



# ABB wind power solutions

## Total solutions for wind power plants

# ABB wind power solutions



The wind is free. Capturing the wind and putting it to work can be challenging.

ABB is one of the few suppliers that have been involved in the commercialization of wind power since the earliest days. As the largest supplier of electrical components, systems and services to the wind power industry, we have decades of experience and have installed more equipment in wind farms than any other supplier.

As you read this publication, you will discover the breadth and depth of ABB technology and services for wind farms. You will also learn how ABB expertise ensures that each wind farm project will be completed on time and begin to reliably and profitably generate electric power.

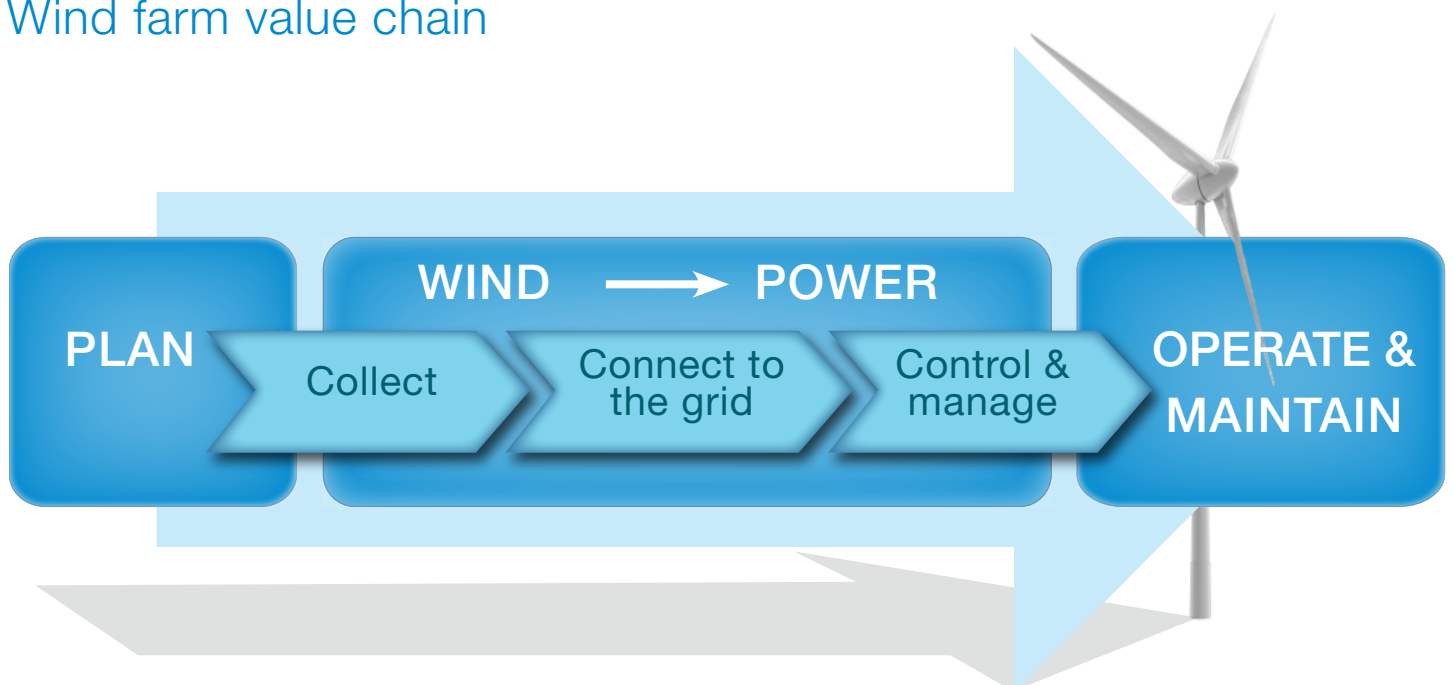
Around the globe, developers and operators are eager to find qualified suppliers to assist in bringing new wind capacity on-line. And around the globe, suppliers are jumping into the wind market, eager to try and capitalize on the tremendous demand. Unfortunately, many of these organizations lack solid knowledge and experience in dealing with the unique challenges of wind farm design, construction and operation, or have narrowly focused expertise in only a few aspects of these projects.

“Of all the forces of nature, I should think the wind contains the largest amount of powers. As yet, the wind is an untamed and unharnessed force; and quite possibly one of the greatest discoveries hereafter to be made, will be the taming, and harnessing of it.”

— Abraham Lincoln, 16th President of the United States



## Wind farm value chain



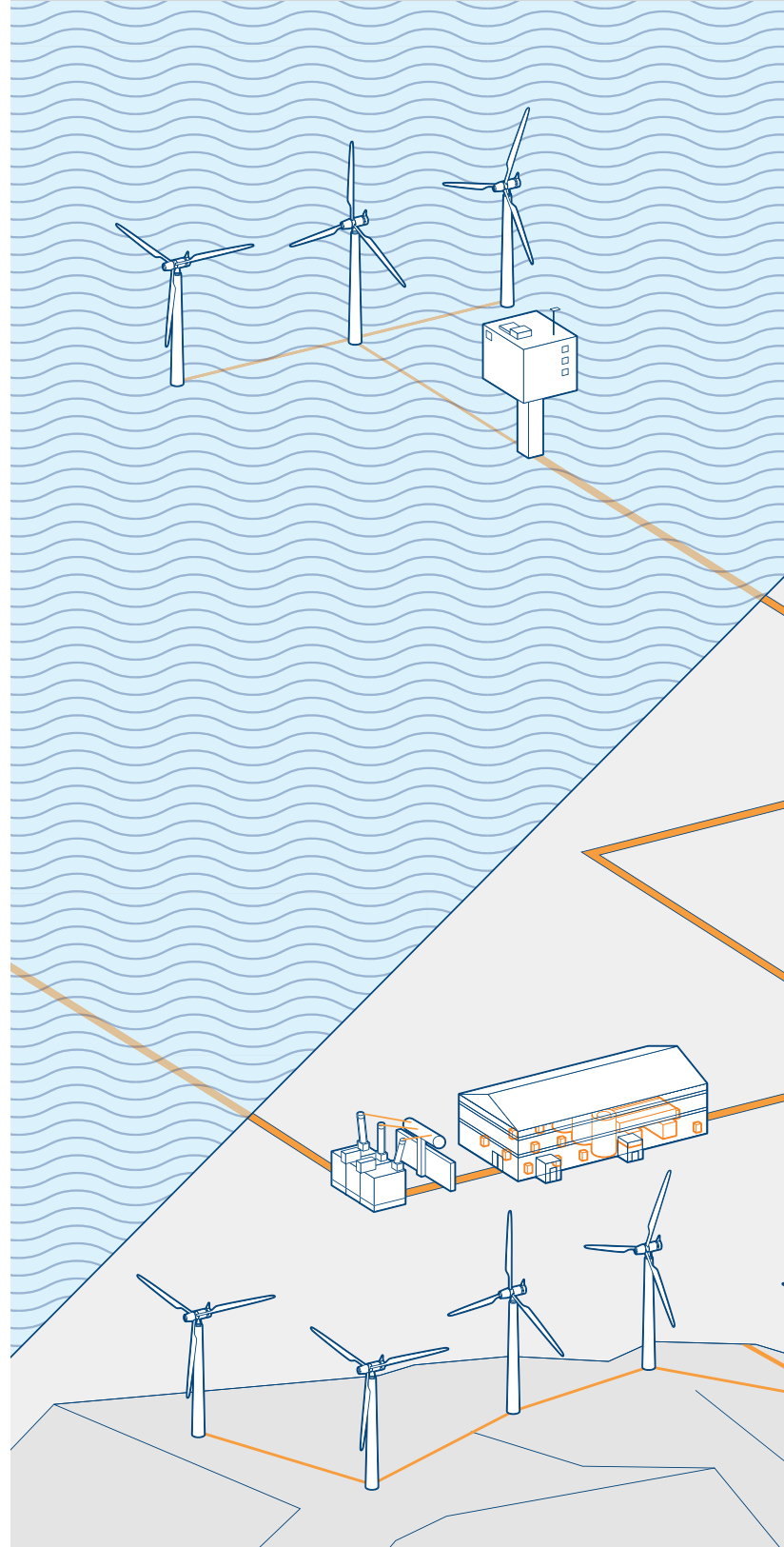
# Planning for farm development

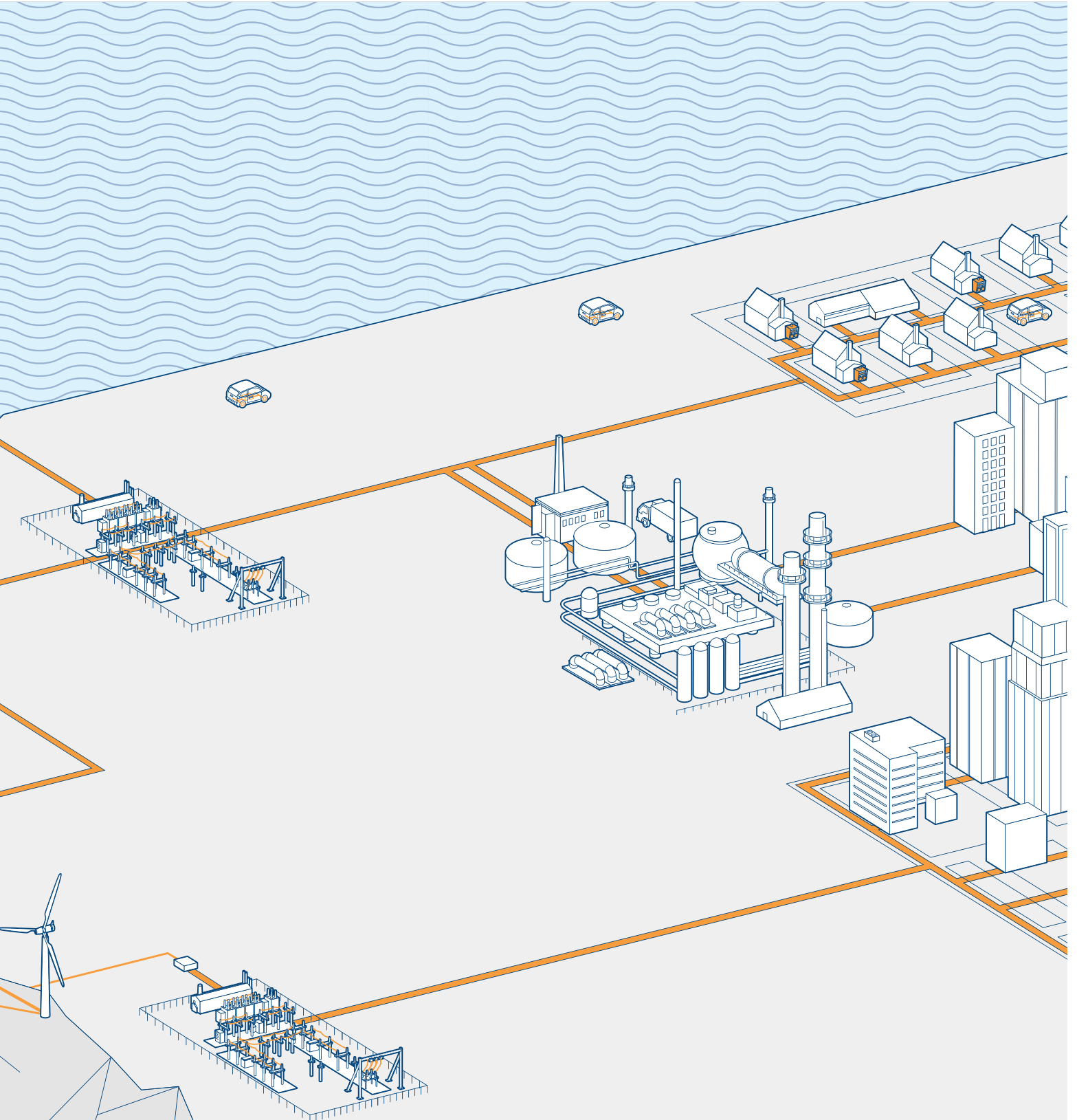
Wind farm developers depend on ABB to provide reliable, high-performing wind power generation solutions. The concepts for these solutions begin taking shape long before there is any consideration of the appropriate technology for a given project.

ABB wind and utility expertise helps improve efficiency and maximize generation capabilities before design begins. ABB Consulting provides the critical system planning, feasibility studies, and other site-specific analysis early in the initial design of the farm. Optimal selection of components needed to collect wind power, consideration of multiple boundary conditions, an appropriate grid-connection strategy and other factors can combine to create a significant difference to the success of the farm.

In addition to realizing the maximum power potential of a farm, ABB consulting related to grid integration and grid code compliance provides a comprehensive approach that ensures compliance, identifies appropriate reactive power handling, determines system impact and provides the maximum power injected into the grid. Our decades of experience with the utilities and their specifications help ABB to speed the approvals, testing and final implementation of the farm. ABB consultancy also addresses reliability/availability optimization with cost/risk analyses.

Our success at serving customers in the wind industry is evident in the fact that more than 75% of our business is from repeat customers who were well satisfied with the design, installation, operation and maintenance of the technology provided. In the end, ABB Consulting assures the wind farm owner that their project will provide reliable power generation and meet production expectations. ABB has a solid reputation for reliability, quality and dependability. Working with a partner like ABB increases the ability to secure the required financing and move the project from idea to reality.





# Collecting the power of the wind



Within each individual tower, the raw power of the wind is collected and converted to electrical energy. The power from each individual tower is then collected and combined so that it can be most efficiently carried to the substation where it will be passed on to the transmission grid. ABB provides technology supporting power collection at each point in the process.

## Solutions inside the tower

**In-tower transformers** The first step in stabilizing and transmitting energy is the transformer within the tower. ABB is the largest transformer manufacturer worldwide. We offer the most complete range of transformer designs for wind power applications, including both liquid-filled and dry-type, with voltages up to 72 kV for offshore applications, all designed to fit inside the turbine. Each ABB transformer is engineered to reduce losses, capturing the maximum possible energy from the farm and delivering it to the grid. Special design considerations harden these transformers, enabling them to withstand the potentially harmful humidity, vibration and harmonics present in the turbine structure. We have more than 23,000 transformer units operating reliably and efficiently in the wind power industry around the world.

**In-tower switchgear** ABB develops, produces and delivers a full range of medium and high voltage solutions for wind power applications. These solutions include switchgear with integrated switching and protection for the wind farm network. Switchgear is available that can be located inside the tower as a complete solution, as part of a compact secondary substation close to the tower or for distribution substations. Each switchgear lineup can be highly customized by selecting the desired features and components, with additional customization available to further adapt the switchgear to meet specific customer requirements.

This wide portfolio ensures that ABB can provide the ideal solution for any application. ABB offers arc-proof, air-insulated switchgear solutions and gas-insulated primary switchgear, both in voltages up to 40.5 kV for onshore wind farms and up to 72.5 kV ready for new generation of offshore turbines and new collection grid at 66 kV.

ABB SafeWind gas-insulated secondary switchgear technology is designed for wind turbines. This compact switchgear solution, available up to 40.5 kV, provides switching and protection of wind power plant networks even in harsh operating environments. The narrow width allows the switchgear to fit through tower doors during installation or replacement.

SafeWind is a completely sealed system with a stainless steel tank containing all the live parts and switching functions. This ensures a high level of reliability as well as personnel safety and virtually no maintenance.

# Collecting the power of the wind

## Solutions outside the tower

**Compact secondary substations** ABB compact secondary substations (CSS) are modular systems that provide all vital medium and low voltage equipment pre-assembled in an engineered enclosure. The unit arrives on site ready to connect to the local grid, minimizing the need for project management and coordination while ensuring rapid startup and commissioning. CSS modules are ideal for remote installations where skilled labor is often hard to find, and all labor is expensive and difficult to manage.

The modular systems are available as walk-in or non-walk-in outdoor enclosures or buildings that require a relatively small footprint. They house switchgear, distribution transformers, low voltage switchboards, connections and ancillary hardware such as battery banks. The ABB global CSS platform provides type-tested and arc-tested substation solutions to suit even the most demanding environmental conditions. These systems provide cutting-edge technology solutions to integrate wind power into the grid, increasing reliability and energy efficiency.

**Pad-mounted transformers** ABB pad-mounted distribution transformers step up the voltage from the low voltage generated by the turbine to the medium voltage collector system. ABB pad-mounted distribution transformers provide a safe, efficient and compact solution for wind farm generator step-up transformers at the base of the tower.

ABB has unmatched experience and expertise in wind power generator step-up applications with our complete scope of transformer offerings, including our Green-R-Pad™ high-efficiency and environmentally friendly family of pad-mounted transformers for renewable applications.

## Collection grid

The energy created in each of the individual turbines comes together via the collection grid. ABB provides the design expertise required to create a resilient, reliable, low-loss grid, ensuring that the maximum power generated in the nacelles is efficiently collected and conveyed to the onshore substations. As part of turnkey grid-collection systems, ABB can provide medium voltage cables customized to the application based on a comprehensive network analysis. The cables are configured based on an optimum balance of cable production and installation (trenching) cost compared to the required transmission availability and reliability.

The cross-section of every cable is customized to the required short circuit and rated current requirements, taking into account the trench conditions and influence of nearby buried conductors. Energy losses are accurately calculated, weighting power losses in various scenarios from 0% to 100% of the rated power output and considering the yearly hours forecasted by the wind-speed statistical distribution.

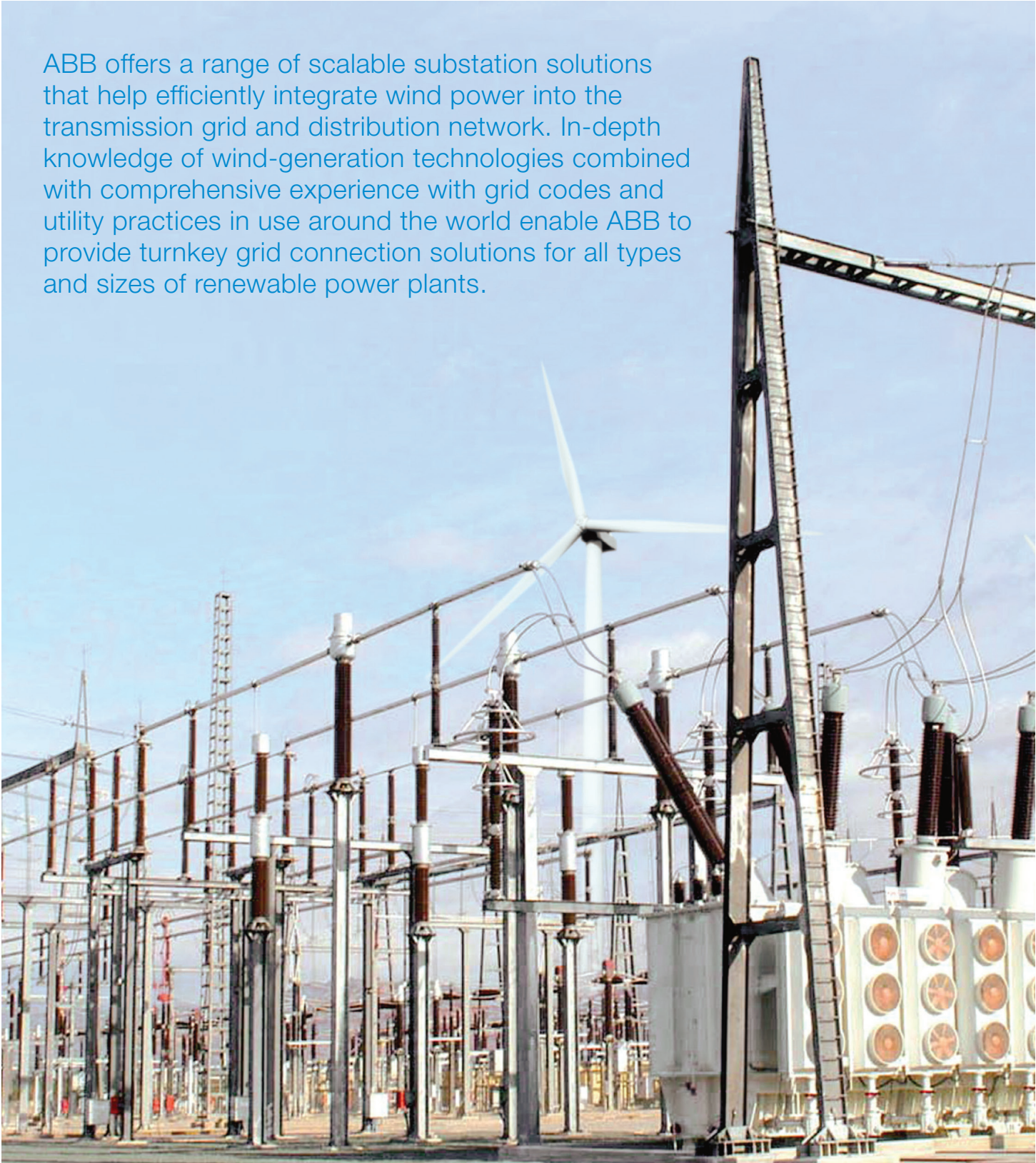
A voltage profile along the medium voltage grid is determined to check the operational limits in every wind turbine generator for different scenarios, modeling all of the cables' electrical parameters. This model also helps precisely calculate actual reactive compensation needs while testing the voltage control system performance.





# Connecting power to the grid

ABB offers a range of scalable substation solutions that help efficiently integrate wind power into the transmission grid and distribution network. In-depth knowledge of wind-generation technologies combined with comprehensive experience with grid codes and utility practices in use around the world enable ABB to provide turnkey grid connection solutions for all types and sizes of renewable power plants.



## Substations

**Pre-engineered substations** ABB's compact and scalable substation solutions facilitate efficient grid connection of all types and sizes of wind power plants. Short turnkey delivery times accelerate project schedules and bring new generation assets online more quickly. Fast and well-documented proposals help to simplify and shorten permitting processes, concession applications and utility negotiations. The customized and fully integrated systems have a small footprint, are based on proven and state-of-the-art technologies and are designed to meet the requirements of customers with a global market presence as well as local specifications.

**Switchgear** In high voltage switchgear, ABB has over 50 years of experience. ABB offers a complete range of high voltage-technology products for power substation applications, including air- and gas-insulated switchgear as well as mixed technology multifunctional modules. ABB's hybrid switchgear modules, PASS and the integrated gas-insulated switchgear (GIS) have taken conventional switchgear technologies to new levels of prefabrication, mobility and functional integration. They are designed to respond to increasing needs of renewable integration and fast installation.

The PASS modular design allows a wide range of configurations inclusive of circuit breakers, disconnecting switches, earthing switches, current and transformers, surge arresters and protection and control systems.

The integrated GIS also comes with a high level of functional integration and the inclusion of a housing that enables a wide spectrum of auxiliary equipment to be installed and configured in the factory, with flexible connection options.

**Power transformer** Every ABB power transformer design is adapted to the individual needs of the customer, and all ABB transformers are built to a common, global design and manufacturing concept. The TrafoStar™ concept, implemented in every ABB manufacturing facility worldwide, provides common design criteria supported by the Six Sigma quality system. TrafoStar also relies on the application of global best practices to guarantee uniform quality and unmatched performance.

Every TrafoStar transformer is built from standardized, service-proven components and modular component blocks to create flexible, dependable, tailor-made products that ensure maximum availability, lower maintenance costs and reduced life cycle costs.

**Substation control, protection and automation** ABB provides systems for control, protection and monitoring of the movement

of energy to distribution grids. ABB systems are available to enable control at every system level, from device to bay to substation. Substation-level solutions, like SAS 600, provide reliable local and/or remote control and monitoring of substations at all voltage levels, in any configuration and of every size. It offers fully distributed functionality and open connectivity to remote control centers or other networks and is fully IEC 61850 compliant.

**ABB Substation automation solutions** provide complete real-time monitoring and control of primary and secondary equipment in wind substations. They allow you to easily and safely interact with the intelligent electronic devices that protect and control the system, as well as with the process, via the operator's workstation. This ensures making the right decisions, taking the right actions and achieving the maximized availability of the farm's power system. Accomplishment of grid codes and utility requirements on protection and metering systems are fully achieved through the flexible architectures available.

**High Voltage Instrument Transformers (HVIT)** The advent of renewable wind energy has spurred new levels of innovation in ABB's HVIT technology. Type CXM wide-range, high-accuracy current transformers, from 25 kV to 525 kV, were developed in part to address the extreme metering and protection requirements required in wind farm substations. They accurately and reliably manage extreme load swings and bidirectional metering applications, from the low current levels demanded for reverse auxiliary power measurement to the maximum current levels of the metered generated power. These capabilities come combined in a current/voltage transformer for a very compact device.

**ABB's station service voltage transformers** provide low voltage power supply solutions for control rooms at remote renewable sites. Power is tapped right from the high voltage circuit and directly transformed down to the low voltage power needs of the control room and ancillary devices such as pumps, fans, motors and lighting.

## Communications

A wind farm consists of many turbines and technologies, often spread across a large geographic area and typically sited in harsh environments. Establishing robust and reliable communication capabilities throughout these farms requires technology that provides proven performance. ABB provides customizable solutions that ensure dependable communication capabilities throughout the wind farm.

# Connecting power to the grid

**Fiber optic communications** offer a number of benefits to wind power customers, including high-speed communications (short delay times) and high bandwidth. They are unaffected by electromagnetic fields and do not interfere with other communications channels. Their resilience to severe weather conditions and long service life make fiber optic networks an attractive choice for the challenging conditions of a wind farm.

**Wireless communication networks** offer a cost-effective, standards-based, wireless, IP network communications system that competes successfully with conventional fiber optic networks.

Tropos wireless mesh technology creates private networks that guarantee high reliability and availability. It relies on a combination of multiple paths, channels and band-usage carried via robust hardware that is certified to tolerate extreme weather, shock and vibration. The result is a resilient, self-healing, high-performance distributed communication network.

Tropos provides tenfold the bandwidth of conventional SCADA radio products for as little as half cost. It supports hundreds of different services and SCADA applications over a single, common wireless infrastructure that supports weight protocols and real-time applications.

ABB's comprehensive suite of communication solutions, with its emphasis on reliability, flexibility and longevity, provides a durable foundation for smarter grids. It delivers future-proof solutions for automation, network management, control and protection functions that will accommodate the fluctuation in renewable power generation to ensure grid reliability.



**STATCOM solution, manufactured in New Berlin, Wisconsin, pictured at a windfarm in Puerto Rico.**

## Power quality

We expect variations in wind but we cannot tolerate variations in power. The quality of the power produced by a wind farm must be monitored and compensated before it can be fed into the grid. Many wind farms rely on ABB hardware and software to ensure the quality of the outgoing power. ABB has vast experience in the field and support our customers with solutions tailored to fit their needs.

**Capacitor banks, inductor banks, and filter solutions.** ABB is the world's leading manufacturer of capacitors, a basic, economical source of reactive power. The reactive power required to achieve a better power factor can be provided using capacitor banks, a low-cost, easily scalable solution.

Using switched capacitor banks, where the capacitors are arranged in banks of suitable sizes, adds flexibility to this solution. Banks are switched in or out automatically by a control system based on the load factor and actual load conditions. This helps achieve the preset target power factor without risking overcompensation. ABB also provides passive filtering solutions at medium voltage levels and active filtering solutions at low voltage levels.

**Static Var Compensation (SVC)** The SVC offers a dynamic compensation of reactive power based on thyristor technology. The two types in use are Thyristor Controlled Reactors (TCR) and Thyristor Switched Capacitors (TSC).

The TCR/TSC type SVC is very useful as a means for dynamic voltage control in a number of situations such as mitigation of voltage fluctuations that are not too rapid, and preventing voltage collapses in conjunction with grid faults. Its dynamic response is limited by the maximum switching frequency of ordinary grid commutated power thyristors, i.e. 100 Hz.

**Static Compensation (STATCOM)** With the SVC Light (ABB trade name for STATCOM) concept, the VSC (Voltage Source Converter) and IGBT (Insulated Gate Bipolar Transistor) technologies have been brought together to create a tool presenting new possibilities for power quality improvement.

SVC Light is a flicker-mitigating device. It attacks the root of the problem, the erratic flow of reactive power through the supply grid down into the loads. The reactive power consumption is measured and corresponding amounts are generated in the SVC Light and injected into the system. This decreases the net reactive power flow to an absolute minimum and decreases voltage flicker.



Products pictured left to right: STATCOM solution, manufactured in Switzerland, pictured at a wind farm in the United Kingdom, close-up: 345kV SSVTs in Texas.

**Energy Storage** Energy storage systems can provide both active and reactive power. By compensating for the variability of wind power injected onto the grid, energy storage can temper voltage variability and provide consistent power levels.

One approach to energy storage is the Battery Energy Storage System (BESS), where ABB has unique expertise.

DynaPeaQ™ is an SVC Light combined with a battery-based energy storage system. The result is independent, dynamic control of active as well as reactive power. By controlling reactive power, grid voltage and stability are controlled with high dynamic response.

PowerStore™ is a flywheel-based, short-term energy-storage system that includes the current generation of inverters and virtual-generator-control software, enabling the integration of intermittent power sources like wind. PowerStore can help achieve up to 100 percent penetration of renewable energy source into remote grids. High-speed software controls the power flow into and out of the flywheel, essentially making it a high inertia “electrical shock absorber” that can instantly smooth out power fluctuations generated by wind turbines.

**Hybrid Reactive Compensation** As grid code requirements for wind integration continue to evolve, hybrid systems that combine multiple power quality and grid-stabilizing assets have become an optimal solution for wind developers.

Specifically, hybrid reactive compensation systems that combine higher performing dynamic VAR systems (STATCOMs and SVCs) with cost-effective static solutions (capacitor and reactor banks) allow wind developers to meet stringent grid code requirements at a lower price. ABB is a global leader in combining PCS 100 and PCS 6000 STATCOM systems with switchable capacitor and reactor banks under a single control system, providing both transient voltage support and steady-state regulation.

**Synchronous Condenser** As an increasing number of wind farms are being integrated to the grid, the system inertia is not stabilizing the frequency as rotating synchronous machines are able to. The kinetic energy stored in the rotor of a synchronous condenser contributes to the total inertia of the power system and is thus beneficial from a frequency control perspective. In addition, Synchronous condensers can contribute with short-circuit power to the network node where they are installed and can also be designed to have a high short-term var-output. This provides for a more robust power system which is less susceptible to voltage sags and sudden load changes.

# Controlling & managing power



Managing power has never been as complex as it is today, and it will become even more complex in the future as a more diverse portfolio of generation assets continues to come online.

Meeting the challenge of managing power in this environment requires connectivity and communication between the local wind power resource as well as other, interdependent resources connected at widely dispersed points on the grid. The need to accommodate power fluctuations created by wind variability makes it essential that other generation assets be integrated in an overall energy management system.

The most common scenario is that other assets are called on to make up for the power shortfall from the wind farm when the blades aren't turning. As wind generation continues to grow and the technology becomes more reliable, that scenario is more frequently reversed. Wind farms are increasingly being called on to serve as backup resources for power needs elsewhere on the grid. Being able to provide functionality for power-system support is becoming more challenging when the input "fuel" is variable and not under direct control. Nevertheless, a proper understanding of the process combined with fast communications and a well-designed control system enable wind farms to provide the needed support functions for power system operations.

## Controlling power

To control the generation, enhancement and distribution of wind-generated power, farm operators must be able to track critical work and operator actions and disseminate data to both the local site and distant operation centers. ABB monitoring technology and related communication systems provide a real-time perspec-

tive at every system level, from device to bay to substation. The Ventyx Plant Operations solutions bring additional value by automating and integrating the process involved in plant operations management.

Symphony™ Plus is ABB's flagship plant automation system for the power generation industries. With an installed base that goes back more than 30 years and now totals over 6,500 installations including a large number of wind farms across Europe, Symphony™ Plus is the world's premier control platform for power and water applications of every type and size. For wind applications, Symphony™ Plus is used today in remote control centers to manage more than 60 wind farms across Europe, monitoring and controlling more than 760 wind turbines in real time.

**Flexible SCADA architecture** Symphony™ Plus' flexible and scalable system architecture fits perfectly with the requirements of wind power automation to coordinate the control of hundreds of wind turbines and multiple wind farms distributed over large geographical areas. Its hierarchical SCADA architecture enables the collection and forwarding of data from individual wind turbines, meteorological stations, transmission and substations to a remote operations center.

**Complete view of operations** Symphony™ Plus' Human Machine Interface (HMI), Symphony™ Plus Operations, gives users a complete view of operations by seamlessly integrating all areas and systems of the wind farm into one view. Local wind turbine

control units, remote terminal units, programmable logic controllers and intelligent electronic devices are integrated into S+ Operations using standard communication protocols.

**Advanced alarm management** Symphony™ Plus Operations advanced alarm management functions provide all the necessary instruments for efficient and robust alarm management. The EEMUA191-compliant alarm analysis tools help users categorize occurring alarms, while the integrated alarm management system keeps the operator focus on what matters most; effective and safe wind farm operation.

**Integrated geographic information system (GIS)** Using the HMI's integrated GIS functions; operators can surf and navigate over a map area, select a wind farm and zoom in on a specific module or unit to obtain real-time and historic data on that particular asset. This provides faster and easier access to operating values, regardless of its location.

For over two decades, Ventyx, an ABB company, has been at the forefront of the development and successful implementation of operations management information systems for the generation industries. eSOMS is a proven plant operations solution that interfaces with industry-leading work scheduling, maintenance management, asset tracking, and data historian software systems, enabling a tighter integration between plant monitoring solutions and plant maintenance and operations.

These solutions provide personnel responsible for plant operation and performance with powerful yet easy to use tools for tracking and analyzing operator actions that can be integrated with Symphony™ Plus data to provide tighter integration between plant monitoring and operator actions.

## Integrating power

Ventyx provides a range of solutions filling every power management requirement. The Network Manager™ SCADA/EMS/GMS is the optimal control center solution to control and manage wind farms at the grid level. These Generation Control Applications include real-time processes that can regulate the generation of wind power in accordance with operational and economic constraints, and maintain system frequency and control area net interchange at their scheduled values.

This energy information system provides decision makers with reliable process information including Automatic Generation Control, Economic Dispatch, Product Cost Calculations and Reserve monitoring, beginning with leveraging the SCADA system

information from systems like Symphony™ Plus.

It is also an energy information system that provides enhanced EMS functionalities to support wind integration, including:

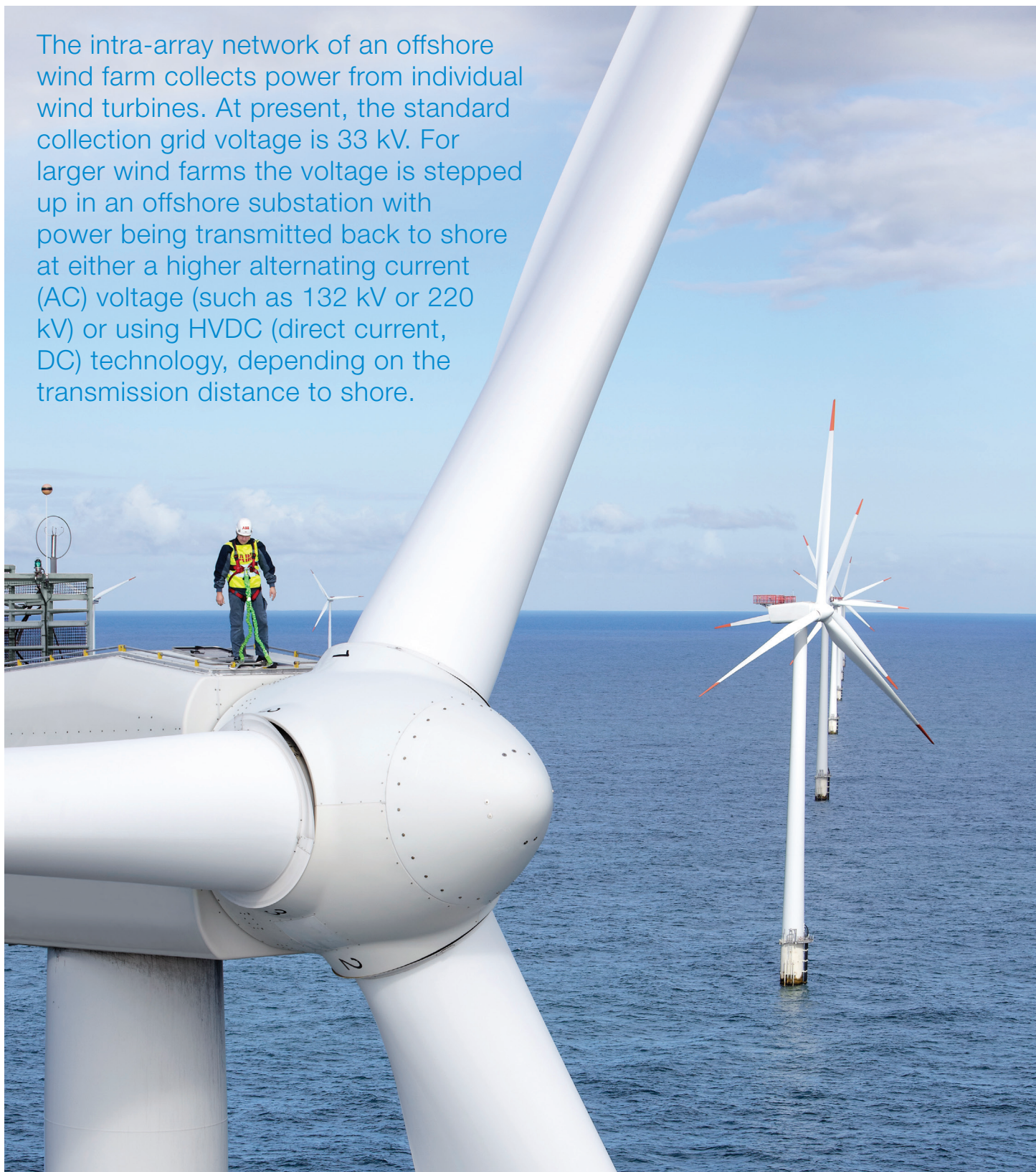
- Contingency Analysis (CA)
- Short Circuit Analysis (SCA)
- Automatic Generation Control (AGC)
- Reserve Calculation (RC)

**Demand Response Management System (DRMS)** The DRMS programs provide real-time pricing and data to producers and consumers, giving customers the ability to make more informed choices about how and when they use power by providing them with incentives for controlling energy loads on the network.

DRMS provides real-time tracking, forecasting and aggregations of demand response and distributed energy resources into virtual power plants. Dividing turbines into logically aggregated subdivisions based on unit location, size or other parameters enables improved forecasting and optimization of these assets. Generation, storage and other resources can be optimized via enhanced unit commitment and dispatch, even for complex asset portfolios.

# Offshore wind power applications

The intra-array network of an offshore wind farm collects power from individual wind turbines. At present, the standard collection grid voltage is 33 kV. For larger wind farms the voltage is stepped up in an offshore substation with power being transmitted back to shore at either a higher alternating current (AC) voltage (such as 132 kV or 220 kV) or using HVDC (direct current, DC) technology, depending on the transmission distance to shore.





## Offshore power collection

Increasing the voltage of the collection grid up to 72 kV offers a number of benefits: reduced number of arrays, less cable per feeder, increased turbines on each string, reduced losses and in some cases for near-shore wind farms it avoids the necessity of having an offshore substation.

ABB has the experience and the products to design and deliver 72 kV offshore collection grids.

**Transformers for offshore applications** ABB has tens of thousands of transformers reliably and efficiently producing in wind farms around the world – including distribution and power transformers representing a wide selection of voltages, both liquid-filled and dry-type.

Inside the turbine tower, the compact design of both our liquid-filled and dry-type transformers makes it possible to install them through the turbine door and requires minimum space in the crowded turbine or nacelle. Dry-type transformers are entirely oil-free, virtually eliminating the risk of fire. They are also moisture-proof, suitable for operation in the very humid ocean sites.

ABB is prepared to meet future requests for higher-voltage transformers in projects with 66 kV collection grids.

ABB BIOTEMP® is a dielectric insulating fluid that provides greener, safer, longer-life transformer oil. When used in offshore, liquid-filled transformers, this less-flammable liquid frees valuable space because active fire suppression and barrier walls can be eliminated. It is also 99 percent biodegradable and non-toxic.

For those projects where offshore platforms are needed, the broad selection of standard ABB power transformers can be used. Wind farm owners and developers interested in reducing the cost of their platforms and substations can work with ABB transformer-design experts to create an optimized design. By working cooperatively at the design phase, ABB engineers can minimize transformer size, reducing its footprint and the need for very costly platform floor space. Although initially more expensive, these high-efficiency transformers can show a payback in under three years.

**Hybrid high voltage breakers** For voltages between 72.5 kV and 100 kV and breaking currents up to 40 kA, PASS M00 multi-functional modules from ABB based on mixed or hybrid technology meet the requirements to connect multi-megawatt turbines to higher voltage collection grids. The PASS modular design allows

a wide range of configurations for harsh operating environments fully comprehensive of circuit breaker, disconnecting switches, earthing switches, current transformers, voltage transformers, surge arresters, and protection and control systems.

The compactness of PASS M00 is a suitable solution for HV wind farm collection grids, providing full gas insulation and short installation time (no HV test is required on site). Plus, the lean design and modular assembly provides high reliability and facilitates fast repairs. In the event of a fault, motor operation is permitted by remote control. It is designed to respond to increasing needs of renewable integration and fast installation.

**Offshore platform technology** Erecting the massive structures needed to create an offshore power-generation plant presents tremendous engineering challenges. The environment is unforgiving and the risks great. To minimize those risks, ABB developed the Gravity Based Structure (GBS) to accommodate HVDC converter stations. These self-contained platforms include all sub-systems and facilities – ventilation and air conditioning, water, sewage, cooling, backup diesel generators, etc. – required to support platform operation.

This approach to platform configuration provides a more effective solution to move and place the platforms, freeing valuable time and reducing expensive equipment needed for the project. That gives wind farm investors and operators a wider window of opportunity to establish their offshore power plants. In addition, the GBS is also less subject to the heavy seas and foul weather that can interfere with transporting and assembling structures at sea.

# Offshore wind power applications

## HVDC Light

Transmitting energy from distant offshore platforms to the grid presents unique and challenging issues. Based on ABB's Classic HVDC technology, HVDC® Light provides low-loss transmission of large amounts of electrical power over long distances. It overcomes limitations of distance and grid incompatibility while ensuring robust performance and minimal electrical losses.

Three characteristics make HVDC Light the ideal solution for collecting and landing power from offshore wind farms.

- The converter-to-shore DC link decouples the turbines from the instabilities of the mainland grid. The wind farm is, therefore, electrically immune from transients that commonly occur onshore due to storms, ground faults or other causes.
- HVDC Light can provide unlimited reactive power to support voltage stability at the connection point, enabling the high voltage power from the offshore wind farms to be fed into the network without any distance limitations. When turbines are de-energized due to a fault, problem or maintenance, external power is required to maneuver and maintain the turbine and, when appropriate, restart it.
- The HVDC Light system has the unique ability to reverse power flow, feeding AC power from the onshore converter station to the offshore platform.

HVDC Light is highly adaptable, able to provide power ratings from a few tenths of a megawatt to over 1,000 MW. It rapidly controls active and reactive power independently of each other, keeping both voltage and frequency stable.

HVDC Light speeds wind farm development because it is easier to get the siting approved for transmission lines. There are fewer conductors, they can be buried and there is no 60 Hz magnetic field or noise. This reduces barriers to permits and speeds implementation by months. Pulling of cables can also be streamlined and installation time reduced since there are fewer cables to manufacture and install.

No one can match ABB's level of experience in HVDC, with 23 HVDC Light systems installed in onshore converter stations and several installations in offshore application. ABB is the only company with in-house manufacturing capabilities for the required power semiconductors, high voltage cables and converters.



## HVDC cables

ABB is the world expert in technologies that solve problems related to the reliable transmission of power, and is the only organization with in-house HV cable manufacturing and R&D. Our technology has been in use for more than 10 years, with the capability to handle all the power a wind farm can produce, up to 1,200 MW, but is also able to economically transmit much lower power levels.

HVDC Light cable has lower losses and a smaller footprint than traditional high voltage alternating current (HVAC) transmission systems, and is able to stabilize intermittent power supplies that might otherwise disrupt the grid. Compared to an AC link to connect the wind farm, this modern, eco-compatible technology, with its very low electromagnetic fields, oil-free cables and compactly dimensioned converter stations, cuts transmission losses by 25%.

While the benefits of HVDC cables are clear, working with this technology requires experience and unique skills. ABB is uniquely qualified to select, install and maintain HVDC cables. ABB HVDC Light technology actually accelerates wind farm development because siting approval is simpler and there are fewer conductors to manufacture and install.



# Operating and maintaining power through life cycle services

ABB's services span the entire product ownership life cycle, from pre-purchase engineering to installation, commissioning and operation. ABB provides a comprehensive portfolio of life cycle services that will increase customers' return on investment and keep ABB products operating at their highest efficiency levels for the longest possible time.



Long, reliable equipment life begins at the point of component design, and later system design, to produce the cleanest, most economical megawatts of wind power possible. Extending product life has been the inspiration behind every ABB wind component for over 30 years and is exhibited in some of the world's most profitable wind farms.

Wind farms are often located in remote or difficult-to-reach sites. Considering the size and complexity of the components required for a farm's electrical system, customers frequently rely on ABB experts to coordinate transportation of the equipment to the site. Once onsite, ABB technicians can provide equipment installation, testing, and commissioning and startup services.

As the equipment is put into service, ABB is available to provide diagnostics, monitoring and repair. ABB preventive maintenance programs for products like switchgear, generators, motors and converters are a simple and manageable way to maximize turbine life and reduce downtime.

Onsite and factory repair of both ABB and non-ABB components is another key offering for wind farm owners. Examples of these services include:

- Generator replace- and-recycle services that provide fast replacement of damaged units
- Converter repair done in our facilities that includes quality assurance via a unique, full test procedure
- Onsite power transformer repair that reduces drastically the cost and time a unit is off line

Service is never far from a customer's site. Regional service hubs are located around the world, each staffed with a crew of qualified ABB service technicians.

Farm managers may choose a turnkey service solution with an ABB custom service contract tailored to their needs. These contracts can be initiated at any stage of ownership. They can comprise a mix of services that could include spare parts agreements, preventive or corrective maintenance, technical support and training. Customers relying on these contracts benefit with improved cost controls, increased operational efficiency, lower capital expenditures, reduced downtime and extended product life.

Some customers prefer to rely on their own service and maintenance teams. ABB supports them with the needed training. Wind turbine manufacturers, power plant operators and service providers attend training at ABB training centers, online through e-learning classes or even at their own site. Training also helps

keep wind turbine manufacturers and wind power plant operator engineers up to date with the latest product developments and information. Training improves both efficiency and performance.

Customers continue to rely on ABB consulting services throughout the life of their wind farms. We advise them on the appropriate timing to restore equipment capabilities through rebuild or refurbishment. In some cases, it is more appropriate to introduce new technology, either as retrofits or replacement, in order to extend the life of their assets. The appropriate new or upgraded software can create new functionality and even higher levels of performance.

## Delivering wind power solutions for a dynamic world

Every day, the world demands more energy. Increasingly, those demands are being met by wind power. Accompanying this increased demand is the move from centralized, mainly carbon-based and controllable power generation to more distributed, less predictable and less controllable sources like wind.

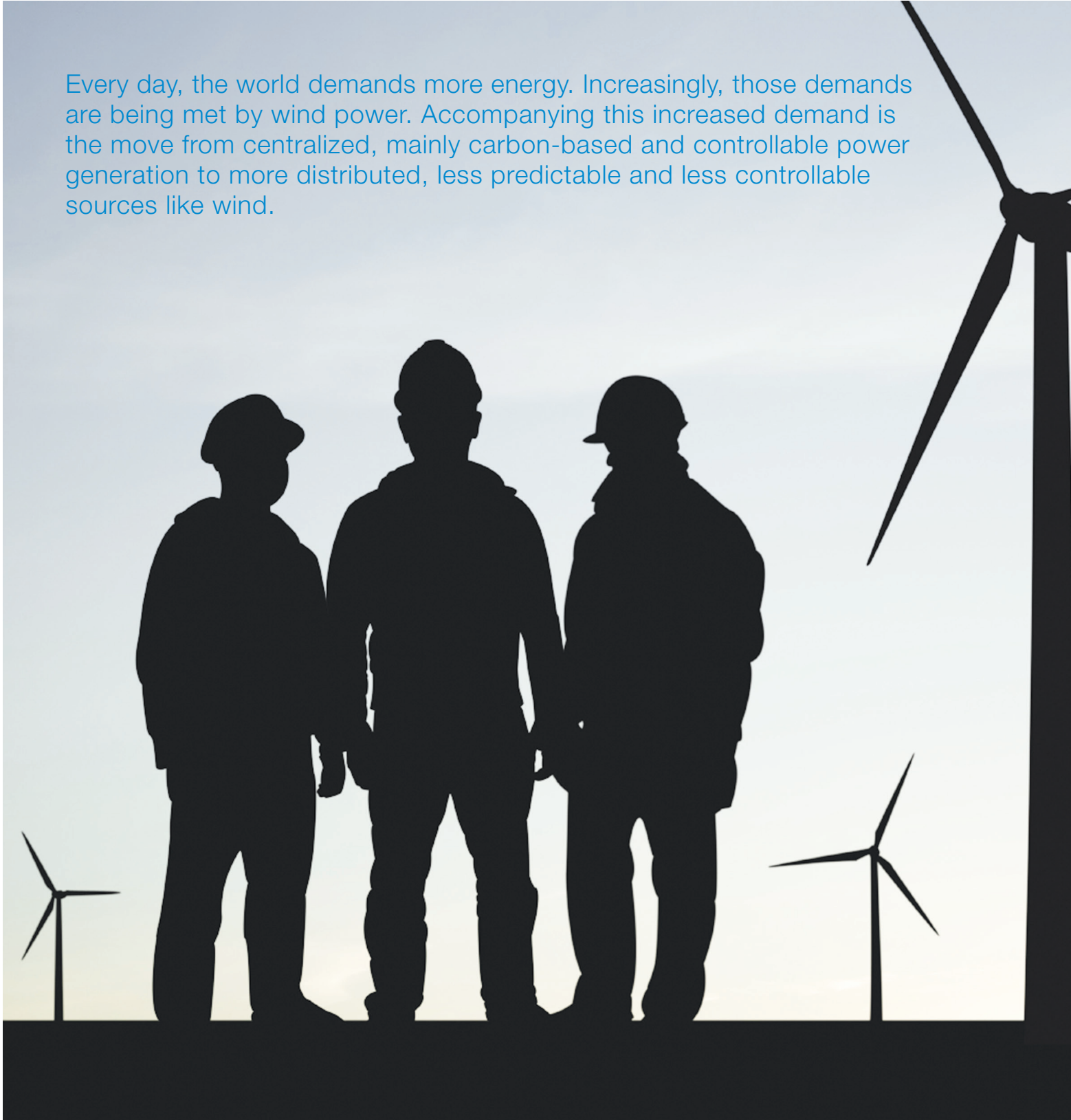




ABB is in the unique position of being the major supplier to the wind industry, manufacturing almost every required electrical component from the turbine to the grid level and beyond. That advantage gives us unmatched knowledge and insight down to the component level, but more importantly provides us with a system view based on a keen understanding of the interdependencies and interactions of the components.

Our deep industry knowledge, decades of experience and global reach make ABB the partner-of-choice for wind farm projects. Developers can expect greater success in obtaining required financing and more quickly realizing the greatest possible generation output. Operators can rely on ABB to support their efforts of more effectively managing and maintaining the farm's generation and distribution assets to create the greatest return on investment.

Wherever the wind blows, ABB is there with the leading solutions to capture that natural energy, reliably convert it to electrical power and safely deliver it to customers. Service is never far from a customer's site. Regional service hubs are located around the world, each staffed with a crew of qualified ABB service technicians.

# ABB wind power solutions

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