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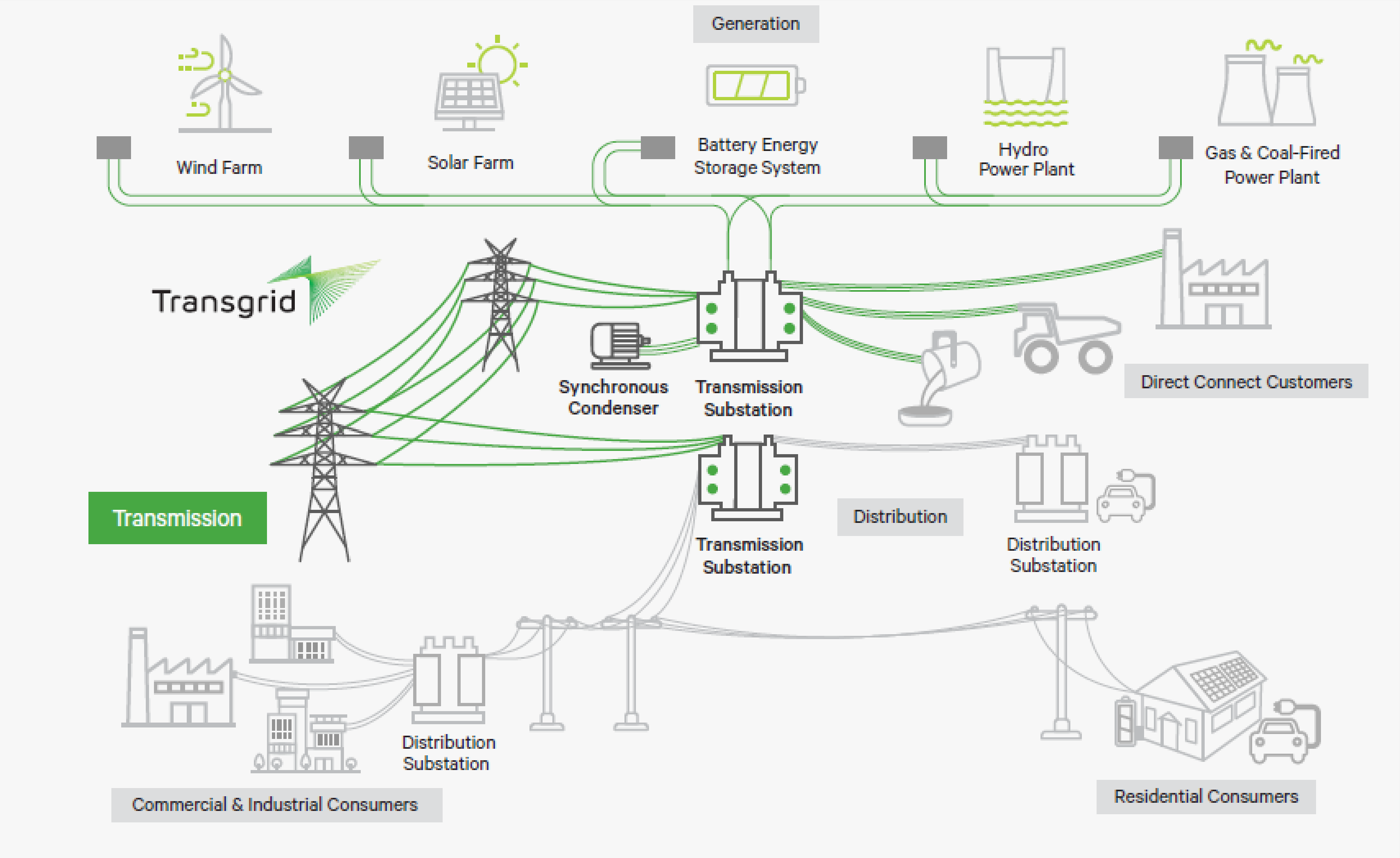
SYNCHRONOUS CONDENSERS – Bringing stability to the grid

Dave Tarrant

Principal Consultant – Rotating Equipment

Stable Grid: Stable *Voltage* and Stable *Frequency*



Stable Grid: Stable *Voltage* and Stable *Frequency*

Key Aspects of a Stable Grid:

REACTIVE POWER COMPENSATION

DYNAMIC VOLTAGE SUPPORT

INERTIA

SHORT CIRCUIT POWER

Key Aspects of a Stable Grid:

REACTIVE POWER COMPENSATION

• **Active (Real) Power -** power that ***performs useful work***, like running motors or lighting bulbs, measured in Watts (W)

• **Reactive Power** - power that oscillates between source and load, creating and sustaining electric and magnetic fields in motors, transformers, capacitors (e.g. transmission lines), etc.

- Doesn't do useful work, ***but critical for active power transmission and voltage support.***

Key Aspects of a Stable Grid:

REACTIVE POWER COMPENSATION

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Key Aspects of a Stable Grid:

DYNAMIC VOLTAGE SUPPORT

- In a grid, voltage needs to be maintained within a specific range (typically ±5% of the nominal voltage).
- Sudden system disturbances (e.g. large load shifts, unit trips, faults, etc) can cause voltage fluctuations
- If the voltage deviates too much from its nominal value, it can lead to grid instability, equipment malfunction, or even cascading blackouts.
- Dynamic voltage support – need real-time, fast-acting devices that **quickly adjust the reactive power**
- The fastest responders are Static VAR Compensators (SVCs), Static Synchronous Compensators (STATCOMS) and Battery Energy Storage Systems.
- Syn cons slightly slower, but have other advantages

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Key Aspects of a Stable Grid:
INERTIA

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Inertia in Power Systems - traditional power stations (e.g. coal, gas, and nuclear) use large rotating machines with significant mass, and because of their rotation, they ***store kinetic energy = inertia*.**

Helps to stabilize the grid - buffer or **resistance to sudden changes** in the balance between electricity supply and demand

Slows down the **rate of change of frequency** by using the kinetic energy stored in the rotating masses to continue generating power for a short period. Gives the grid operators **more time to react**

MW.s of Inertia: how much total energy the inertia can provide to the system.

E.g. 180 MW.s can generate 180MW of active power in reaction to a drop in system frequency for 1 second, or lower MW for an increasing amount of time. After that time, the machine will start slowing down.

Inertia constant: MW.s/MVA (s)

Key Aspects of a Stable Grid:

RATE OF CHANGE OF FREQUENCY (ROCOF)

RoCoF - how quickly the frequency in the power grid changes, typically in Hz/s.

High RoCoF is a problem:

- Grid Instability and Blackouts
- Automatic Disconnection of Generators
- Protection Systems Malfunction (activate unnecessarily)
- Harm to Sensitive Loads (e.g. large industrial motors/drives)
- Increased Stress on Grid Components (e.g. pole slip, rotor surface currents, shaft torsional stress, auxiliaries, etc)

Key Aspects of a Stable Grid:

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Key Aspects of a Stable Grid:

SHORT CIRCUIT POWER

Short circuit power (or short circuit capacity, SCC) - *the ability of the grid to handle fault conditions, such as short circuits, without compromising:*

- *fault resilience (*ability to provide sufficient current to isolate and clear the fault without causing a severe drop in voltage or large fluctuations),
- *protection systems (*may not detect the fault in time or may not operate correctly)
- *voltage stability*.

Weak grids with low short circuit power - even small disturbances can cause **voltage instability**, which can lead to voltage collapses and broader grid failures.

Key Aspects of a Stable Grid:

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SHORT CIRCUIT POWER

Another aspect:

Power Quality and Harmonics - grids with low short circuit power are more prone to **voltage distortions** and **harmonics** (i.e. **poor power quality**) caused by non-linear sources (in particular ***power electronics e.g. inverters***).

In generators, grid voltage harmonics create asynchronous stator current harmonics - produces currents in the rotor damper circuit and body surface. ***Can result in an additional 10% heating effect***

So What's The Problem?

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Modern Grid Development is potentially the problem…

- Growth of renewable generation
- Mostly non-synchronous, connected via inverters ("Inverter Based Resources" or IBRs)
- Displace existing, high inertia/SCC generation – coal-fired and gas-fired plants being shut down
- Located in remote parts of the grid

CONSEQUENCES:

Lack of Inertia

Lack of Short-Circuit Power

- Potential for Unstable Grid!

Solution - Synchronous Condenser

At this stage the best fit is Synchronous Condensers, at least as *part of the solution*.

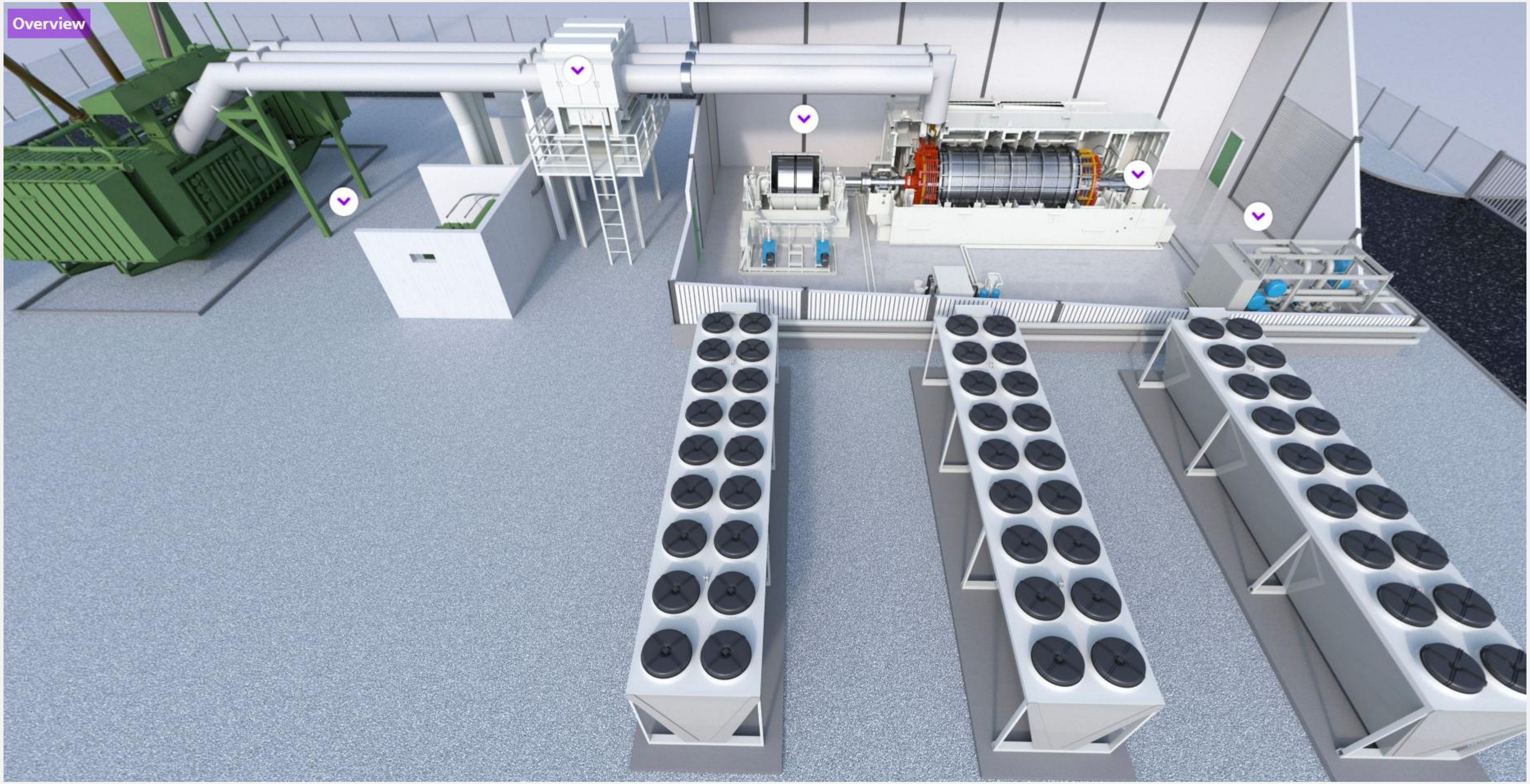
They provide:

- Reactive Power Control
- **Short Circuit Power**
- **Inertia**
- Some level of Dynamic Voltage Support

Comparison Table

Feature / Device	**Synchronous Condenser**	STATCOM	SVC	Capacitor Bank
Response Time	Slow (hundreds of ms)	Fast (few ms)	Moderate (tens of ms)	Very fast (but no control dynamics)
Reactive Power Control	Continuous, smooth	Very fine and fast control	Stepwise (via thyristor switching)	Fixed or switched (discrete steps)
Voltage Support	Good dynamic & short-circuit support	Excellent dynamic support	Good support	Basic/local support only
Inertia Contribution	**Yes**	No	No	No
Short Circuit Capacity	**Increases system strength**	Does not increase short-circuit level	Does not increase short-circuit level	Does not increase short-circuit level

Key Components



Alternative – Salient Pole

What do I need to specify?

Partly as per a normal generator:

- Voltage (at Point of Connection, typically)
- **Short Circuit Power**
- **Inertia level**
- Reactive power range – usually SCC determines machine size, but MVARs can be specified if key

Considerations

Not always in Owner's control but can influence (and usually at a price):

- Indoor/outdoor
- Starting method (pony motor, SFC)
- Flywheel
- Noise level
- Backup supplies (batteries / diesels)
- Life of Plant
- Level of QC in the Factory

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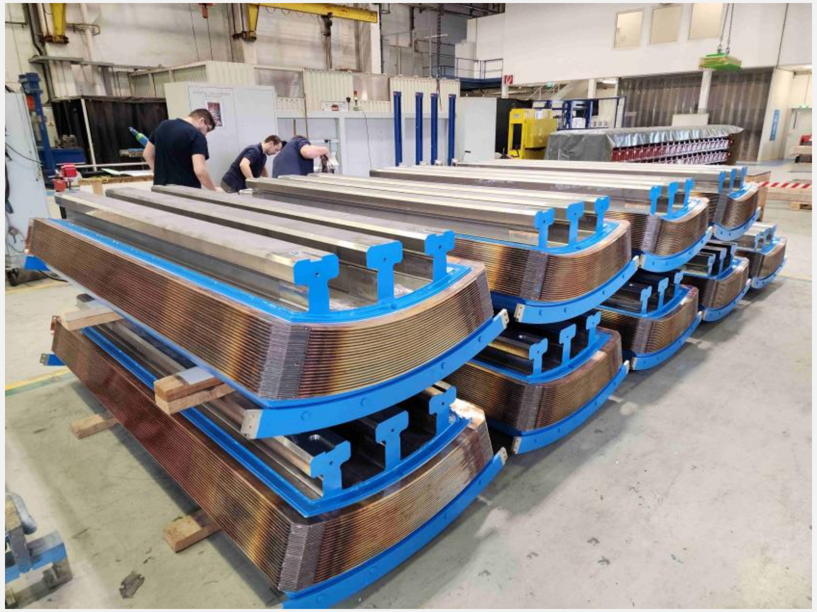
Considerations

- One or two (or more) machines
- Operating temperature range
- Civil design input
- Transport weights (200-300 tons – road/bridge limitations)
- Testing and modelling (AEMO’s requirements)
- Online monitoring requirements (PD/rotor flux monitoring)
- Availability/operational requirements (99% availability…)



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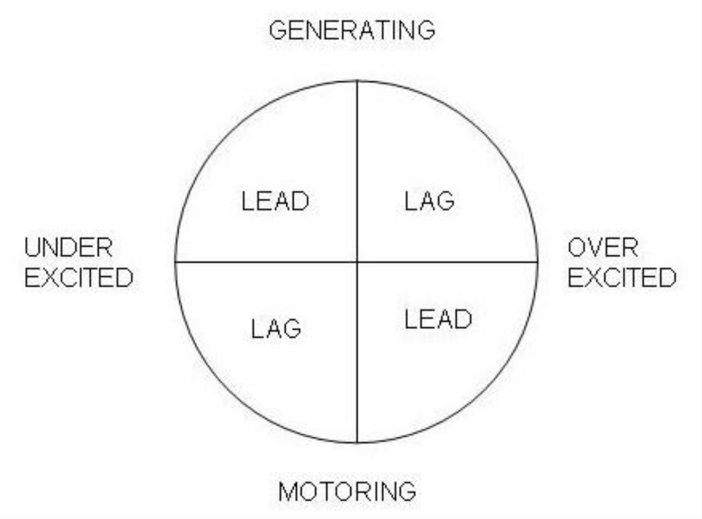
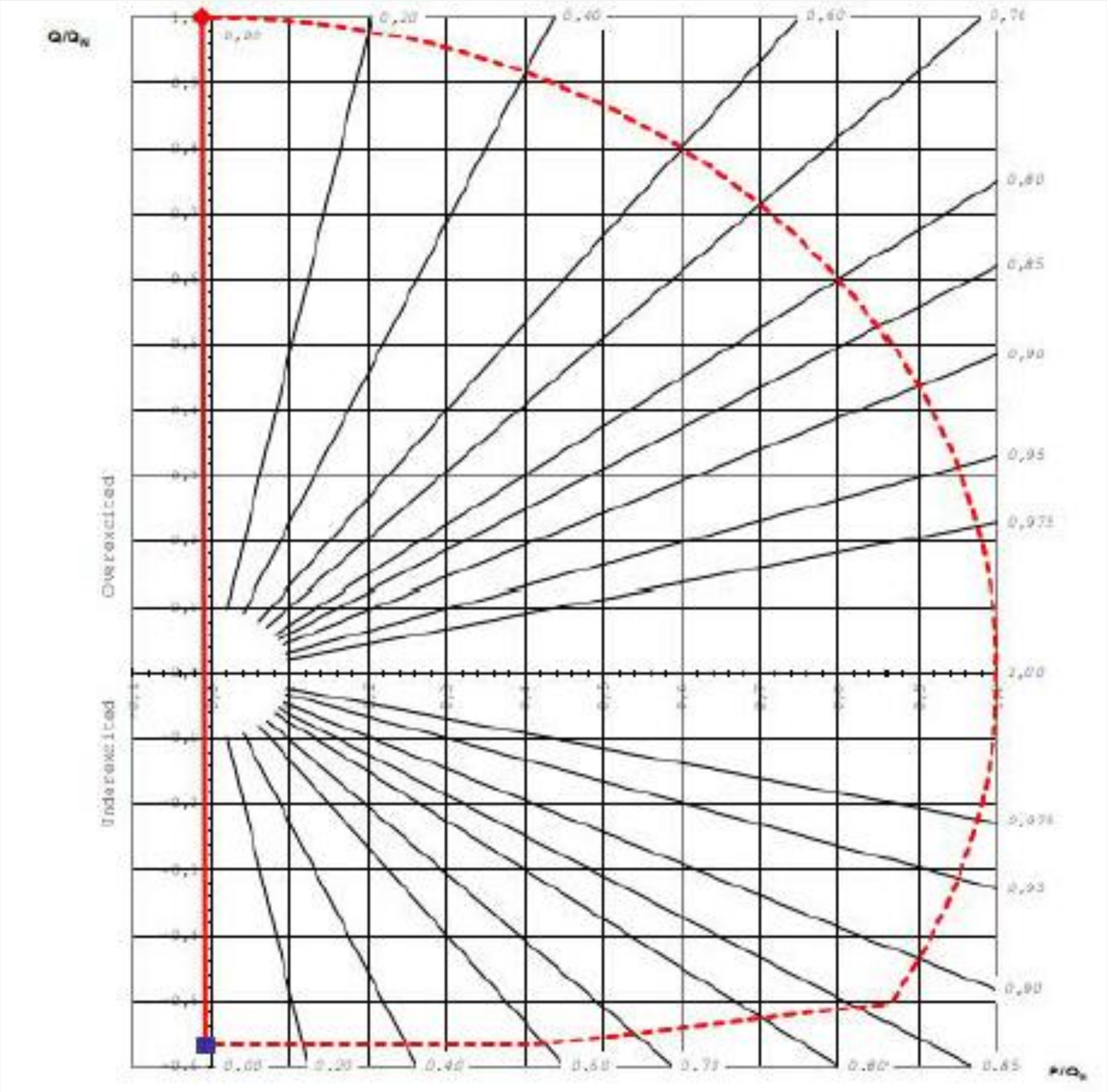
Operation

Looking more at operations:





Maintenance

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They’re essentially generators without the optional extras (turbines) – minimum maintenance

- Minor inspection: 2-3 years
- Major inspection: 9-12 years

Depends on:

- Type and OEM, and **manufacturing quality**
- Ambient conditions
- Operating regime (typically designed for 10 000 starts/stops)
- Routine maintenance done correctly (oil checks/change, filters, fans, pump changeovers, etc)
- Predictive maintenance strategies (online PD/rotor flux/trending)

SUMMARY

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- Not new technology, re-purposing of existing well proven tech
- Not cheap, but effective and reliable
- Essential for inertia and short circuit power in a renewables-dominated grid
- Better quality of supply
- Best used together with STATCOMs
- If the needle swings again, can be used as generators…
- Keeping traditional generators relevant in an increasingly “green” world

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