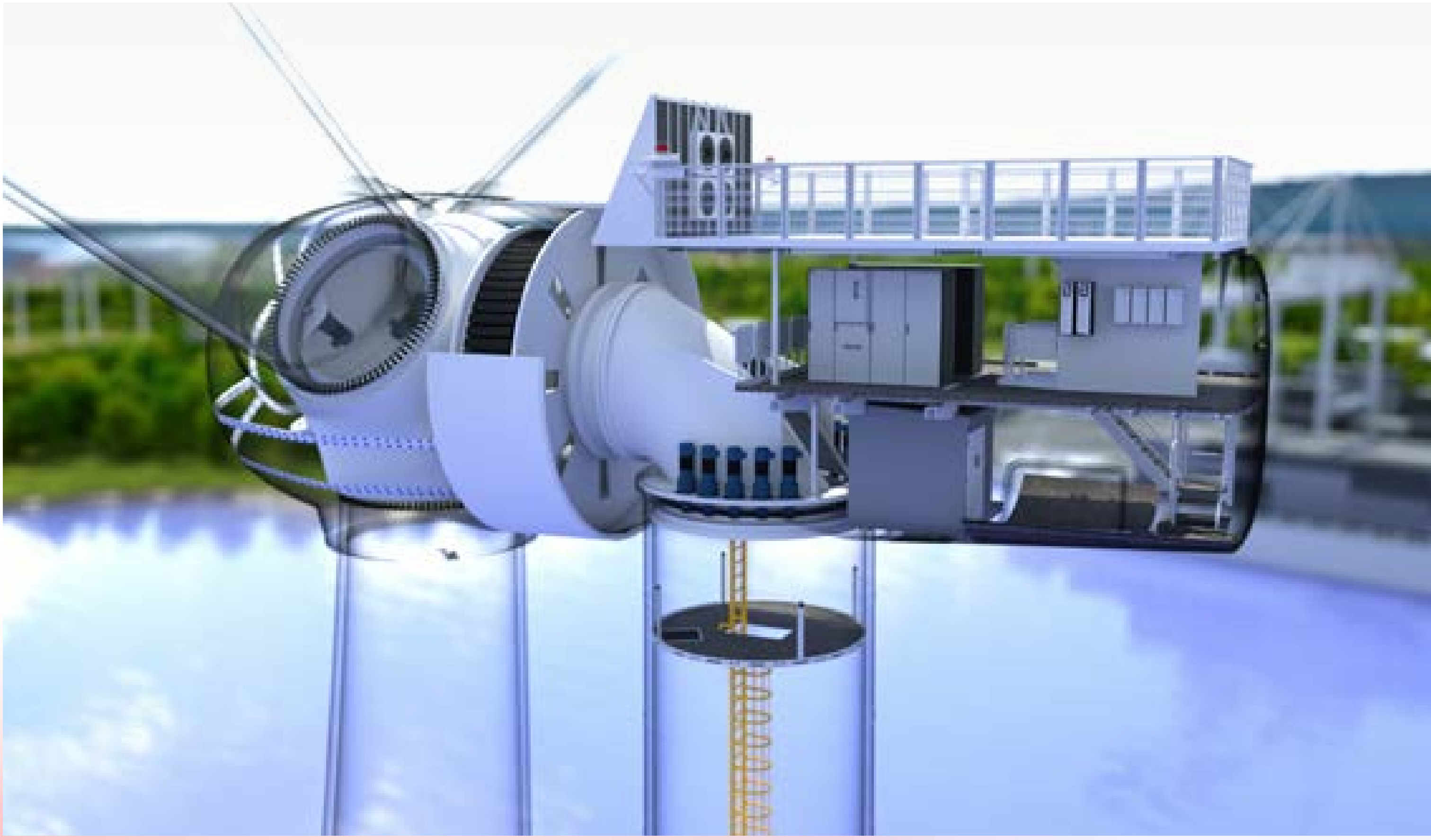
WHITE PAPER

THE MODERNIZED POWER CONVERTER

A game changer that increases your wind turbine lifetime and boosts clean electricity production



THE GROWING DEMAND FOR ELECTRICITY

World demand for electricity continues to grow, doubling over the last two decades alone. The crucial question that emerges is: How will we rise to the challenge and meet that demand without driving up the cost to those who need it?

Abundant and affordable energy is the linchpin[1] for meeting human needs, securing adequate supplies of essentials like water, food and transportation, and ensuring we can enjoy today's modern conveniences and the latest technologies.

No less than 25,000 TWh of electricity was consumed in 2023. More than half of that was provided by energy sources other than wind, solar, or hydropower, i.e. renewable sources[2]. Clean, renewable energy accounted for only 25% of the world's power generation. Nevertheless, wind power has great potential to meet the world's energy needs. Renewable sources have grown from 3,000 to 9,000 TWh over the last 20 years globally, showing that wind and solar can quickly scale to meet the market's demands.

Numerous strategic initiatives have been implemented to accelerate wind farm development and drive down the levelized cost of energy (LCoE)[3]. Unlike coal power plants, which require ongoing expenditure on fuel, wind energy is a freely available natural resource that allows us to take advantage of existing installations. Thus, there are clear economic benefits to be gained by extending the operational lifetimes of wind farms.

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COST FACTORS IN WIND ENERGY

Cost factors in wind energy can be grouped[4] into four categories:

- **Investment in manufacturing and installation of wind turbines**
- **Operational and maintenance costs**
- **Obsolescence and safety costs**
- **Decommissioning expenses**

Over the last decade, technological developments have led to larger, more powerful turbines, and economies of scale have significantly reduced manufacturing and installation costs. In the case of onshore wind energy, overall costs have decreased by 68%, paving the way for a fourfold growth in construction from 44 GW of new installations in 2013 to 140 GW in 2023. For offshore, costs have reduced by 59%[5] and new construction has increased 11-fold over the same period. The advances in technology that have made this growth possible are testament to the industry's commitment to innovation and sustainably increasing production to meet demand.

However, operational, maintenance, obsolescence, and decommissioning costs remain high, accounting for more than 25% of the LCoE[4]. This is due to the fragmented approach that has been taken: efforts to rapidly develop increased turbine power production have been separate and independent of the focus on reducing costs. A more comprehensive approach taking into consideration the lifecycle of wind turbines would have paid off in terms of lower costs and improved safety.

There is a clear connection between the fragmented cost reduction activities and safety. Currently, the drive to cut operational costs often means that the industry opts for on-site repairs of electrical equipment. The on-site work increases the risks faced by technicians. In fact, there is a straightforward way to prevent avoidable accidents and injuries: it is simply doing the repairs with certified service providers.

Reports from the industry indicate that operational, maintenance, obsolescence and decommissioning costs are continuously rising – a trend that is due to complex repair procedures, older components that are difficult to source, and the quality of components designed more than two decades ago when the wind industry was in its infancy. These factors are causing wind farm outputs to decline at a rate of around 1-2% per year[6]. Repairing or replacing the original components without respecting the original design principles causes safety hazards, and reliability declines rapidly. In addition, turbines were initially designed for an operational lifetime of 20 years, after which the wind farm was to be decommissioned.

This situation poses two significant challenges:
- The costs associated with the disassembly of turbines and the logistics to remove the components and cable are high, amounting to around 3% of total turbine lifetime costs[4].
- The disposal of turbine components results in environmental risks and, therefore, calls into question the sustainability of the electricity produced by the turbines.

However, advances in technology mean that it isn't necessary to replace or decommission the turbine completely. Modernizing critical electrical components in the turbine achieves increased power production and reduced maintenance costs. By aligning their efforts, industry experts and academic institutions will enable the obstacles facing the wind industry to be overcome - but urgent action is clearly necessary.

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DOUBLE THE LIFETIME OF WIND TURBINES

Determining the position of a wind turbine within its lifecycle is based on where the individual components are in their respective lifecycles. As with any technology, reliability is tied to the availability of the components.

Wind farms need to last beyond the initial 10-15 years that were planned when they were built, with owners needing to use their assets twice as long as initially estimated. They also need to enhance performance and reliability while increasing the assets' production. The strategy presented here is a path to achieving those goals. It will not only make wind energy more affordable for the consumer but allow owners to scale up the power production and efficiency of their existing equipment, all while addressing the promise of sustainability in the renewable energy sector. The strategy is not merely a theoretical concept – it is a practical and achievable set of solutions to **double wind turbine lifetime**.

Major electrical components of wind turbine

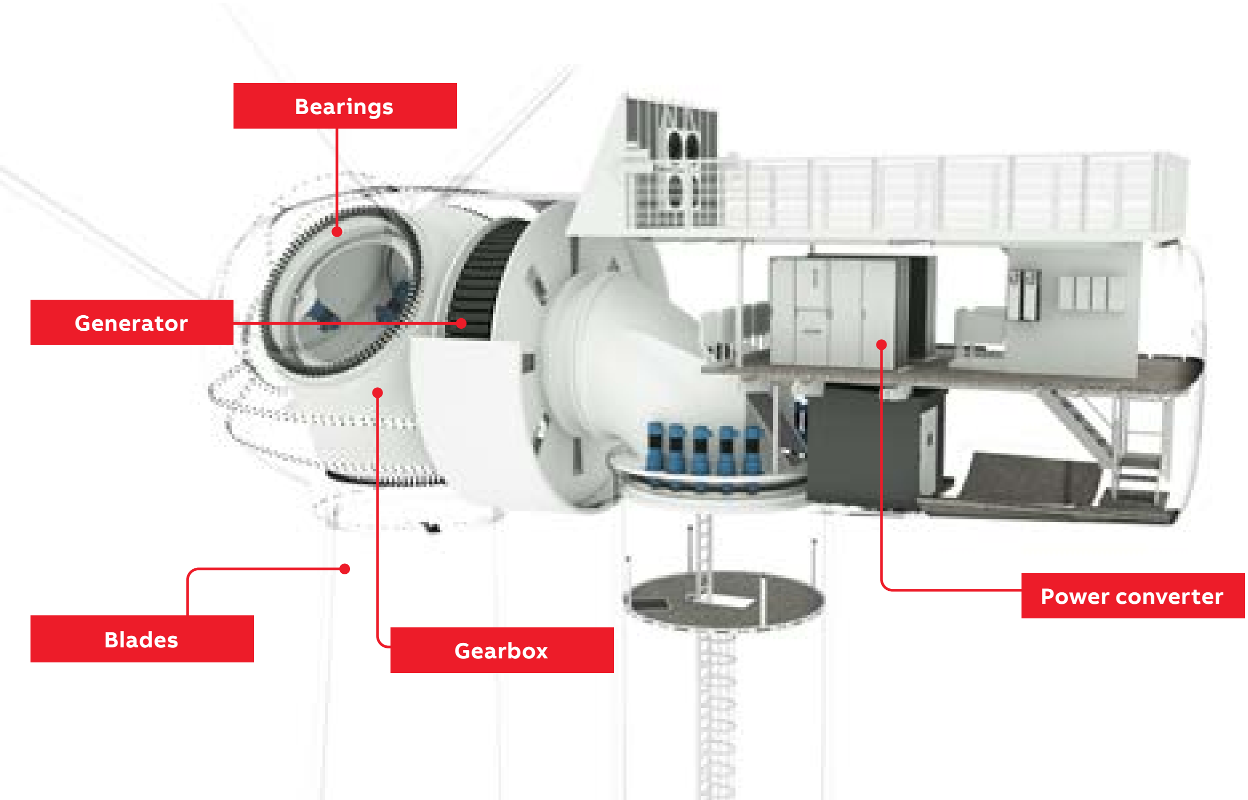

Figure 1 shows the major components of a wind turbine:
- mechanical components like blades, bearings, and gearbox
- electrical components (power converter and generator)

Comparison of lifetime of major turbine components

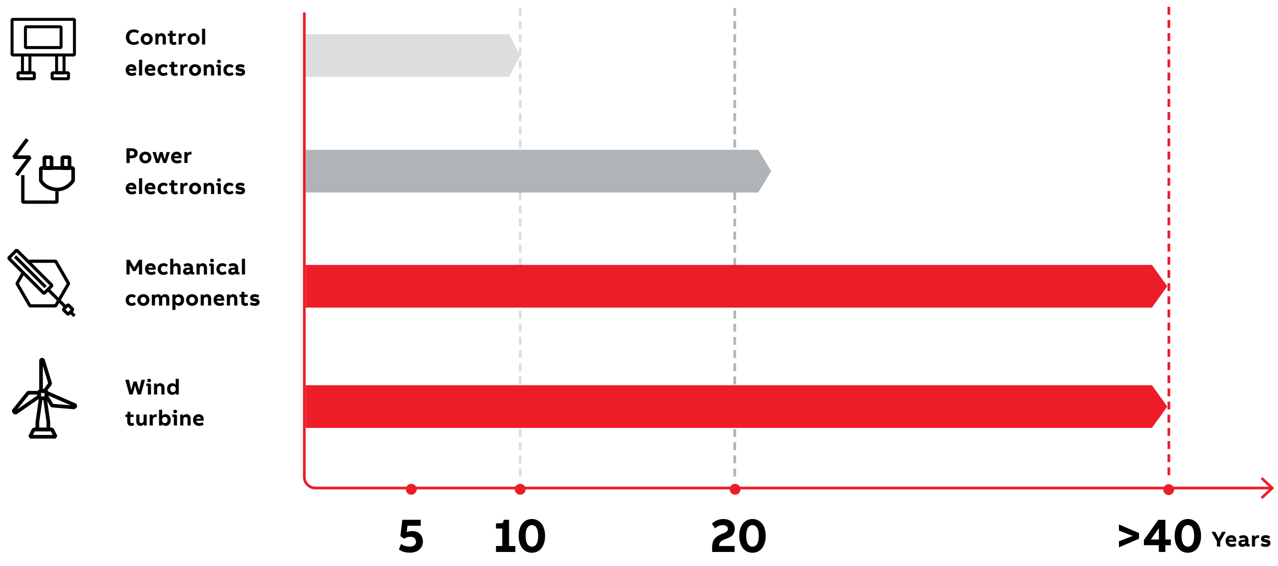

Figure 2 shows the component life expectancy.

Mechanical components should last up to 40 years, provided that regular maintenance is performed. The lifetime of the electrical components is shorter due to harsh environmental conditions within the nacelle. Electronics are much more sensitive to changes in temperatures, dust accumulation and humidity. One example is the controller, which regulates current flow from the generator to the power grid. It has a relatively short lifetime of 10-15 years because its electronic circuit boards are susceptible to corrosion damage caused by environmental issues. With the controller acting as the internal operations center of the turbine, this often leads to a reduction in productivity as repairs are taking place.

The semiconductors provide another example of components facing reduced life expectancy. They switch currents in the 1 kA range at micro- and millisecond intervals and have a lifetime of only 15-20 years. The stresses that arise from rapid thermal cycles result from those fast on-off switching sequences. However, with regular maintenance, the rest of the components in the converter - like busbars and cooling systems – support operation for up to 40 years, which then mirrors the lifespan of the mechanical components. It is therefore evident that through modernization of the converter controller and power electronics components, the lifetime of the converter and, consequently, of the entire turbine can be extended twofold or more. Upgrading selective older component technology within the equipment, while respecting the original design principles, ensures that the modernized system will provide both quality and reliability.

TECHNOLOGICAL ADVANCES IN HARDWARE AND SOFTWARE

In the last decade, the electronics industry has witnessed a quantum leap in component performance and reliability. For example, the central processing unit (CPU) in today's controller hardware is up to five times faster than the units that were installed two decades ago.

The advanced design with no moving parts ensures less failure risk, and provides better protection against the environment and longer operational effectiveness. Similarly, the semiconductor industry has developed packaging which is more robust against thermal cycling and cosmic radiation. Furthermore, each year sees the introduction of semiconductors with higher switching frequencies and power ratings.

Software development, which is a crucial aspect of advances in turbine technology, goes hand in hand with enhanced hardware performance, ensuring the optimal functioning of the entire wind turbine system. The industry has recently seen impressive breakthroughs in software. For example, the MP^{3}C advanced control methodology, which has been deployed by ABB and requires the new, fast controller CPUs to operate, improves converter efficiency by up to 5%[7]. Additionally, the industry has reported that combining new control software and improved semiconductors enables input and output power factor profiles to be optimized, increasing power by 5-10%. This naturally boosts the earnings from each turbine. Similarly, new control software provides inertia response, ensuring power continues to be produced in the event of grid disturbances and therefore helping operators provide electricity continuously. Finally, the combination of modern control hardware and control programs enables use of the grid forming control scheme, which provides the desired voltage even when the main grid voltage is absent. This ensures stability, or power grid inertia, and synchronization of the wind turbine with the power grid.

The benefits of converter modernization - like **enabling a 5-10% power increase** or **saving 35% of electricity costs**[8,9,10] – are today already having a positive impact in many process industries, which have been using power converters for four decades. It is now time for this same strategy to be applied to the wind industry.

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CONCLUSION

Half of the installed base of wind turbines have been operating for 15-20 years. It is time for the industry to focus on the modernization of the power converters.

Bringing the latest technology to the older style converters will **double their lifetime** and enhance power performance. A solution that respects the original converter system design, and can **increase power production by up to 10%**, improve system efficiency and ultimately enable grid-forming capabilities, is already available. Finally, modernizing power converters paves the way for deployment of IoT data acquisition systems. This enables models to be developed that will allow the consumed lifetime of critical components to be calculated in real time, resulting in improved reliability and increased production of electricity.

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READY TO DRIVE THE FUTURE OF WIND ENERGY?

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