SYNCHRONOUS CONDENSERS PROVIDE INERTIA FOR GRID STABILIZATION

Grid support

As renewable energy sources proliferate, the number of high-inertia generators – ie, fossil-fuel plants – decreases, both in unit numbers and as a share of the total power capacity. ABB's grid synchronous condensers can replace lost inertia and stabilize grid frequency and voltage.

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The electrical power landscape is predicted to change more in the next 10 years than it has in the last 100 [1]. This shift is primarily due to the move from large, stable, centralized fossil-fuel power stations that supply consumers with electricity via transmission and distribution networks toward a topology that features increasing numbers of widely distributed renewable energy resources →01. This evolution has the double impact of adding volatile supply sources while removing traditional high-inertia generators such as oil- and coal-fired power stations.

Reducing spinning inertia can disrupt more than production: Inertia is also vital for compensating sudden grid changes.

The removal of high-inertia generators has serious implications as replacing these stable, predictable and controllable energy sources with an increasing number of fluctuating renewable sources means energy supply and price cannot be taken for granted anymore. Most renewable energy sources – such as wind and solar – are non-controllable and have availability that depends on weather conditions. This

unpredictability impacts the price of electricity and has made tools for planning the purchase and use of electricity a necessity for large consumers.

Moreover, because energy must always be available exactly at the time of consumption and energy storage technologies are still relatively costly, large consumers are expected to help by implementing demand-side management – ie, by shaping their grid loading schedule to fit energy availability and price profiles. However, such forward planning may not always be possible and adaption must then be done on the fly, which can impact production stability and quality or, in some cases, lead to process shutdown.

The dramatic reduction in the amount of spinning inertia, also known as kinetic reserve, in the grid can have an effect even more severe than production disruption: Inertia is vital for compensating sudden changes in the grid – such as when a generator trips and goes offline – to ensure grid frequency remains within tightly controlled limits (reduced frequency can cause other equipment, such as power electronics, to trip, possibly resulting in a blackout). Grid inertial capacity is like a car's shock absorbers smoothing out a sudden bump in the road to keep it

Inertia helps compensate for sudden grid changes and ensures grid frequency remains tightly controlled.

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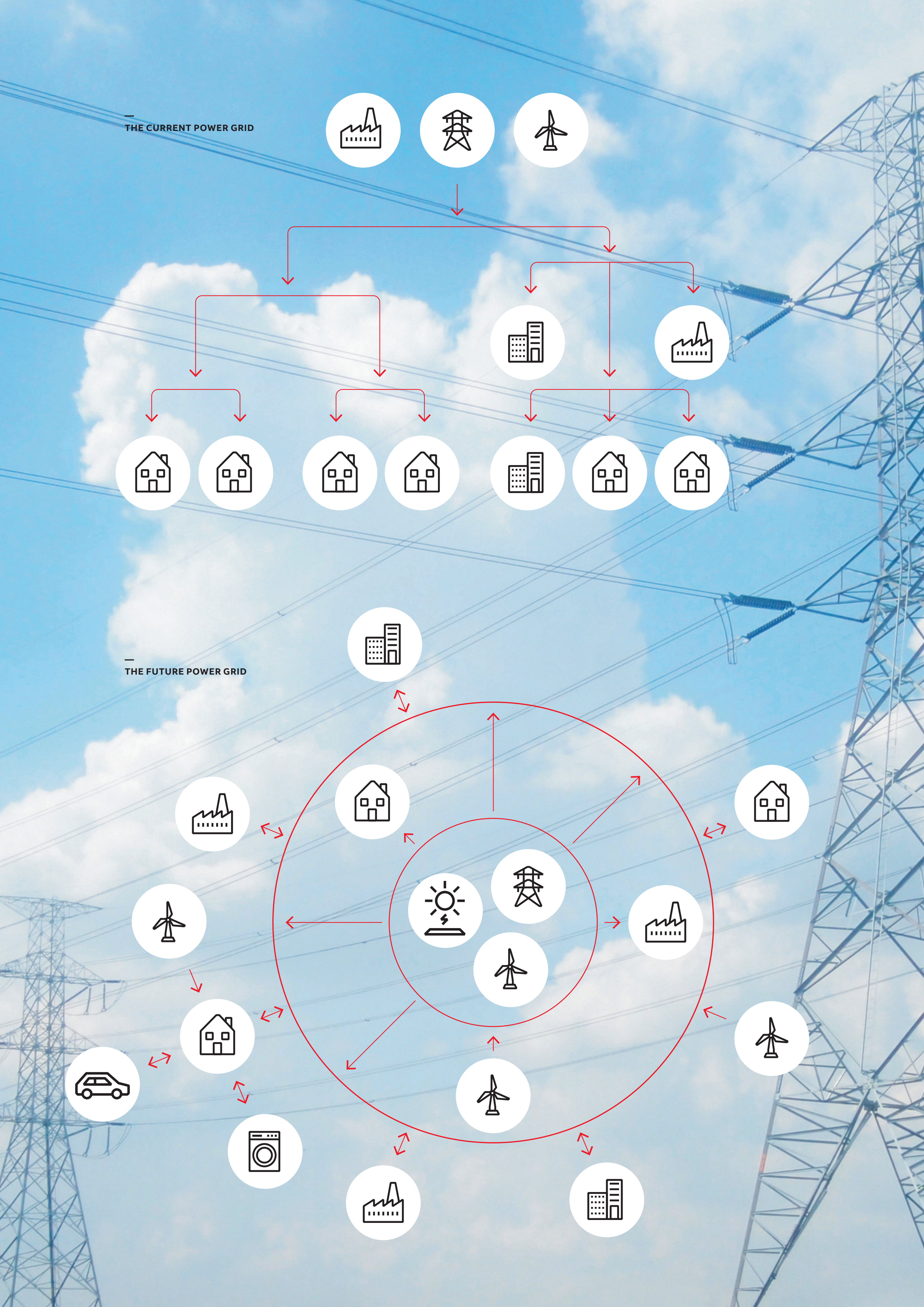
THE CURRENT POWER GRID
THE FUTURE POWER GRID

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01 As more renewable energy sources come online, power grid topology evolves from a pyramid to an interconnected net.

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02 The ABB synchronous condenser.

safely straight and level. Power grids rely on their inertia reserves to keep them in balance.

How can a power grid's inertia be maintained in the face of the removal of high-inertia generators in fossil plants? The answer lies with synchronous condensers.

Synchronous condensers deliver vital inertia for grid stability

A synchronous condenser is a large rotating device that stores physical inertia to deliver instantaneous support for grids, enabling them to maintain stability irrespective of the upstream network voltage or frequency →02-03.

In essence, a synchronous condenser is a motor without an active load, or a generator without a prime mover. Apart from the pony motor used for starting and the possible addition of a flywheel, there would be no need for any shaft ends to protrude from the synchronous condenser

Fifty or more years ago, synchronous condensers were used widely in the power industry, but are now much less common. The reason for their decline is that their former primary function – reactive power compensation – is now handled by a diversity of other solutions.

Physical inertia from a rotating synchronous condenser delivers exactly the amount of inertia needed to counteract any frequency variation, purely electromechanically, without the need for the control system and algorithms required by other methods of stabilization.

However, a synchronous condenser's capabilities are not confined to reactive power compensation. In other words, grid stabilization is often about more than simply injecting or absorbing reactive power and a synchronous condenser can provide this extra performance.

Adding a flywheel

When additional inertia is needed in a system, additional synchronous condensers can be added to the configuration. A more effective and economical approach is to include a flywheel in the synchronous condenser design.

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The synchronous condenser delivers exactly the inertia needed to counteract any frequency variation.

Combining a mid-size synchronous condenser and a flywheel has the advantage of multiplying the available inertia several times. Moreover, this measure improves the potential to reduce losses compared to fulfilling the inertia requirement by installing a larger synchronous condenser.

In an arrangement where two mid-sized synchronous condensers are connected via a three-winding transformer, the utilization of flywheels provides a cost-effective way not only to increase the available inertia by a significant amount but also to deliver a higher level of redundancy, lower maintenance demands and offer greater controllability.

Safety enclosure

A large rotating synchronous condenser contains a considerable amount of stored energy. Therefore, it is vital that the installation is designed with the highest levels of safety in mind and that potential risks are handled correctly. Risks are usually defined as the product of probability and consequence and therefore, ABB's synchronous condenser flywheel design seeks to minimize these two aspects. The probability of an adverse event is reduced by safe design, extensive testing and well-proven materials. Potential consequences are handled as a secondary safety function by providing reliable protection devices.

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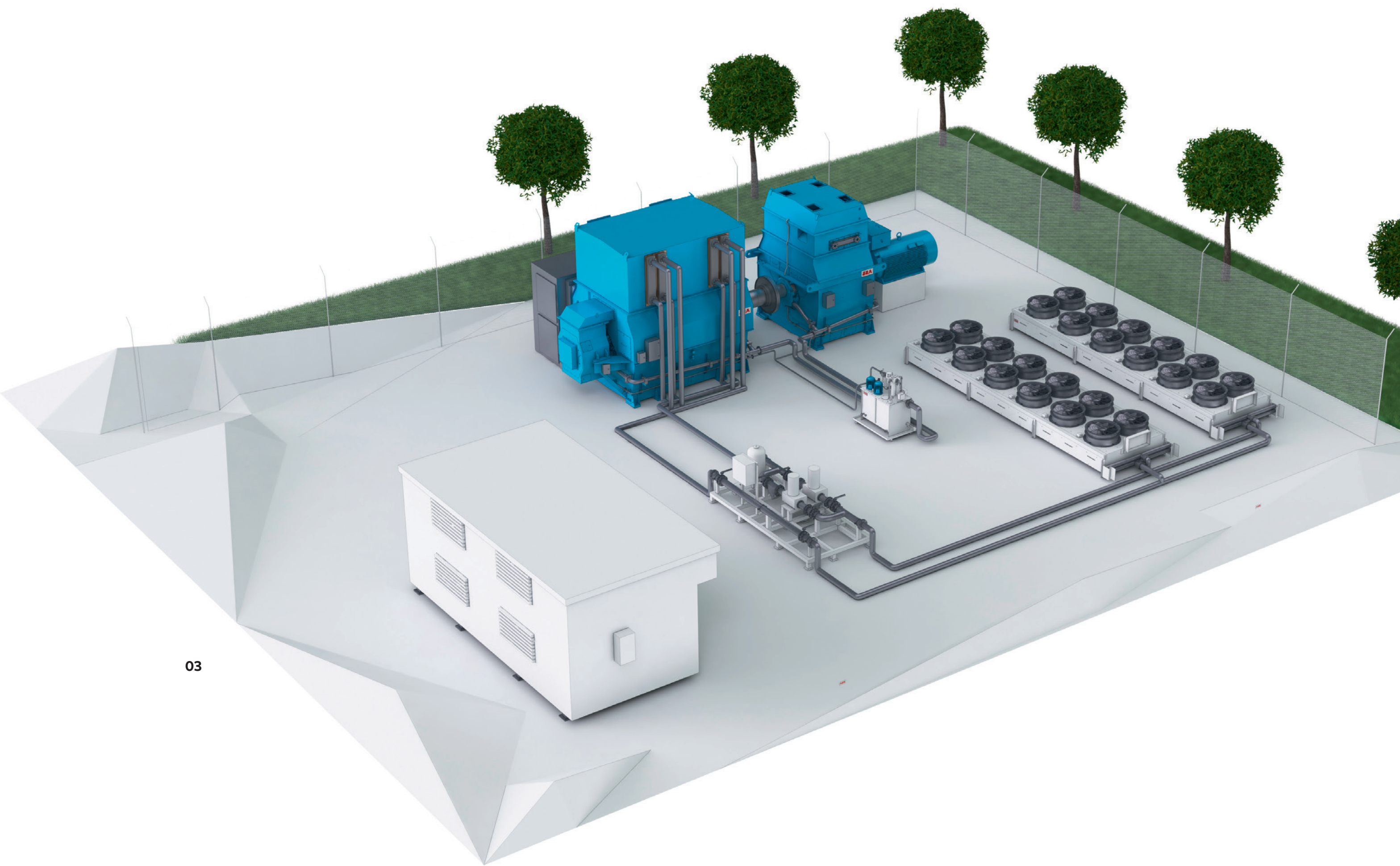
ABB has upgraded its synchronous condenser flywheel with a patent-pending integrated safety device.

For efficient planning, commissioning and operation purposes, ABB has chosen to upgrade its synchronous condenser flywheel with a patent-pending integrated safety device rather than relying on external protective functions. The device encloses the flywheel and is dimensioned in a way similar to that of the stator that encloses the rotor in an electrical machine.

Grid support in the field

Two ABB synchronous condensers have been installed as an integral part of the Darlington Point 275 MW (AC), 333 MW (DC) solar farm in New South Wales, Australia – currently the largest solar farm connected to Australia's grid. The technology will enhance the stability of the local power grid as the penetration of renewable energy increases in this area of the country →04-05.



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03 Typical synchronous condenser setup.

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04 The two ABB synchronous condensers at the Darlington Point solar farm.

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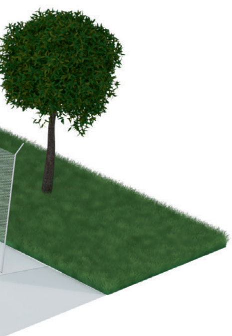
05 Aerial view of the two ABB synchronous condensers at Darlington Point in relation to the associated electrical equipment.



Spinning into the future
The networks of the future will require decentralized solutions to maintain grid stability and resilience. Synchronous condensers are a well-proven solution that can be activated almost instantaneously to strengthen weak or compromised networks, even in remote areas. The devices offer a number of advantages, such as inertial support for frequency stability, voltage regulation and short-circuit current contribution to help resolve faults. These are all functions that can be demanding to provide using power electronic systems on their own.

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It is anticipated that the need for synchronous condensers will continue to grow.

It is anticipated that the need for synchronous condensers will continue to grow as grid operators seek new approaches to address network quality issues and ensure reliability and continuity of supply. As well as entirely new systems, rotating equipment from decommissioned fossil fuel plants can also be harnessed to provide a reserve of inertia for grid stabilization. Over the next decade, it is expected that several hundred new synchronous condensers will be deployed, either on their own or in combination with static power electronic devices. •

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References

[1] World Economic Forum, with analytical support from McKinsey & Company, "Fostering Effective Energy Transition A Fact-Based Framework to Support Decision-Making." Available: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_report_2018.pdf. [Accessed September 9, 2022].