

# Patented Synchronous Power-train

Type 5 Grid Connection  
at Type 3 Cost

Power-train Brochure




*Recipient of the "Efficient Solution" label from the Solar Impulse Foundation.*

**SyncWind's**

Synchronous Power-train  
is a key to a zero-carbon future.





## For power systems to be stable, they need System Strength and Inertia – so need Synchronous Wind Power

Synchronous wind turbines have large “fault current” ability, which provides system strength. So, they easily ride through voltage faults and maintain stability as the fault clears. Together with their inertia, this “fault current” keeps the grid synchronised if frequency wavers.

### What does physical inertia do?

*It enables grid frequency to be stable. Any device or system with physical inertia has the momentum to “ride through the bumps”, without slackening speed. By contrast, controlling a system with little inertia involves working very fast with the “gas pedal” to alternatively squirt in more power, or reduce the amount squirted in, depending on whether the system has slowed down or sped up. In an electricity system, inertia normally comes from synchronous generators, which inherently (through electro-magnetic reaction) combine their physical inertia in an instantaneously co-ordinated way, even when hundreds of kilometres apart. But most wind turbines’ generators are not synchronous like this, so the increase of renewable energy is causing system inertia to reduce. With a low inertia electricity system, multiple generators would have to “work the gas pedal” in an instantaneously co-ordinated way, to maintain a steady frequency. This is unproven with current power electronic converter (PEC) wind turbine technology, which has zero inertia connected to the grid (shown for example in this background photo) and has a good chance of undershooting, overshooting, or getting out of rhythm and losing control, causing blackouts.* **By contrast, SyncWind’s system enables wind turbines to drive synchronous generators.**

# Introducing **SyncWind**'s synchronous power-train system

1

**Improves power system stability (helps prevent blackouts)** in low and high voltage, under- and over-frequency events, due to synchronous generator connected directly to the AC grid (because of constant speed gearbox output), providing physical inertia and high short-circuit currents.

2

**Lighter more compact design** reduces transportation requirements and facilitates installation in less accessible locations.

3

**Reduce capital costs** Improve your production margins by not having power electronic converters (PECs).

4

**Reduces gearbox fatigue** Extends life and reduces service costs/downtime due to mechanical variable speed input.

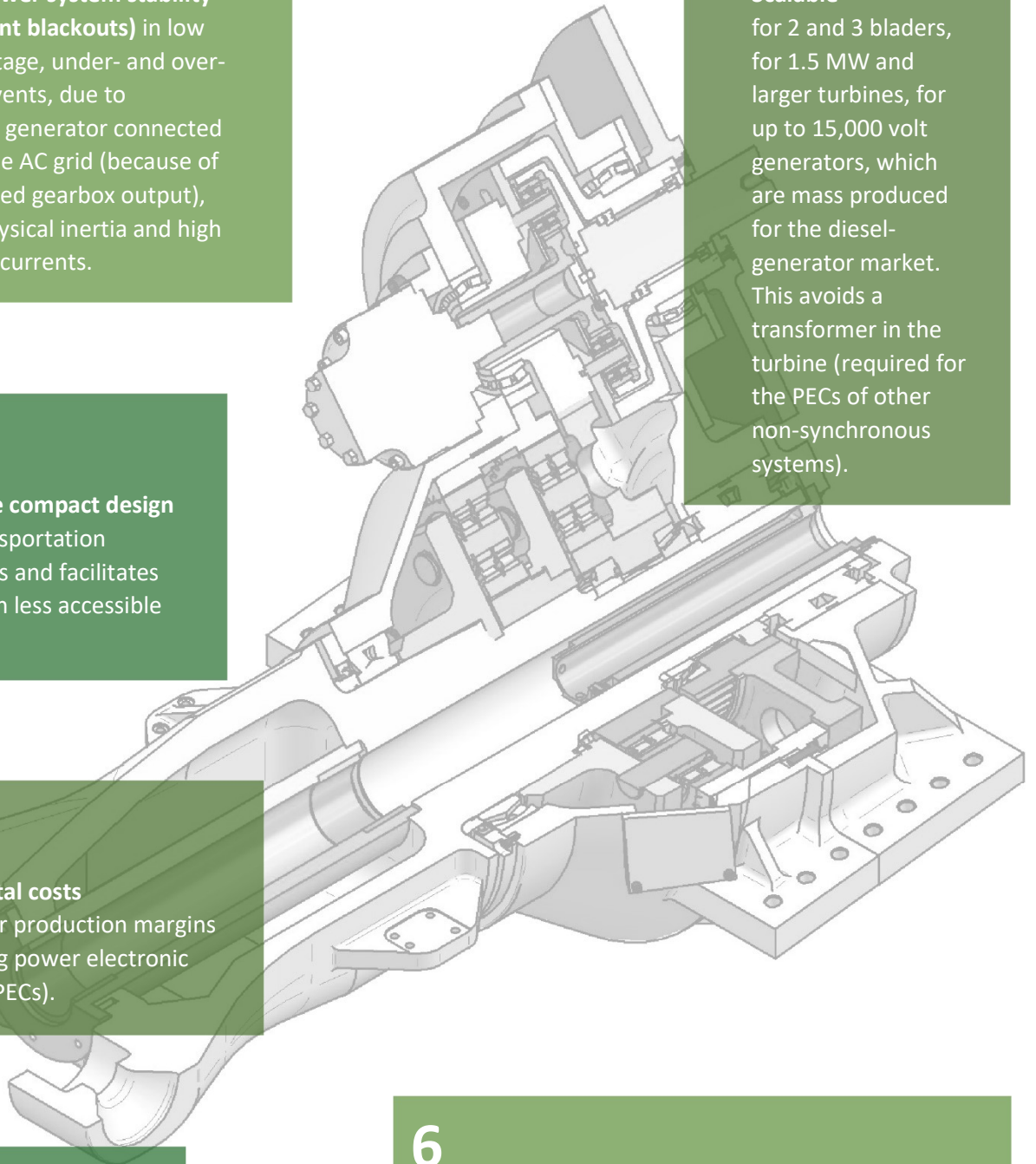
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**Scalable** for 2 and 3 bladers, for 1.5 MW and larger turbines, for up to 15,000 volt generators, which are mass produced for the diesel-generator market. This avoids a transformer in the turbine (required for the PECs of other non-synchronous systems).

6

## Easy Integration

Most wind turbines have 3-stage gearboxes and 4-pole generators. The LVS-TLG design and synchronous generator can easily be adapted to this layout, within existing space constraints and leaving gearbox 1<sup>st</sup> stage unchanged.



Few people challenge the logic and global trend towards renewable energy generation. However, whilst harnessing Mother Nature's gifts, wind turbines need to assist grids to retain their in-built resilience and system strength to withstand wild weather, and system events or faults which can cause sudden fluctuations in voltage and/or system frequency.

## Proven by more than 1000 turbine-years in the field:

- Synchronous wind turbines are trusted and understood by electricity system operators, because of the system strength (high fault current) and physical inertia that they provide.
- Avoid the prospect of future constraints by electricity system operators resulting in additional costs for synchronous condensers and/or more expensive PECs.



### Speed to market

Reduce R&D costs. Get to market quickly with existing, patented technology.



### Proven performance

10% of New Zealand's wind power is synchronous. The 48 MW wind farm using Windflow™ turbines is the last to be curtailed if the system needs to curtail wind power. More than 1000 turbine-years track record in NZ and Scotland. The first TLG synchronous power-train was installed in a 3-blader in Devon, England in 1990.



### Support

Get the backup and support of **SyncWind**'s professional engineering experience.



### Non-competitive

Proven patented technology complements your manufacturing capability. **SyncWind** does not plan to manufacture 3-bladed turbines or develop a turbine larger than 1000 kW.



### Confidence

Provide buyers the reassurance of IEC-certified machines.

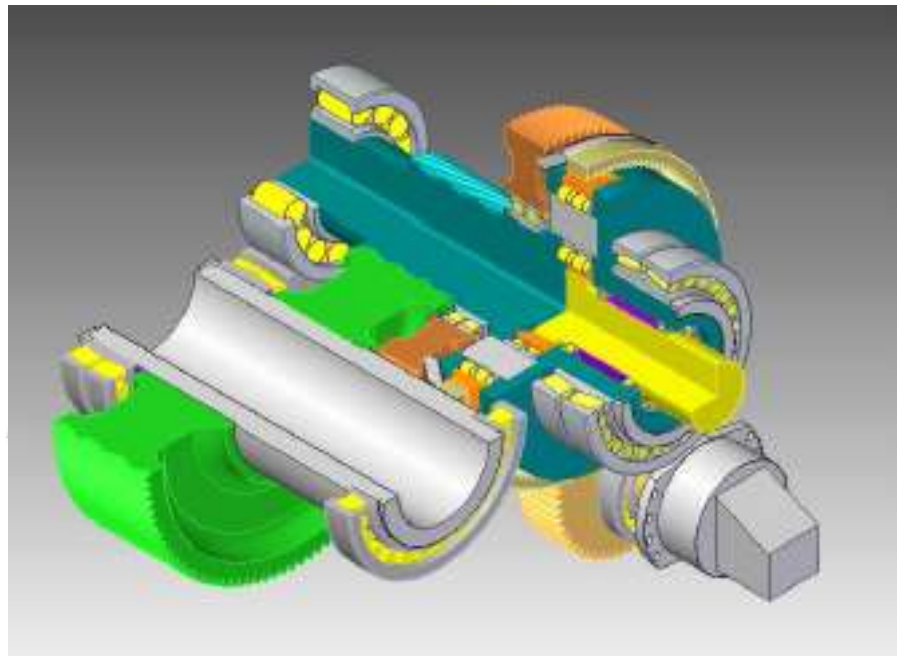
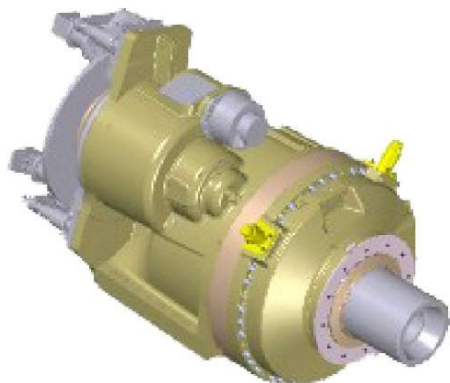


### Intelligent solutions

Spearhead the industry with forward-thinking solutions from wind industry veteran Geoff Henderson. Access unrivalled depth and breadth of experience in wind turbines from over 35 years in the industry.

# SyncWind's LVS-TLG Synchronous Power-train

is the right choice for the multi-MW market:



## Facilitates grid stability

The LVS-TLG system enables synchronous generation. Scalable for manufacture in mid- to large-sized wind turbines.

## Reduces gearbox downtime

Gearboxes are very sensitive to torque fluctuations. Grid faults can put torque spikes through systems. These and other momentary overloads cause damage to gearboxes. SyncWind's patented TLG protects the system from overloads and ensures gearbox reliability by controlling peak loads mechanically. It allows wind turbine rotor speed to vary while generator speed stays constant.

## Delivers broad-band variable speed capability

The LVS feature enables broad-band variable speed for better energy capture, reduced cut-in wind speed and reduced noise

## Lighter, more compact design

Enjoy a significant saving in production costs. For the same reliability and life, the SyncWind system delivers a modern gearbox that weighs 10-15% less than a gearbox for a PEC turbine.

A gearbox can be the single most expensive component in a wind turbine. A lighter gearbox means lower mass throughout, transportation costs can be reduced, and the machine will be cheaper to produce.

## Eliminates costly PEC systems

SyncWind's synchronous power-train eliminates the need for power electronics. The LVS-TLG hydraulics are integrated into the overall hydraulic system.

## Low-cost hydraulic system

For every 1 MW of turbine in PEC systems, you need 1 MW of PEC (Type 4) or 30% of that (Type 3), whereas the hydraulic LVS-TLG system has only a 5% rating.

PECs might be cheaper per kilowatt, but the LVS-TLG hydraulic system (which replaces PECs) has 5% of the kilowatt rating, so it is a fraction of the cost. For a 1 MW machine, it is a 50 kW hydraulic add-on, not a 300 kW or 1000 kW PEC add-on.

PECs ... Power electronic converters are used to connect almost all wind turbines, and all PV panels, to the grid.

## Power-Train Advantages

1. TLG removes torque spikes, makes gearbox lighter and more reliable.
2. LVS enables broad-band variable speed.
3. The LVS-TLG utilizes a low power (5% of rated) hydraulic sub-system:
  - Keeps cost low.
  - Reacts torque hydrostatically using power-splitting differential stage.
4. Enables synchronous generation (constant generator speed, only varies if grid frequency varies).

## Synchronous Generator Advantages

1. Synchronous generator enhances grid stability relative to asynchronous generation:
  - Voltage stability (LVRT/HVRT) enhanced by high fault current.
  - Frequency stability enhanced by mechanical inertia.
2. No additional hardware required to have all attributes (not only inertia) that grid traditionally gets from synchronous generators:
  - System strength due to high fault current.
  - Inertia.
  - Reactive power.
  - Synchronous condenser mode (small extra motor to do this with no wind).
  - Frequency keeping (load following).
3. No power electronics (lowers purchase cost and long-term cost).

## No Power Electronics (PEC) = Lower Overall Power-Train Costs

Power-Train Component	Conventional Type 3 (DFIG & 3-stage g'box)	Synchronous LVS-TLG	Notes
Gearbox	60	60	Lighter vs more complex
Generator	20	15	Mass-produced for diesel generators
Hydraulics	10	20	Low cost because only 5% of power
PEC, Static VAR Compensator (SVC)	10	0	Big saving because 100% of power
<b>OVERALL</b>	<b>100</b>	<b>95</b>	<b>Lower overall cost</b>

Note: Numbers are estimates of relative cost within turbine build. Operating and maintenance (O&M) costs are separate and support elimination of PECs. All other components (tower, rotor, etc.) unchanged.

## No PECs, SVCs, Sync-cons\*, DVARs\* = Lower wind farm cost = Much lower COE\*

- Power-train costs are lower (per above table)
- O&M costs are lower (no PECs)
- No need for auxiliary services equipment for grid connection (Sync-cons\*, DVARs\*, etc.)

Thus, lower overall societal cost of renewable future due to:

- lower turbine cost (because of power-train capital + O&M cost savings)
- lower wind farm auxiliary costs
- larger wind farm potential/less curtailment

\* ... **Sync-con** = synchronous condenser  
**DVAR** = dynamic VAR controller  
**COE** = cost of energy

The wind industry can avoid upcoming costly additions to electrical systems by adopting **SyncWind's** synchronous power-train. For example, the value of avoiding sync-cons alone is \$300-500 / kW.

# Voltage Faults and Frequency Swings

The most common events that can disrupt a power system are voltage faults and frequency swings. They can occur independently or one can lead to the other. The following brief summary is an overview, which does not discuss all possible events that can tend to destabilise electricity systems.

## Voltage Faults

The most common disturbance on a power system is insulation failure which results in a short circuit, causing the voltage to fall abruptly. During voltage faults, synchronous generators predictably contribute up to ten times rated current ensuring rapid detection and clearance of the fault by conventional protection relays.

## The Role of Fault Current

**Synchronous wind turbines are not just riding through, keeping the wind farm online, but they also contribute large amounts of fault current (up to 1000% of rated) into the short circuit, which helps clear the fault quickly and ensure stable generation after the fault. High fault current is a key definition of “system strength”. Its role is important both during the fault (normally <0.1 s) and immediately after.**

The grid voltage can fall towards zero during a short circuit, temporarily disrupting the balance between the power generated and the power that can be delivered to the system load. A synchronous generator can easily “ride through” these voltage faults. During the short circuit event, its fault current is useful for activating protection systems. Together with the generator’s rotational inertia, fault current also helps the generator stay in synchronism with the system through its effect on the magnetic forces on the rotor:

- during and immediately after brown-outs (where voltage remains significantly above zero), and
- immediately after momentary blackouts (zero voltage events) when the risk of loss of synchronism is greatest, but the high current magnetically forces the generator into synchronism.

Thus, synchronous generators are well-known to be able to ride through such events, ready to deliver power again the instant the short circuit has been cleared by the system protection.

The PEC wind industry has invested in developing electronic controls and capacity to ride through low voltage events. This attribute is not inherent in the technology, but involves a certain level of complexity which can be unreliable at the system level. And fundamentally it cannot provide the same high (up to 10 x rated) fault current as synchronous generators, because PEC systems will fail at such over-currents.

## Frequency Swings

Frequency swings occur when there is an imbalance between the power generated and the power that can be delivered to the system load. This can be due to a voltage fault (as explained above), or if there is a sudden loss of load, or a generator suddenly goes off-line.

## The Role of Inertia

**The fault current of synchronous generators keeps the power system in synchronism through its effect on the magnetic forces (or “reactive” effect) on their rotors. Rotor oscillations are inherently damped out by rotor eddy currents or built-in amortisseur windings. Inertia has an essential role in any frequency swing by ensuring that frequency cannot swing wildly, but takes some finite time to fall or rise, in accordance with Newton’s Laws. PECs have no inertia and decouple the wind turbine-generator’s inertia from the power system so output frequency can change instantaneously, and they must rely on complex control strategies to try to achieve frequency stability.**

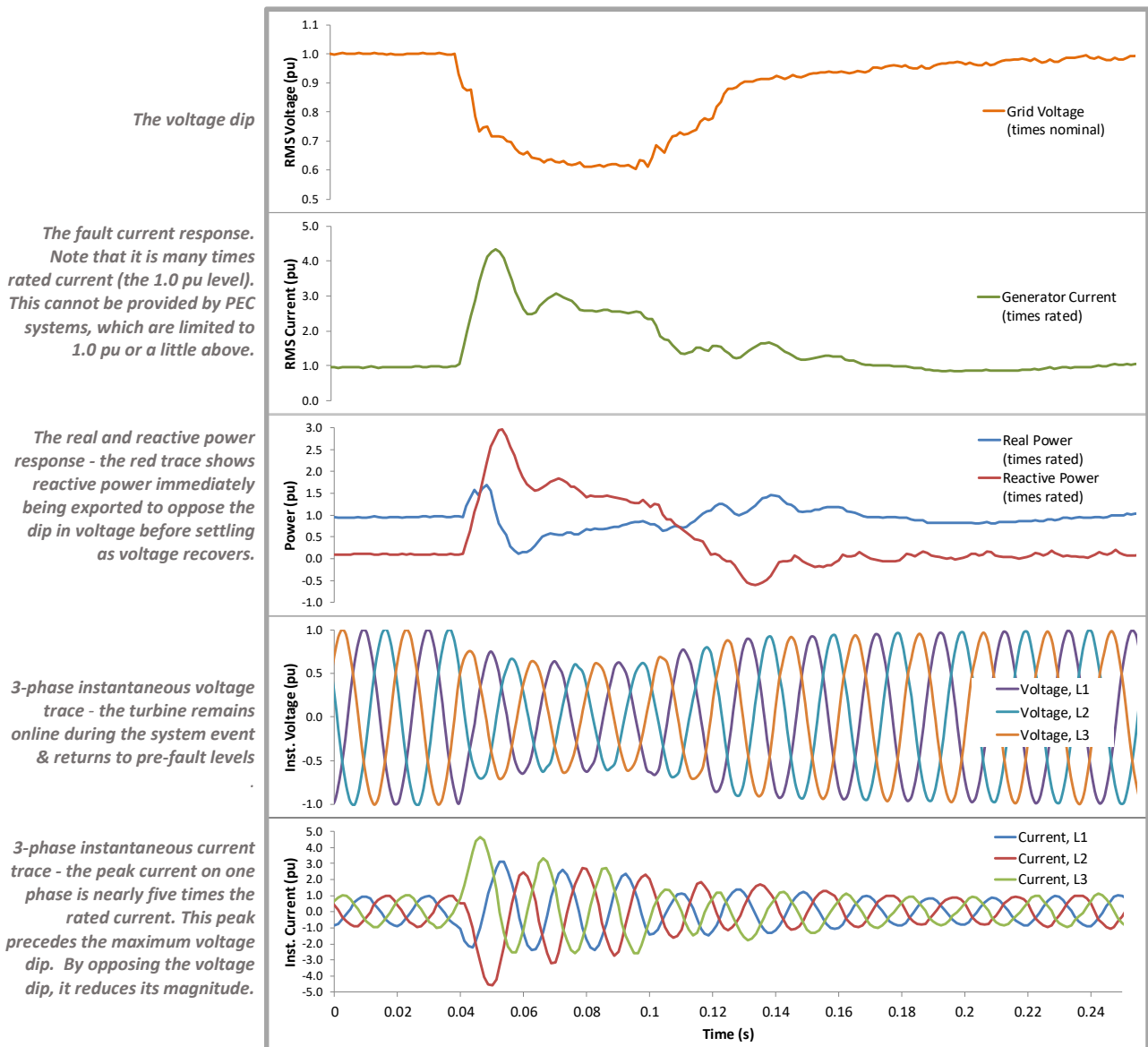
New and existing systems therefore, should plan to have a proportion of wind power based on synchronous generation. 10% of New Zealand's wind power is synchronous (48 MW Te Rere Hau wind farm shown here).



## Example of fault contribution & ride-through of a Windflow™ 500 synchronous turbine

Data from an event recorded at the Te Rere Hau wind farm (shown in photo above) on 8 September, 2012.

Figure 1: A system voltage dip to 60% of normal voltage that lasted around 100 ms (0.1 seconds).





# Inertia is Critical for Grid Stability

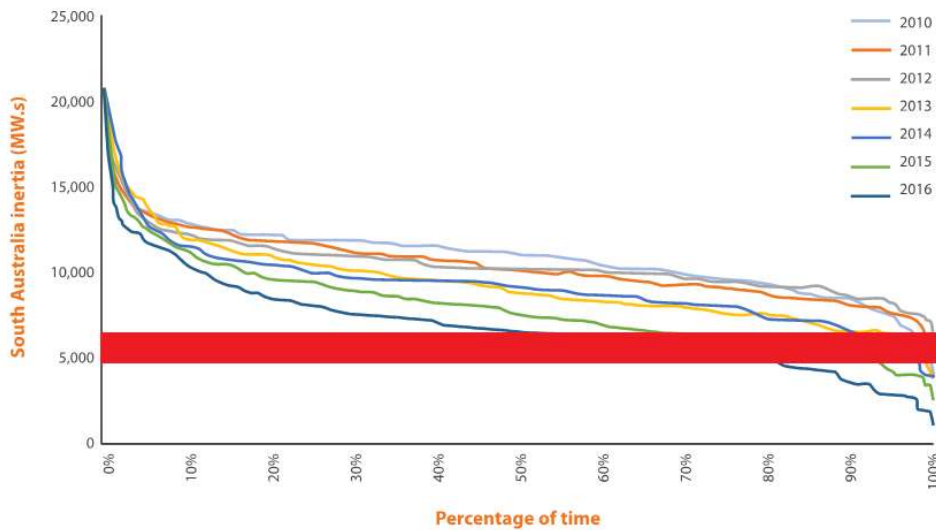


Inertia is critical for stability in power grid systems, which almost always use alternating current (AC) of 50 Hz or 60 Hz frequency. Power grids rely on the mechanical inertia of synchronous rotating power plant to maintain grid integrity and stability during load fluctuations and electrical disturbances.

The level of inertia in power grids has been in steady decline as renewable energy with PECs has displaced conventional synchronous generators.

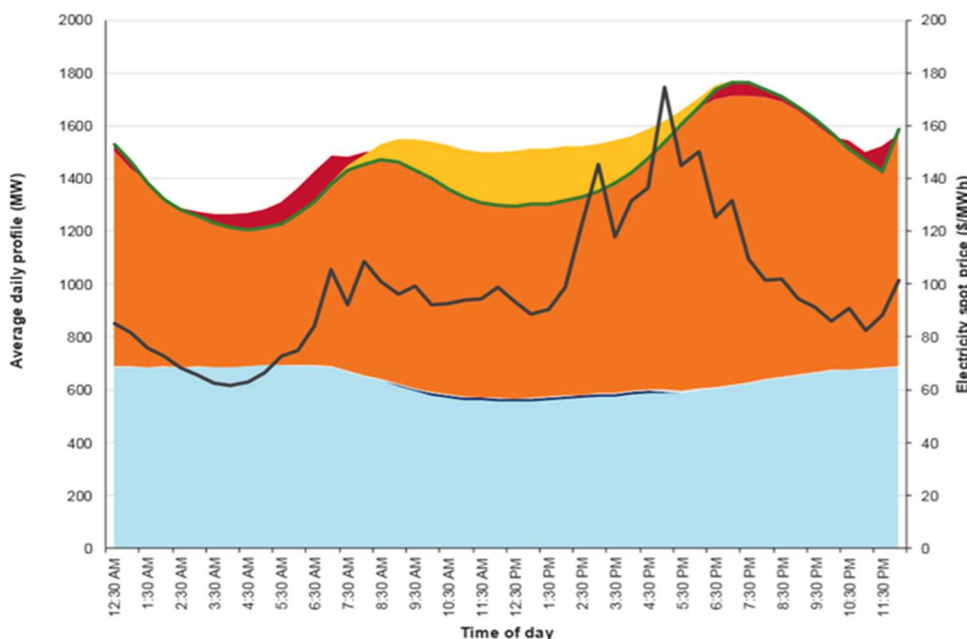
Australia has hit this issue before most nations, because of its combination of low population density and large-scale displacement of coal-fired power by renewables. Figure 2 shows that the growth in connections of wind and solar power in South Australia between 2010 and 2016 led to inertia levels reducing significantly, by a factor of three or four at the “95-percentile” level.

Figure 2: Reducing system inertia in South Australia – exceedance lines for 2010-16



The thick red line is inserted on Figure 2 (a form of cumulative probability diagram) to indicate that, at some time between 2010 and 2016 inertia levels became unacceptably low. It is not a thin, precise line, because the issue is probabilistic.

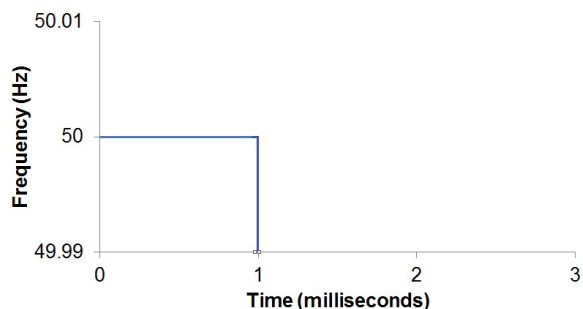
Figure 3: Average daily supply profile for the 2017-18 financial year in South Australia



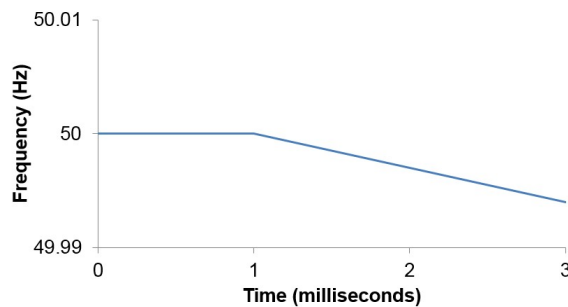
The light blue shaded area in Figure 3 shows how wind power generates 50% of South Australia’s power on average, the highest penetration in the world.

**Figure 4 below sets out the basic principles.**

Figure 4: Fundamental PEC versus Synchronous generator frequency response



PEC generator on its own has no inertia so frequency can change abruptly on a millisecond timescale



Synchronous generator contributes to frequency stability

An AC grid made up entirely of PEC systems would not be able to control frequency stably to connect remote generators and loads. All systems would become stand-alone.

If PEC generators are significant in the generation mix, the system has low inertia, and so frequency jitter increases. In the event of a sudden large change in system demand, the frequency governors have insufficient time to respond before the magnitude of the frequency deviation is too large to correct and the power system must shut down.

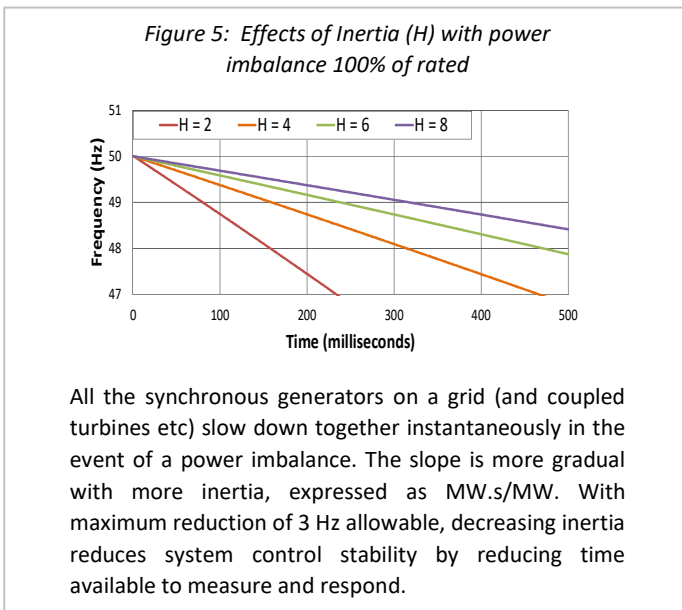
The number of PEC generators that are on line varies from one hour to the next, making it difficult for system operators to be confident that the system has sufficient inertia to be stable for a large contingency, which could happen at any time.

**When synchronous generators supply the grid, inertia is inherent in all the synchronous generators on line. During a change in system demand, electromagnetic effects make all of the synchronous generators on a grid slow down together instantaneously at a rate that is determined by the total system inertia.**

Providers of “fast frequency response” services (FFR, also called “synthetic inertia”) employ PEC control systems to approximate the inertial power contribution of synchronous generators. This has proved to be a workable approximation for large-scale power connection such as HVDC inverters, which control 100s – 1,000s of MW from a single control source. The same cannot be said for 100s – 1,000s of individual small-scale inverter-connected DER facilities, each employing its own controller, with diverse designs and settings, which taken together must provide a secure and reliable, unified response if the responsibility for system stability is to be placed in their domain. Current thinking is that a secure power system will always need some classical inertia on the grid to provide assurance of a reliable frequency response to contingencies.

Frequency fluctuations caused by routine changes in load are smoothed by their inherent inertial response allowing time for the governors to respond to correct the situation.

If that is not possible in sudden large changes in load, inertia provides time for under-frequency load shedding systems (UFLS) to shed load in an orderly fashion to restore the balance between generation and the load. Because the inertia component comes as part of the generation, system operators can be confident of understanding the inertial capability of the system for any generation mix or magnitude of system demand.



This inertial effect is instantaneous, direct and inherent, independent of any generator controls.

A power system needs to have sufficient inertia at all times to respond to both small and large fluctuations in the balance between generation and demand, which cause under- or over-frequency events. The inertia is required to keep the rate of change of frequency slow enough, so the system governors can respond and minimise the effect of any foreseeable disturbance. Effective system security planning depends on the absolute assurance that sufficient inertia is present on the system for any combination of generation, transmission and connected demand.



## Lessons from the South Australian blackout

The blackout in South Australia in September 2016 highlighted issues that PEC generation can have riding through multiple voltage faults. The wind farms in South Australia were carrying half the state's load. When half of them shut down, there was a major load imbalance.

Investigations showed there were errors in the wind farms' control systems' setup. When the wind farms curtailed their contribution, the connector to Victoria picked up the resulting deficit and tripped out on overload. When the Victoria connector tripped, only 300 MW of synchronous generation remained. The remaining PEC wind farms provided no inertia, and the frequency fell at over 6 Hz/s, too fast for load-shedding to avoid blacking out the entire state.

## What conclusions have come from AEMO's technical analysis?

From its analysis of the Black System event, many of AEMO's conclusions provide valuable guidance for improving the management of extreme conditions in South Australia (SA) :



- The following factors must be addressed to increase the prospects of forming a stable SA island and avoiding a Black System:
  - Sufficient inertia to slow down the rate of change of frequency and enable automatic load shedding to stabilise the island system in the first few seconds. This will require increases in SA inertia under some conditions, as well as improvements to load shedding systems combined with reduced interconnector flows under certain conditions.
  - Sufficient frequency control services to stabilise frequency of the SA island system over the longer term. This will require increases in local frequency control services under some conditions.
  - Sufficient system strength to control over voltages, ensure correct operation of grid protection systems, and ensure correct operation of inverter-connected facilities such as wind farms. This will require increases in local system strength under some conditions.

In 2019 the Australian Energy Regulator initiated court proceedings against the operators of four wind farms in South Australia for failing to comply with ride-through requirements before the September 2016 blackout.

# Grid Instability is a Major Barrier to a Zero-Carbon Future Worldwide.



## Australia

Since 2017, AEMO has followed through on its call for increased system strength by:

- requiring the South Australia network to improve its system strength, causing increased fossil-fuelled power, curtailing wind farms until \$170 million investment in synchronous condensers (sync-cons) is made
- requiring most new wind and solar farms to install sync-cons.

## Texas

The Texas utility, ERCOT, is closely monitoring inertia levels due to the growth of wind farms and has determined that 100 GW.s is their minimum acceptable level. Several times in the last 10 years, it has fallen to about 130 GW.s.

As a result, in 2017 they planned to bring an additional 3 GW of fossil-fired power on line by 2020 assuming wind power would grow by 9 GW in that period.

## British Isles

Ireland has the highest penetration of renewable energy in Europe and has been working to address grid stability since 2010. The system operator is designing incentive schemes for providers of inertia and is limiting (i.e. curtailing) the short-term penetration of renewables.

Great Britain has issues in Scotland, where old thermal power stations are having to run as sync-cons, and England, which in August 2019 experienced a blackout similar to South Australia's 2017 blackout.

## The Dilemma

- Wind power mainstream and solar PV reduce grid stability.
- If solution is more electronics, batteries and sync-cons, renewables become more expensive, creating political resistance.
- If blackouts become more frequent, renewables get a bad name.

**So, synchronous wind power is a key to a zero-carbon future.**

**Synchronous generators will easily ride through system disturbances that have caused wind farms to shut down, contributing to (if not causing) blackouts.**

**Physical inertia and large amounts of fault current are two attributes, in terms of which PEC systems cannot compete with synchronous generators.**

Synchronous generators increase system strength through their ability to contribute significant fault current, enhancing system stability, voltage control and the operation of protective devices. Synchronous generators would have contributed to voltage and frequency control.

Synchronous generators would have provided inertia for frequency stability, slowing down the system collapse sufficiently to allow load shedding to reduce excessive load.

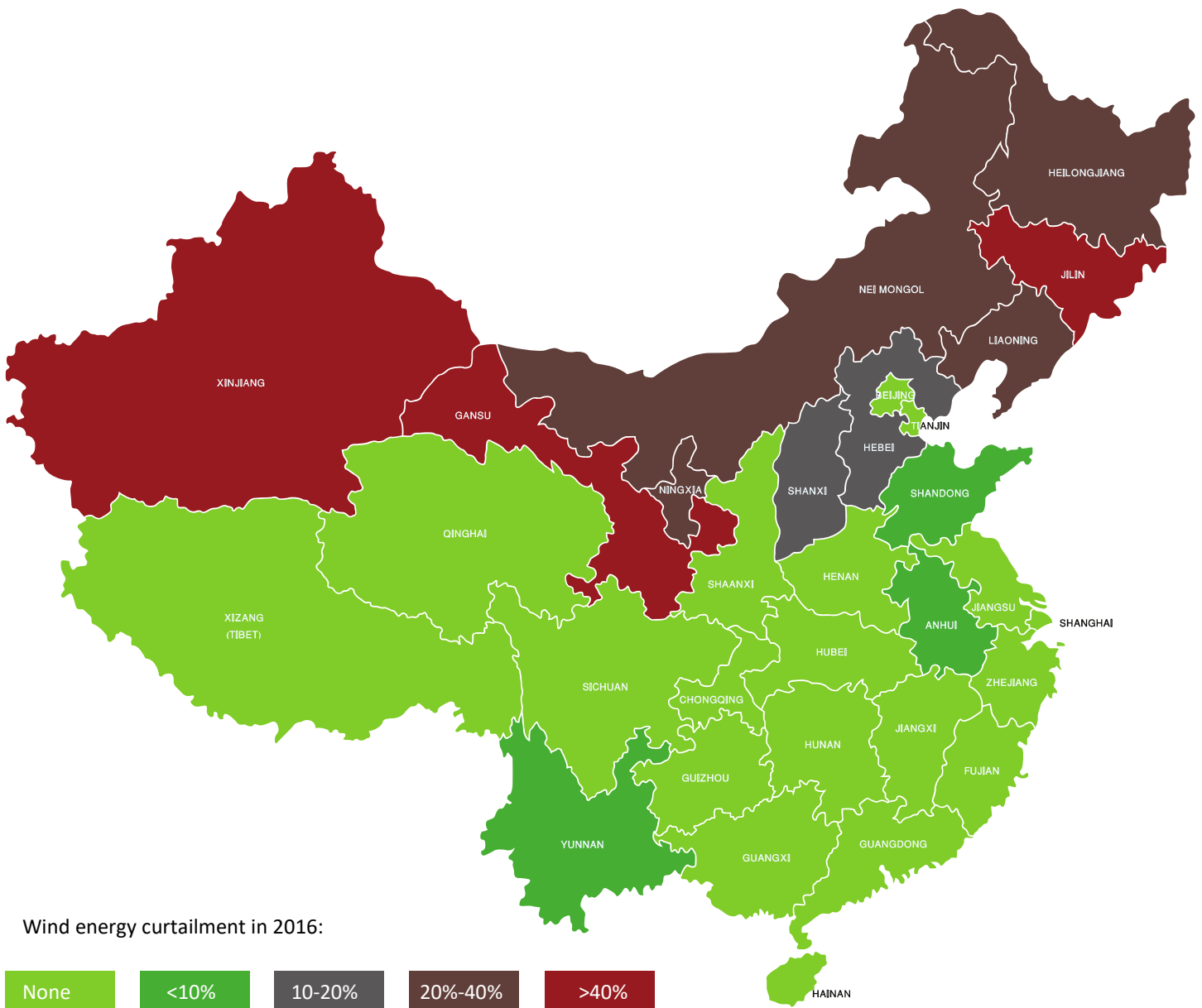
# China Grid Issues

Currently, wind turbines are mainly erected and connected to the grid in the north-western provinces. This poses problems, as the electricity generated there cannot be transported to the load centres in the East of China.

How much is due to stability concerns? A lack of ultra-high-voltage lines can result in the curtailment of up to almost 50% of the potential electricity generated by wind in some provinces e.g. Gansu.

Stability is a matter of degree. Faults can be caused by many external events (weather and non-weather) and can cause low-voltage, high-voltage, over- and under-frequency events at different parts of the system.

**Synchronous generators improve system stability in voltage and frequency faults.**



# Grids need physical inertia

The final report in June 2017 by the Australian Government's Chief Scientist, Dr Alan Finkel, 'Independent Review into the Future Security of the National Electricity Market' states that:

**'Security and reliability have been compromised by poorly integrated variable renewable electricity generators, including wind and solar...**

**Security should be strengthened through Security Obligations for new generators, including regionally determined minimum system inertia levels...**

**Technologies that provide a fast frequency response (FFR), including 'synthetic inertia' from wind turbines, can partially compensate for a decrease in physical inertia. However, international experience shows that at present, in large power systems, FFR cannot provide a complete substitute for physical inertia. That is, a minimum level of physical inertia from synchronous technologies is required.'**

The Finkel Report then goes on to make numerous recommendations as to how Australia can continue to make a transition to achieving increasing levels of renewable electricity generation.

**SyncWind**'s synchronous wind turbine power-train exactly fulfils the recommendations in this Australian Government Review on how to avoid adverse effects from increasing amounts of wind power on the grid.

This is because **SyncWind**'s synchronous wind turbine power-train enables the use of synchronous generators directly grid-connected, and thus provide system strength and physical inertia like the synchronous machines that have kept the lights on before the advent of wind turbines.



**Synchronous wind power is proven and cost-effective.**

**Synchronous generators enhance system security, reliability and resilience.**



**The primary determinant of system reliability is knowledge:**

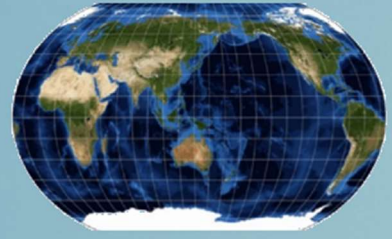
- Proven performance, that is easily modelled and well understood.
- Classical frequency and voltage controls.
- Classical short-circuit (fault current) characteristics.
- Conventional protection systems.

**The primary requirement for knowledge is predictability:**

- Windflow's 106 wind turbines – all synchronous - have accumulated more than 1000 turbine-years track record.
- Assembled from proven subsystems and components (including off-the-shelf generators for the diesel genset market) which have individually, demonstrated millions of satisfactory operating hours.

**The primary requirement for reliability is simplicity:**

- Simple to set up, operate and control.
- Electrical and mechanical maintenance practices and knowledge are transferable from maintenance of conventional power plant.



Partner with  
**SyncWind** Power Ltd  
to take this global.

We  
'Synchronise the *Wind*'  
directly into the grid.



© **SyncWind** Power Ltd  
Christchurch, New Zealand  
phone: +64 21 946 335  
Geoff@windflow.co.nz  
[www.SyncWind.org](http://www.SyncWind.org)

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