemens provides online support through the use of a so-called “Web eye”: A trained offshore wind turbine technician is equipped with data goggles and a camera and is directly connected to the transformer specialists at the Siemens transformer plant for real-time support. This enables immediate response to any servicing requirement that might occur.

The new standard: transmission at 66 kV

The first practical application for the FITformer REN is in an offshore wind farm off the Danish coast. Wind turbine manufacturer SGRE has equipped the turbines at the 28-MW wind farm “Nissum Bredning Vind” with the new Siemens transformer.

Experts already expect the 66-kV transmission voltage to become the new standard for offshore wind projects. After all, the higher voltage means that more wind turbines within a field can be connected to a single cable, which translates into substantial further savings.
Siemens offer a wide-ranging product portfolio of reliable high-quality components for all types of railway transportation and infrastructure applications. To enable the connection between the power network and the special power supply for the train (e.g. 15 kV / 16.67 Hz) Siemens offers special, so-called line feeder transformers to be installed beside the track. They convert the power from the network to suitable levels for all rolling stock equipment. The special short-circuit and overload conditions create very particular demands in terms of reliability for these line feeder transformers.

As soon as the electricity passes through the pantograph of the train, another onboard traction transformer that is customized according to the train’s specific needs in terms of power, weight, and size ensures that the drive motors and the on-board electrics are reliably supplied with the right voltage and current. Traction transformers from Siemens are used in AC trains all around the world, for example for high-speed (HI) and electric multiple-unit “regional” trains (EMUs) and for electric locomotives for freight transportation as well as for passenger service.

The latest innovation from Siemens in the traction transformer segment is the Tractronic® Thinity™. Its winning features are its particularly low weight and high efficiency. Thanks to its revolutionary tank design, it can save up to 25 percent in weight. With innovations like this, Siemens has supported the railway industry for decades.
Transformers and Big Data

Smart energy management is becoming more and more important. Digitalization, networking, and the so-called Internet of Things make it possible to tap the full potential of energy management: increased availability, optimized operation and maintenance schedules, and increased energy efficiency.

Data right from the grid nodes

Siemens’ state-of-the-art transformers with their digital capabilities assume a new, important role in this context: providing and exploiting digital information. They are positioned at virtually all nodes of an electrical grid, which makes them ideal “informational hubs” for the entire power system.

Real time access to the data that is available in or on the transformer can be a real game-changer for grid operators, industrial facilities, and data centers. Such data includes valuable information about the condition of the entire grid.

New perspectives for optimized grid operation

Processing and analyzing this data, for example in Siemens’ MindSphere®-based cloud applications, allows for optimized load management and consequently enables substantial improvements in the operation of entire power networks and industrial plants. As the number of digitally connected transformers grows, analyses become more and more precise and optimization opportunities grow further.
Intelligence for a longer lifetime

With assets as expensive and crucial as power transformers, it is key to ensure a long lifetime with constant reliability. For decades, maintenance within defined intervals was common – no matter whether the transformer really needed inspection or not. With the use of data collected on the transformer and sent through intelligent diagnostics algorithms, condition-based maintenance has become possible.

A smart cubicle called SITRAM TDCM is an online monitoring system that provides all this: It measures, stores, and analyzes indicative values from transformers. The system is able to provide prognostics and recommend corrective or improving actions to be performed.

The SITRAM TDCM system, which incorporates the domain knowledge of a leading OEM, assists users in optimizing their asset management: It helps reduce the risk of failure and uses maintenance resources effectively.
Siemens Transformers are true pillars of the power grid. Throughout the world they perform safely, reliably and practically unnoticed by the general public. Their hidden qualities are impressive. And upon closer inspection, it’s quickly apparent that modern transformers from Siemens are loaded with remarkable technology. They are much more than just voltage transformers.
Despite all their differences, what do London, Shanghai, and Moscow have in common? Extreme population density, outrageous land prices, and huge power requirements – with an upward trend. These characteristics pose a real challenge for local power companies, who do their best to transmit power to consumers at high voltage levels in order to keep transmission losses as low as possible. But how far can they go when the goal is to deliver electricity – this essential elixir of the modern world – as efficiently as possible to the vibrant centers of metropolitan areas? And how does this affect the population?

**The new generation of transformers: ideally suited for big city centers**

Using extremely compact and exceptionally quiet transformers from Siemens with alternative, environmentally friendly insulating materials, it is now possible to erect a transformer substation in the heart of a major metropolis. In many cities, gone are the days of the large transformer building occupying lots of prime real estate in the middle of the city and serving – other than its main purpose – only as a space for advertising posters. New substations in urban environments are often hidden from public view and have auxiliary uses.

One example is found directly on Seven Sisters Road in the London Borough of Islington, not far from Finsbury Park and the Emirates Stadium. To reliably continue meeting the city's growing power requirements, the British transmission system operator National Grid built a new transformer substation right in the middle of the densely populated Highbury district. This is no longer a risky endeavor when Siemens transformers are filled with alternative insulating fluids.

The new Highbury Station deploys three 400/132-kV, 240-MVA transformers with synthetic ester as insulating fluid. This fluid is a “very special kind of juice.” Compared to conventional, mineral-based transformer fluids, it offers considerable advantages: The liquid is extremely fire-resistant and completely biodegradable, meaning that the transformers can be operated in direct proximity to residential buildings and even in nature conservation areas.

**The new generation of transformers: ideally suited for big city centers**

But that’s not all. The Siemens transformers in Highbury have yet another surprise up their sleeves: They also contribute to a sustainable reduction in carbon emissions. While the transformers are operating, a heat recovery system captures the waste heat and uses it to supply environmentally friendly heat to the nearby Montem Primary School as well as to several residential buildings.
Advantages of ester-filled power transformers

Higher fire safety
- Higher flash and fire point
- Fire point above 300°C
- K-class rating (IEC 61100 / 61039)
- Lower gas conversion factor
- Tank rupture prevention

Smaller footprint
- Eliminate rocks, grating, and support steel
- Change containment size
- Shorter bus duct length

Lifetime extension
- Slower polymerization
- High capability to absorb water from cellulose
- Dielectric strength unaffected by water
- Higher temperature limits

Cost savings
- Lower annual insurance premiums
- Lower losses during operation due to shorter bus duct length

Advantages of ester-filled power transformers
Highest performance with minimum space requirements

Similar to London’s Highbury Station, the Hongyan substation in the Chinese megacity of Shanghai is centrally located. This is a city where buildable land is at a premium – which is why the local power company SGCC decided to put its new substation completely underground. Here, six 500-kV single-phase autotransformers from Siemens with a total capacity of 3,000 MVA are doing their job. Although they’re the highest-capacity underground transformers of their type in the world, they’re also remarkably compact: only nine meters long, less than seven meters wide, and just over seven meters tall – ideal for transport and setup in tight spaces such as an underground substation. The three transformers meet the highest requirements in terms of insulation and magnetic leakage and can have a short-circuit impedance of up to 22%. This ensures extreme operating safety, as does the water-cooling system that was specially developed by Siemens for these transformers and which guarantees reliable cooling even when air circulation is low.

Safe operation and remarkable performance

Change of scene: Moscow on the Moskva River, only about 400 meters from the Kremlin. The mayor of Moscow, Sergey Sobyanin, inaugurated the new Bersenevskaya substation in 2016. For this project as well, the fire and environmental protection requirements were remarkably high. And once again, Siemens provided the solution in the form of transformers insulated with synthetic ester. For the new substation, Siemens custom-built a total of four transformers with a total capacity of 400 MVA for voltages from six to 110 kV. The transformers can even be regulated in the high- and medium-voltage range under load. For the provider – the United Energy Company – this means that the substation operates reliably and flexibly at all times. The transformers in the Bersenevskaya substation are an exciting example of “Ingenuity for life” in practice: innovative engineering that makes our lives a little bit better each day and provides true added value.

On the following pages, we invite you on an interesting and exciting journey through the power grids of the world. Experience what Siemens transformers can do and learn about what makes them unique.
A high level of specialization and a clear focus on quality, along with international know-how and innovation leadership in a clearly delineated market segment – that’s what sets typical “hidden champions” apart. They’re specialists who are largely unknown to the public but whose actions are highly innovative, extremely customer-oriented, and tremendously successful. Generally, they’re of prime importance for the overall context of a system.

Spectacularly unspectacular

In the power system, Siemens transformers act as hidden champions, characterized by quality and innovation in countless power grids around the world: Decade after decade, they reliably render their services, usually unnoticed by the general public; they are extremely powerful and strictly focused on customer requirements.

Well-prepared for new challenges

The increasing complexity of grids and the growing demands placed on our power supply infrastructures create countless new challenges for power transmission and distribution. Thanks to future-oriented technology, efficient transformers from Siemens ensure that electricity arrives reliably and safely at every location where it is needed – today and in the future. These transformers are known especially for their additional, innovative features that offer significant added value, such as their use of alternative, eco-friendly insulating fluids, their use of waste heat for heating purposes, and their extremely low noise levels during operation. All of this makes Siemens transformers a classic example of “Ingenuity for life.” And a contemporary design concept makes quality leadership in electrical and mechanical design visible.

More information:

Brochure: Power transformers
Machine and network transformers from 30 to over 1,300 MVA

siemens.com/transformers
Regardless of whether power is generated by conventional means or from renewable energy sources: Before it even begins its journey from the generator to the consumer, it flows through a transformer that increases the comparatively low generator output voltage to the level required for efficient transmission.
Electricity is a highly versatile, clean, and extremely efficient energy carrier. With electricity, energy can be made available almost anywhere in the world at a reasonable cost. Another increasingly important benefit of electricity: Converting wind and solar power into electricity makes it immediately usable.

**Getting renewable energy to where it’s needed**

But for electricity to arrive at the location where it is needed, it must first be fed into the supply network. This is where transformers come into play. For central power generation in large power stations, “step-up transformers” are used – large power transformers that convert the generated electricity to the requisite voltage level for power transmission on high-voltage lines.

**Transformers enable grid connection of renewables**

Distributed power generation from renewable energy sources is becoming increasingly important in modern energy systems. Electricity is generated by numerous smaller units, such as photovoltaic cells or wind turbines. Transformers are then required to feed this electricity into the supply network. On offshore platforms that collect electricity from several wind turbines, for instance, transformers increase the voltage to the level required for subsea cable transmission from the platform to the point of grid infeed on the mainland.

**Managing the downsides of renewables**

Renewable energy sources have many advantages, but they can also negatively affect power grid stability due to their intermittent nature or by adding unwanted DC to the grid. Such disturbances can be effectively managed by special transformers and variable shunt reactors.
Variable shunt reactors: the key to efficient and flexible grid operation

Such fundamental changes as those currently taking place in the power supply infrastructure have not been seen since the introduction of comprehensive electrification: The number of distributed power generation units, often based on renewable energy, is increasing at an amazing rate. At the same time, large conventional power plants are being retired, which also means retiring sources of reactive power generation.

Reactive power compensation is becoming a must
Due to their nature, however, wind power and photovoltaic plants do not provide reactive power and their output is highly intermittent, depending on the time of the day and weather conditions. Furthermore, in some regions, the existing overhead lines are being replaced by underground cables, which require a higher degree of reactive power compensation. The combined effect of these factors necessitates additional, highly flexible reactive power compensation, which helps equalize load fluctuations in the grid and at the same time improve a grid’s black-start capabilities.

The variable shunt reactor: a new solution to the problem
Siemens has developed an entirely new solution to meet this challenge: the variable shunt reactor with an extended regulation range. Siemens implemented the world’s first prototype for the German transmission system operator Amprion: a large variable shunt reactor with an extremely wide regulation range of 80 percent at 400 kV. Thanks to a tap changer with 33 tappings, it can cover a rating from 50 to 250 MVAr for a 400-kV three-phase unit.

Cost-saving and ready for the future
The benefits of the variable shunt reactor are clear: Flexibility for future network changes, improved blackstart capabilities, and reliable operation, as the reliability of tap changers has been combined with the proven design of shunt reactors. Another benefit is that variable shunt reactors can be coordinated with existing capacitor banks to provide comprehensive reactive power control. This makes transmission grid operation much more efficient and stable. On top of that, the utilization of costly SVC equipment is optimized, as it can be used to the full for dynamic grid stabilization, which is its original purpose.
Transformers directly in the tower

For years, distribution transformers from Siemens have represented a high level of safety in operation as well as excellent electrical, mechanical, and thermal properties. That’s why these transformers are also ideal for use in wind farms. For this type of application, Siemens produces both GEAFOL cast-resin transformers and FITformer REN-type, ester-filled distribution transformers. The latest development is the FITformer REN model that enables transmission at the 66kV level for even more efficiency and highest proven reliability.

Installed up high to keep costs low

The extremely compact transformers fit directly into the nacelle, where they convert the power produced by the generator to the voltage required for the wind farm’s internal grid. Installation in the nacelle reduces material and enables the highly efficient connection of the wind turbine to the power grid, making power generation from renewable energy sources even more eco-friendly and economical.

To enable the transformers to withstand the strong vibrations in the nacelle, Siemens developed a mechanically reinforced version specifically for wind turbines.
Transporting a power transformer from the Siemens factory to its deployment location is a logistical tour de force that takes place on a regular basis. One of the most spectacular transports was when the world’s first 1,100 kV HVDC transformer was transported from the transformer factory in Nuremberg (Germany) to its final destination: Guquan Converter Station in China. The shipping dimension were 13.6 m by 6.14 m by 5.9 m at a weight of 536 tons. It left the plant at night and was shipped to the harbor, where it first was transported by a barge and then handed over in the port of Antwerp to a container ship with the destination Shanghai. In China, it once again was put on a barge and then a special heavy weight transporter – a journey that took several weeks. Every meter, from start to finish, required extreme finesse and precision work on the part of the specialists involved.

Experience the journey of this giant first-hand!
Affordable grid infeed of offshore wind power

Large AC transformer platforms are a major cost factor of offshore wind farms. They collect the electricity generated by the individual turbines in the wind farm and convert it for transmission to the mainland. Construction, transport, installation, operation, and maintenance of such platforms account for a large portion of the total grid access costs.

Bringing down grid connection costs by more than a third

The cost of connecting near-shore wind farms to the AC grid can be reduced by up to 40 percent with the new offshore transformer module (OTM®) from Siemens. An OTM is about a third of the weight and size of a conventional AC substation. This means that it can be installed on the same foundation as a wind turbine – without the use of a heavy-lift crane and in much less time. OTMs are also low-maintenance, making them less expensive to operate.

Environmental benefits included

The new solution also benefits the environment: The transformers are filled with flame-retardant, biodegradable ester insulating fluids, and no mineral oil is used.

Reliable low-maintenance operation proven in practice

The first project to use OTMs for grid connection is the Beatrice wind farm in the Moray Firth off the north coast of Scotland. All three of the 310-MVA transformers for the 220-kV level are designed to withstand harsh operating conditions on the high seas – for example, with a special coating – and require a minimum of maintenance. Cooling is especially important: The OTM is cooled solely by natural convection, without fans or other moving parts, which significantly reduces its vulnerability to failure.

More information:

- IPDF: Alternative fluids
- One pager: Transformers for the offshore transformer module (OTM®) made by Siemens

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Safe and efficient power flow with phase-shifting transformers

Modern, meshed grids frequently have several lines running between two substations, often even at different voltage levels. The power flow in such networks usually adapts naturally according to the ratio of impedances. Under specific grid conditions, this can cause an overload of one line while considerable capacity is still available in other parallel connections.

Better control of the power flow

A phase shifter can be used to regulate the current load, thus inhibiting unplanned power flows and at the same time improving grid efficiency and stability by preventing loop flows and line outages due to overload.

In 2017, Siemens delivered two such phase shifters in the United States. A local power company in California needed to optimize the power flow to its 230-kV grid. The goal was to prevent unplanned power flows across the border to Mexico in the event of an overload.

Technology that lives up to the highest standards

To achieve this, the power company decided to use two phase shifters from Siemens. The requirements for the devices were especially high: Network and system regulations in the two countries required an unusually large asymmetrical phase angle from -80.1° to +31.3 degrees, and placed high demands on controllability and cooling. The transformers also had to conform to the IEEE 693 standard regarding seismic safety because California is a region with a high incidence of earthquakes. This was assured by a finite-element mathematical model which was specifically developed to permit the requisite seismic analyses of the phase shifters.

Use case: World's first phase-shifting transformer with ester insulation liquid

Use case: Phase-shifting transformers for California, USA

Masterful performance at network hubs

The energy superhighways of the future

The transformer is at the start of it all

The local utility opted for two PSTs as their 500kV transmission lines instead of the neighbors in Mexico, the solution allows them to push more power onto utilities on both sides. The power flow needs to be controlled so that the energy produced in one country can be transmitted to its 230-kV grid. The goal was to prevent outages due to overload.

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The share of electricity in the energy mix that comes from renewable sources is on the rise. This is also changing the requirements placed on power grids in many different ways. One major challenge that must often be overcome right where the electricity is generated is to bridge – with low losses – the usually long distances between the generation sites and the centers of consumption.

High-voltage direct-current transmission is the key technology to solve this problem. Siemens is constantly moving the development of this transmission technology forward.
Renewable energy sources are often generated far from the large centers of consumption. One example is offshore wind farms, which are especially powerful and efficient. However, the electricity they generate must first be transmitted from the open sea to the coast and then on to the centers of consumption – in Germany, for example, from the far north to the south, with its strong economy and great hunger for energy. The existing AC grid is reaching the limits of its abilities. The capacities are insufficient, and the power losses during transmission would not be economically justifiable.

**Great performance, low losses**

That’s why high-voltage direct-current (HVDC) technology is being used more and more. This technology makes it possible to connect offshore wind farms to the onshore grid with minimal loss. In addition, it allows electricity to be transmitted to the load centers over long distances with low losses. HVDC regularly helps reduce CO₂ emissions, since it is no longer necessary to generate fossil-based power near the load centers. More and more new transmission voltage records lead to even greater efficiency.

Efficient, powerful, and maintainable transformers are needed at multiple points in an HVDC system. In particular, these are the converter transformers that first transform the alternating current into direct current and then back into alternating current at the end of the transmission link. Siemens is carrying out pioneering work in this area, as HVDC technology is breaking new ground in many respects.

**Record-breaking HVDC transformer technology from Siemens**

The HVDC transformer manufactured in the Siemens transformer factory in Nuremberg, Germany, is a particularly impressive example of this pioneering work. It operates in the heart of the HelWin1 offshore platform, which went into service in 2015 – far out in the North Sea, approximately 85 kilometers from the mainland. The platform connects two offshore wind farms to the mainland. It transforms up to 576 MW of alternating current into direct current for this purpose.
Siemens is setting another record with its converter transformers for the 1,100-kV HVDC link being built between Changji and Guquan in China — currently the world’s biggest and most powerful HVDC project and expected to go into operation in late 2018. The link is 3,284 kilometers long and achieves the enormous transmission power of 12 gigawatts — equivalent to the average output of 12 coal-fired power plant units.

**World-leading technology, local added value**

Trailblazing technological innovations, which are used in the next generation of Siemens converter transformers, are what make this transmission capacity possible. The converter transformers, whose 587.1 MVA of power make them the most powerful in the world, are manufactured in the Siemens factory network, led by the Nuremberg transformer factory. While the prototypes are manufactured at the Siemens transformer plant in Nuremberg, serial production takes place at the Siemens transformer plant in Guangzhou, China. Several further units are assembled by local Chinese transformer manufacturers that benefit from the transfer of Siemens’ technology. The same applies to another new converter transformer model, which can be connected directly to the Chinese 1,050-kV three-phase grid.

**HVDC is bringing Europe’s grids closer together**

HVDC technology is also making an increasingly important contribution to the international energy trade and to stabilizing the power grids, which are now subjected to very heavy loads in many places. One current example is the 1,000-MW “Nemo Link,” one of the common-interest projects established by the European Commission that are expected to create an integrated energy market within the European Union. Nemo Link will establish a connection between the Belgian and British power grids. This will increase power supply reliability in both countries and promote the inclusion of renewable energy sources, such as offshore wind, into the European power infrastructure. A total of eight converter transformers with a nominal power output of 365 MVA each will be supplied by the Siemens transformer factory in Nuremberg for this HVDC system, which is designed for a transmission voltage of 400 kV.
The constantly increasing relevance of electricity as an energy source means that reliability of supply and availability are becoming ever more important. Digitalization, industrial processes and day-to-day activities depend on the reliable availability of electricity.
Although the “blackout baby boom” – the sudden increase in the birth rate in New York nine months after the major power failure of 1965 – is more in the realm of urban legends, large power failures in today’s world have far-reaching consequences. After all, it’s more than just the lights that go out. In reality, our entire modern infrastructure would fail to operate after just a short period.

That’s why a reliable power supply is more important today than ever before – for economic as well as societal reasons. At the same time, decentralization and digitalization of the energy system create entirely new risks. Security-related demands on grid operators are therefore skyrocketing, since security of operation and of supply are more paramount today than ever before.

**Grid resilience has become a sine qua non**

The experts agree unanimously: The key to a power transmission infrastructure that offers maximum reliability is grid resilience. A term derived from the field of psychology, resilience describes the ability of a system to anticipate risks smartly, learn from previous incidents, and provide a comparatively stable response to disruptions on this basis. For transmission networks, this means in practice that all elements must be comprehensively protected physically, systemically, and from an IT perspective. The proverbial weakest link must not be substantially more susceptible than the strongest.

**Transformers are a key focus**

Transformers deserve particular attention when it comes to establishing a resilient transmission infrastructure. They are the hubs holding everything together in a grid infrastructure. But at the same time, this is where the grids are particularly vulnerable: if a power transformer in the grid should fail, it cannot quickly be replaced. It can take weeks or even months to obtain a replacement, since a large transformer is not an off-the-shelf product.
Many requirements need to be met

Transformers in transmission grids must therefore be capable of withstanding many different stresses and risks for a period of decades. Operational disruptions such as voltage spikes and climatic influences like extreme temperatures, hurricanes, or – in coastal locations, for example – salty air can present a real challenge. Furthermore, in many parts of the world, natural disasters like earthquakes are an ongoing latent risk, while in other locations, vandalism can be a threat. Ultimately, in state-of-the-art grids with digitalized operation, it is essential to protect the transformers’ control systems against unauthorized access and manipulation. There are many aspects to the operational safety and reliability of transformers, and Siemens takes them all into account – as early as during the transformer layout and design stage and continuing through construction all the way to installation and commissioning.

Getting a grip on insidious aging processes

Even so, the list of potential risks is still far from complete. One factor that is growing in importance is aging. This is affecting more and more grid components, while at the same time, demand on transmission performance continues to rise. This issue is increasingly causing headaches for many grid operators, since the components in their transmission grids are beginning to show their age, particularly in the industrialized countries. In other words, the risk of age-related outages is also on the rise. This is where continuous status monitoring comes into play, as part of Transformer Life Cycle Management (TLM™). By monitoring key parameters, transformer experts at Siemens can recognize aging processes and damage at a very early stage. Outages become predictable and can therefore be averted in advance. Repairs and refurbishments by Siemens can also substantially extend the potential service life of a transformer.

The ultimate emergency solution

So, what happens if a transformer fails despite all the protection and security measures put in place? Here too, Siemens has a suitable and modern answer: mobile, plug-and-play transformers that are ready for immediate use. Thanks to their compact and light design and their versatility, they can be installed quickly and easily in the event of an outage. This restores normal grid operation much faster than other measures and helps cut the cost of outages quite substantially.
It's a scenario feared by energy utilities and grid operators alike: a natural event like a hurricane or flood that damages a power transformer. Replacing this type of transformer is a complex, costly, and time-consuming process that can take weeks, and in most cases even months. But the power supply must be restored as soon as possible.

**Much faster power supply recovery**

This is where the newly developed, mobile, plug-and-play transformers from Siemens (mobile resilience units) provide a remedy. They enable the power supply to be restored in just a fraction of the time normally required, and thus play an important part in ensuring a more reliable energy supply.

**Designed for the utmost flexibility**

Plug-and-play transformers are a true multipurpose tool for the grid: They are designed for multiple voltage levels, with high-temperature insulation material like aramid fiber and a flexible cooling system to keep their weight and size to a minimum and assure maximum mobility. Special plug-and-play bushings and cable connections, as well as several other features, cut the time needed for installation from several weeks to just a few days.

**Suitable for environmentally sensitive areas**

If required, the transformers can also be filled with environmentally friendly and flame-retardant esters, enabling them to be used in environmentally sensitive areas as well as in densely populated locations. Their compact design makes it possible to transport them filled with oil, so there is no need for oil handling on-site, which further shortens the installation time.

More information:

- Brochure: Grid resiliency solutions for power transformers
- Picture slideshow: Installing a mobile resilience unit within three days
- Whitepaper: Bypassing transformers
Three pillars of safety

Prevent
Continuous status monitoring is an important element in ensuring safe transformer operation. By monitoring key parameters, it is possible to recognize signs of aging and damage at a very early stage. Outages become predictable and can be averted in advance. Perfectly coordinated refurbishment based on recorded and analyzed measurement data can help to substantially extend the service life of a transformer and take action before serious damage occurs.

Protect
Customized solutions from Siemens can provide highly effective protection for transformers against a whole series of risks. Non-magnetic steel inserts, for instance, protect the transformer against overheating through geomagnetically induced currents during solar storms. Some protective devices, such as bullet-resistant shielding, can even be retrofitted. Alternative insulating fluids like esters with a high ignition point markedly reduce the risk of explosion and fire.

React
Outages can never be completely ruled out, even when all precautionary measures have been taken. It’s best to be prepared and able to act swiftly to restore the power supply again quickly. The Pretact solution provided by Siemens to meet present-day needs is its “plug-and-play” transformers, so-called mobile resilience transformers. These are comparatively compact and lightweight, and can be transported and installed quickly and easily, which helps keep the duration and costs of an outage to a minimum. Since the mobile resilience transformers can be extensively adapted to suit individual requirements, there is no need for grid operators to keep a large number of separate replacement devices on hand for every voltage level, which makes for a clear cost advantage.
No chance for trigger-happy vandals

It has long been standard practice to set up power transformers, depending on their location, in such a way that they will reliably withstand potential external effects of natural events – lightning, earthquakes, or geomagnetically induced currents. The increasing regularity of extreme climate conditions also poses little risk to the operational safety of transformers in transformer substations in most cases. They are also sufficiently immune to operational disruptions like voltage spikes.

Substations have become vulnerable targets
But today, a completely different and unpredictable risk is taking on disturbing proportions in some parts of the world: the deliberate destruction of equipment. In rural areas of North America, in particular, there are increasing reports of transformers at power stations and in transformer substations being shot at with powerful weapons. For example, unknown individuals in San Jose, California, shot at a transformer substation with high-powered rifles in April 2013.

Within only 20 minutes, the attackers put 17 power transformers out of action, thereby threatening the safe supply of power to the whole of Silicon Valley.

Transformers in full armour
As part of its unique Pretact® concept, Siemens has developed a bullet-resistant protection system for transformers. The shielding can be fitted with the transformer ex-factory, and existing transformers can be retrofitted on-site. The transformer is protected against small arms fire by specially developed panels that are attached with steel brackets. Additional foundations are not required. The panels even withstand an assault from VPAM class 13.50 BMG machine gun projectiles. Some of the panels are moveable to access pumps and fans for maintenance purposes.

Thanks to Siemens’ innovative development, transformer operators in the affected areas have access to a solution that effectively minimizes the risk of outages caused by vandalism and improves the security of the power supply.
Power transformers are valuable capital assets that usually operate reliably for decades without interruption. It’s all too easy to forget that the solid and liquid insulating materials inside them are subject to natural aging processes.

A revealing blood count
The analysis of a transformer’s insulating liquid is particularly helpful in evaluating its internal status. The Siemens specialists examine it in detail as part of Transformer Life Cycle Management (TLM™). Just like a blood count, this analysis can provide important information that – to continue the medical analogy – can save the life of a power transformer.

The art of transformer rejuvenation
Preventive actions taken in a timely manner can extend the service life of a power transformer appreciably and help protect the investment. SITRAM® REG oil regeneration and the highly efficient oil drying solution SITRAM® DRY, which removes detrimental accumulations of moisture, are just two examples. These services can be performed on the energized transformer.

More about Transformer Lifecycle Management and extending a transformer’s service life.
What happens during a blackout?

If the power fails in your own home because a fuse blows or a residual current circuit breaker trips, the problem is usually rectified quickly and the consequences remain easily manageable. But what happens if a large power transformer – one of these huge giants in a substation, that can easily weigh up to 400 tons – fails, possibly leaving an entire part of the city or rural area without electricity? The consequences are more serious than many might first imagine.

Outages must be prevented before they happen

The April 2015 Quadrennial Energy Report of the U.S. Department of Energy concluded: “High-voltage transformers are critical to the grid. They represent one of its most vulnerable components. Despite expanded efforts by industry and Federal regulators, current programs to address the vulnerability may not be adequate to address the security and reliability concerns associated with simultaneous failures of multiple high-voltage transformers.” That’s why outages must be prevented before they happen. And if a fault occurs, the power supply has to be restored as quickly as possible.
A large number and variety of transformers ensure that power flows from the transmission grid to the regional distribution system and ultimately makes its way reliably to the consumer. Consumers range from industrial plants with high power requirements to electrically operated rail vehicles all the way to residential households. For a number of years now, growing volumes of distributed power generation have also been part of the mix at the distribution system level, creating entirely new demands on the distribution systems.
Distribution transformers guarantee that all consumers are reliably supplied with the right voltage for their needs. It may sound simple, but depending on the supply area, grid structure, and the nature of the consumers, this may actually involve many complex challenges – and distribution transformers must handle them successfully and reliably.

A wide range of requirements to be met
For reasons of cost-efficiency, distribution transformers are installed as close as possible to the consumers, since the shorter the distance between the power distribution system and the consumer, the lower the transmission losses. On the other hand, however, the available space in the vicinity of the consumers is often very limited. In addition, the distribution transformers must be extremely safe and dependable in order to preclude any risks to people and equipment. And ultimately – in densely populated areas in particular – they must run as quietly as possible to avoid noise pollution.

Two tried and tested product lines
The proven distribution transformers from Siemens, the liquid-filled FITformer and the GEAFOL Neo cast resin transformers, excel at meeting these requirements. They also score high in terms of environmental compatibility, efficiency, and maximized availability. As a result, they save time and money, while assuring outstanding grid and application stability.

Canada offers a textbook example of maximum efficiency, with pole-mounted transformers with amorphous cores that keep losses to a minimum. In 2016 alone, Siemens installed 1,200 of these high-efficiency transformers, with power ratings of 25 to 100 kVA, for the Saskpower utility company in Canada’s Saskatchewan Province.
Particularly demanding: industrial applications
Industrial firms have an entirely different set of requirements: For many businesses, electricity is an essential resource in production, for example in the iron and steel industry as well as in the chemical industry, where the power supply is subject to particularly stringent quality and safety demands. After all, if a continuous process comes to a standstill, the losses will quickly run into the millions. For example, if an aluminum electrolysis freezes because of an interruption of the power supply, the metal solidifies and is wasted and the melting pots have to be repaired. That’s why the power supply infrastructure for manufacturing operations is often configured redundantly. And since industrial applications often require high current levels and voltages, they use various special industrial transformers in addition to the traditional power or distribution transformers.

The absolute measure of all things is maximum availability and power quality – also for data centers, the backbone of today’s information society. And this will further grow in importance as the "Internet of Things" develops. Of course, transformers must operate with the same level of reliability.

True all-rounders that keep the trains running
Tractronic® traction transformers for trains and locomotives have a special position among transformers. The particular challenge for these “mobile” transformers is to provide maximum performance in the smallest possible space and to cope with the different types of electricity, frequencies, and mains voltages in different countries. Siemens can look back on more than 100 years of experience in this special field – which is a robust base for customized traction transformers that prove their worth based on maximum reliability, efficiency, and safety in operation.
Impressive in all aspects: transformers for industrial processes

For many industries, electricity is the key resource for production – in mining and the metal industry, for example, or in chemical plants, metalworking, or in the oil and gas industry.

To guarantee the necessary current ranges and voltages, along with a reliable power supply and maximum safety, the special transformers used in industry must meet very specific requirements – for instance delivering high energy volumes at low voltage and high currents, making large volumes of DC electricity available for fused-salt electrolysis, or satisfying special safety requirements associated with the handling of flammable and explosive materials.

That’s why every individual transformer is customized for its particular situation, thus enabling it to serve reliably and for many years under especially tough conditions.
The history of Siemens’ transformer business dates back to the 1890s, when electrification suddenly kick-started the second industrial revolution and pushed the development of modern industrial society. From the earliest days of electrification, Siemens transformers made it possible to transmit power over long distances and make it available everywhere.

In 1890, Siegmund Schuckert founded a transformer factory in Nuremberg. The transformer business of Siemens & Halske and Schuckert & Co. were merged in 1903 to form Siemens-Schuckertwerke GmbH – the nucleus of today’s Siemens Transformers Business Unit.

1900–1920
The demand for transformers increased steadily during this time, while transmission voltages rose and more and more power was required. Siemens-Schuckertwerke produced large transformers with overvoltages of up to 110 kV and with outputs up to 30 MVA. The largest units delivered during this time were rated 60 MVA at 110/25 kV. The transformers for the first European 100 kV transmission line also came from the Nuremberg transformer plant.

1920–1950
The “Roaring Twenties” witnessed great progress in the development of transformer technology: Oil transformers were monitored for the first time with a Buchholz relay. In 1923, the first five-legged cores for high-current three-phase
Transformers were produced, and four years later the manufacture of transformers with tap changers for uninterrupted voltage adjustment under load began. At the end of the decade, 60-MVA three-phase oil transformers were produced for the 220-kV voltage level. In the thirties, the production of 270-kA furnace transformers, whose voltage was adjustable under load, was started, and a test transformer for one million volts was produced in 1933.

1950–1970
The electricity consumption of industrial enterprises and private households all over the world increased strongly in the decade after the Second World War. In the early 1950s, Siemens-Schuckertwerke introduced computers to calculate and scientifically investigate the performance of transformers. New technologies and material, such as cold-rolled, grain-oriented electrical sheets were introduced in transformer production, and changeover switches were integrated into the transformer tanks. In 1957, 660 MVA three-phase 400/231-kV transformers were built for the construction of the 380-kV network in Germany.

In 1966 Siemens-Schuckertwerke, Siemens & Halske, and Siemens-Reiniger-Werke were merged, and in October, Siemens Aktiengesellschaft was founded. Three years later Siemens and AEG-Telefunken, the two German pioneers in electrical engineering, pooled their activities in the field of transformer construction and set up the joint subsidiary Transformatoren Union, which became one of the world’s largest transformer manufacturers.

1970–1990
In the 1970s, several production and testing facilities were modernized and expanded. Transformers of more than 1,000 MVA and 1,500 kV were manufactured and tested, and the export share of industrial, power, and special transformers as well as reactor coils grew continuously. At the same time, HVDC transformers were developed. The rationalization of production processes, improved transformer reliability and availability, and consistent quality assurance helped Transformatoren Union keep its international competitive edge in the 1980s. This was an economically difficult decade that was characterized by worldwide overcapacities in transformer building. In the late 1980s, Transformatoren Union was fully integrated into Siemens.
1990–2000

The 1990s saw several important technical improvements, such as the development of a new, high-quality corrosion protection that set new standards in environmental protection. At the same time, HVDC picked up momentum on the world market, especially in emerging economies, and Siemens delivered HVDC transformers for projects of ever-increasing size, such as the Tianshengqiao-Guangzhou HVDC transmission system in southern China, which has a transmission capacity of 1,800 MW and operates at 500 kV.

2000–2010

Siemens’ global transformer engineering and manufacturing network was formed in the early years of the new millennium. VA TECH was integrated into Siemens in 2005, which combined the strengths of two of the world’s top transformer manufacturers. Today, Siemens’ unique, worldwide transformer engineering, production, and service network with offices, production centers and service facilities in more than 190 countries is one of the world’s most effective and innovative companies in the industry.

2010–2017

Developments like ester-insulated power transformers, the extremely quiet “whispering transformer,” the highly innovative Pretact® concept, and the extremely powerful offshore transformer module (OTM™) for offshore wind power plants underscore Siemens’ performance and competitive position. Since March 2017, a new, shared design for all transformers making the innovations hidden inside the transformers visible ensures a uniform contemporary look across all product types.

2018

Today’s world is connected, and we believe it is about time to also connect transformers digitally. We are paving the way for a completely new product class: the Sensformer. No matter if you operate a transformer in a power generation plant, an industrial application or in the grid: Your assets will let you know their operational status and give an indication when abnormalities occur. The consequence: more transparency and flexibility at minimized risks and cost.
Powerhouses in the neighborhood

The transformer is at the start of it all

The energy superhighways of the future

Masterful performance at network hubs

Up close to the consumer