The future of grid forming inverters

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Hitachi Energy

Overview

About Hitachi Energy

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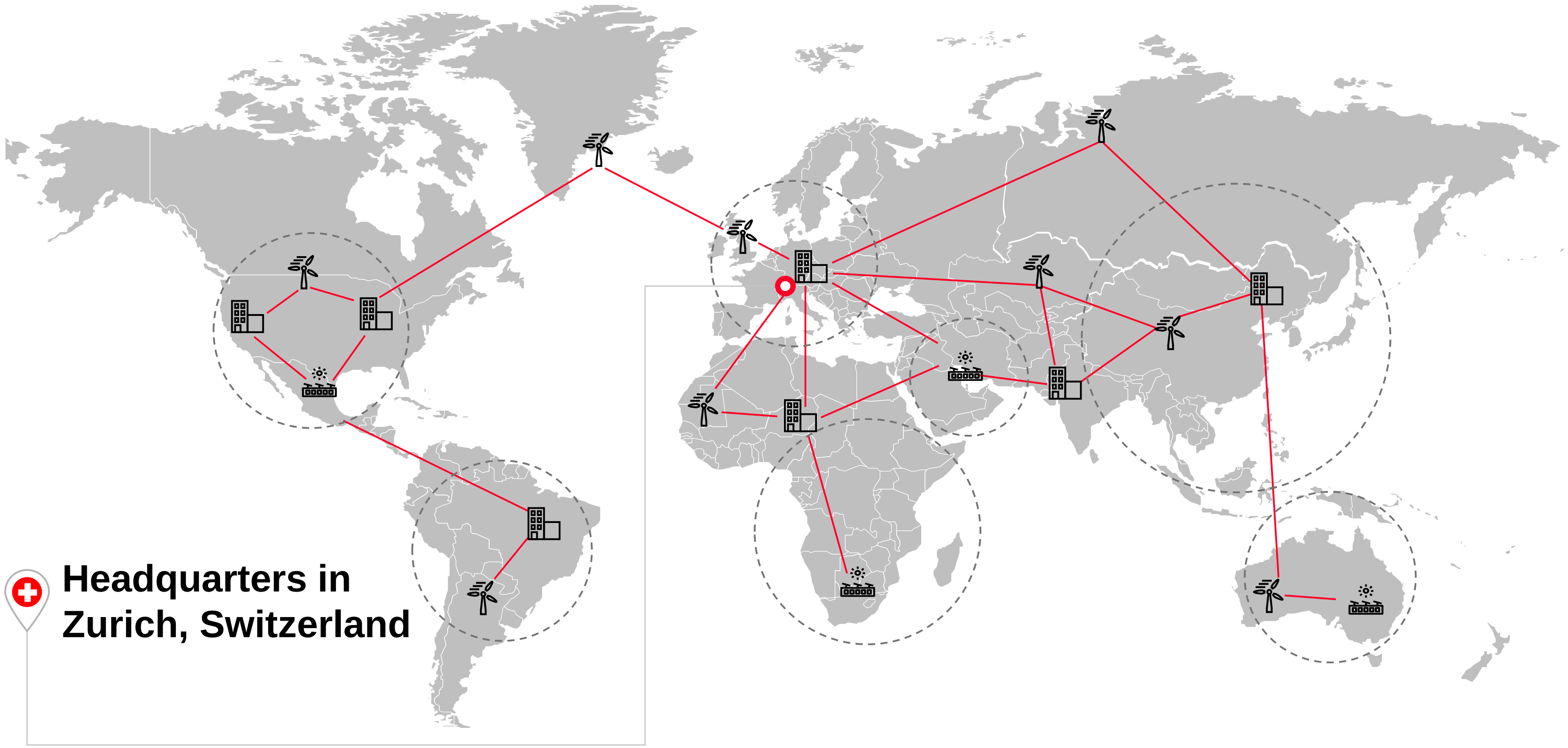


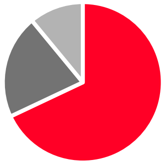
38,000 employees

90+ countries with 200 offices	**~250** years' heritage combined
5,500 sales employees & field engineers	**2,000** engineers & scientists in R&D

Four Business Units

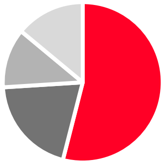
Grid Automation	**High Voltage Products**
Grid Integration	**Transformers**

Customers



- Transport & Infrastructure
- Industry
- Utilities

Offering



- Services
- Software & Automation
- Systems
- Products

Geographies

- Asia, Middle East & Africa
- Americas
- Europe

Public

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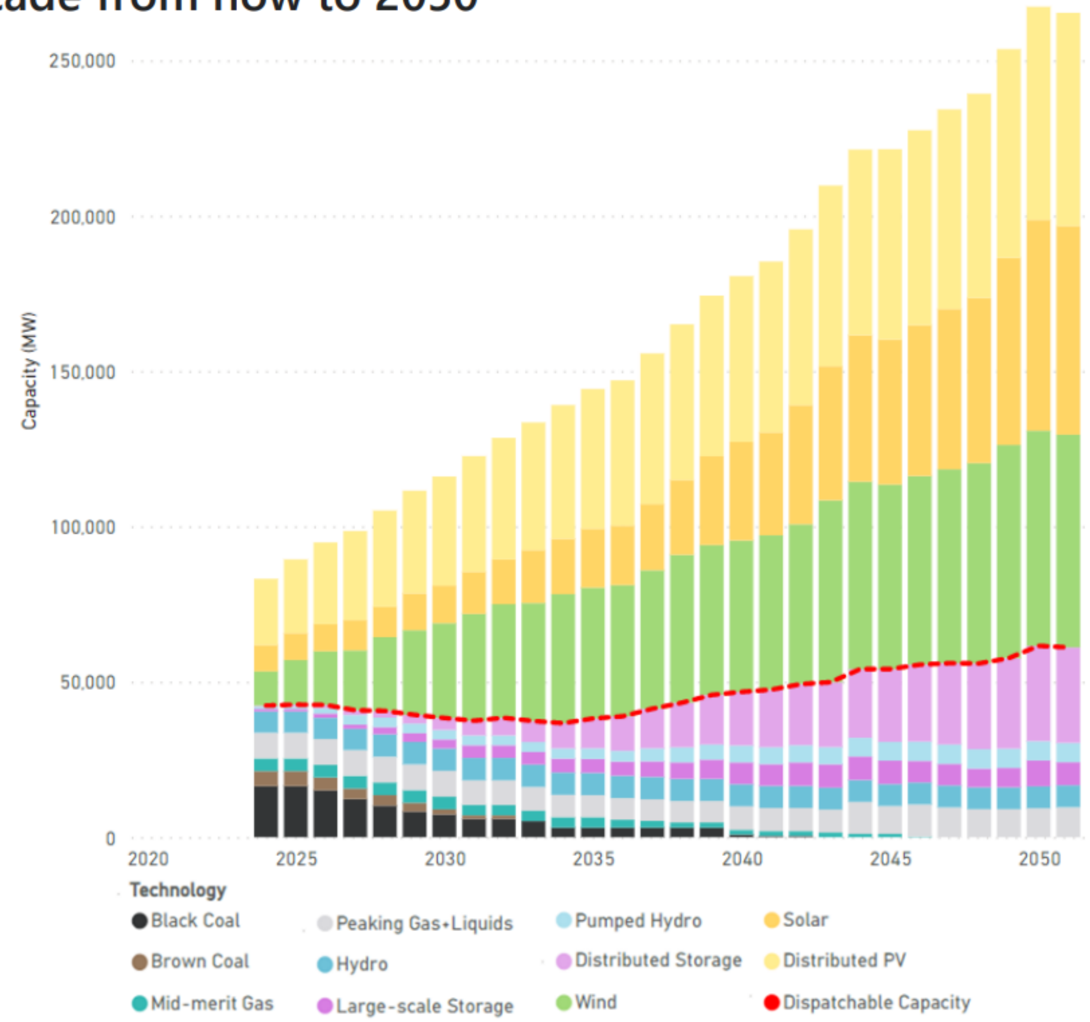
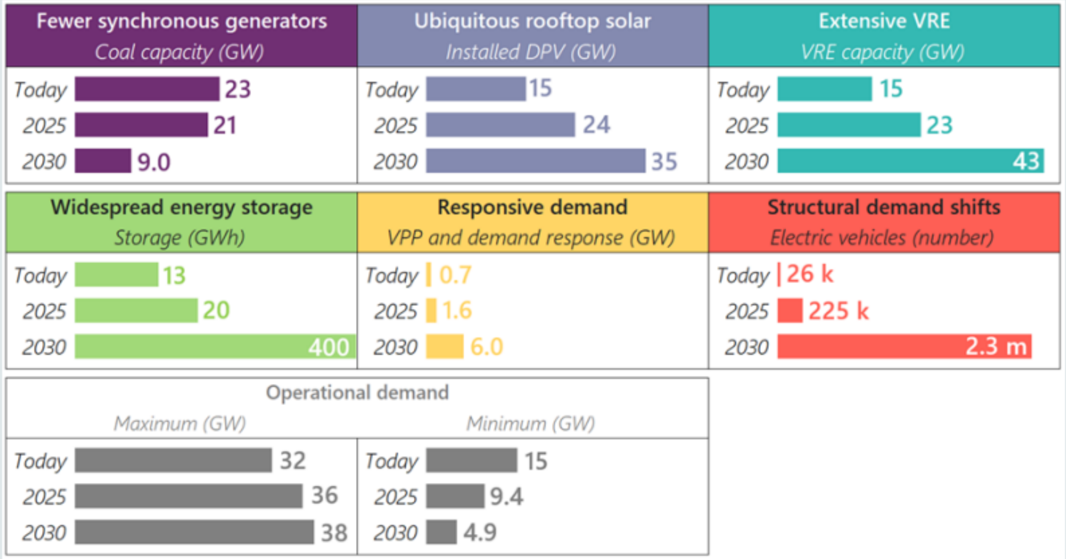
Need to replace 14GW of Synchronous Generators in 8 Years

Renewable generation capacity to at least double every decade from now to 2050



The Draft ISP 2022 highlights that **profound transformation** is anticipated that will **rapidly cross uncharted operational conditions.**



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What services are required to operate a stable and secure grid?

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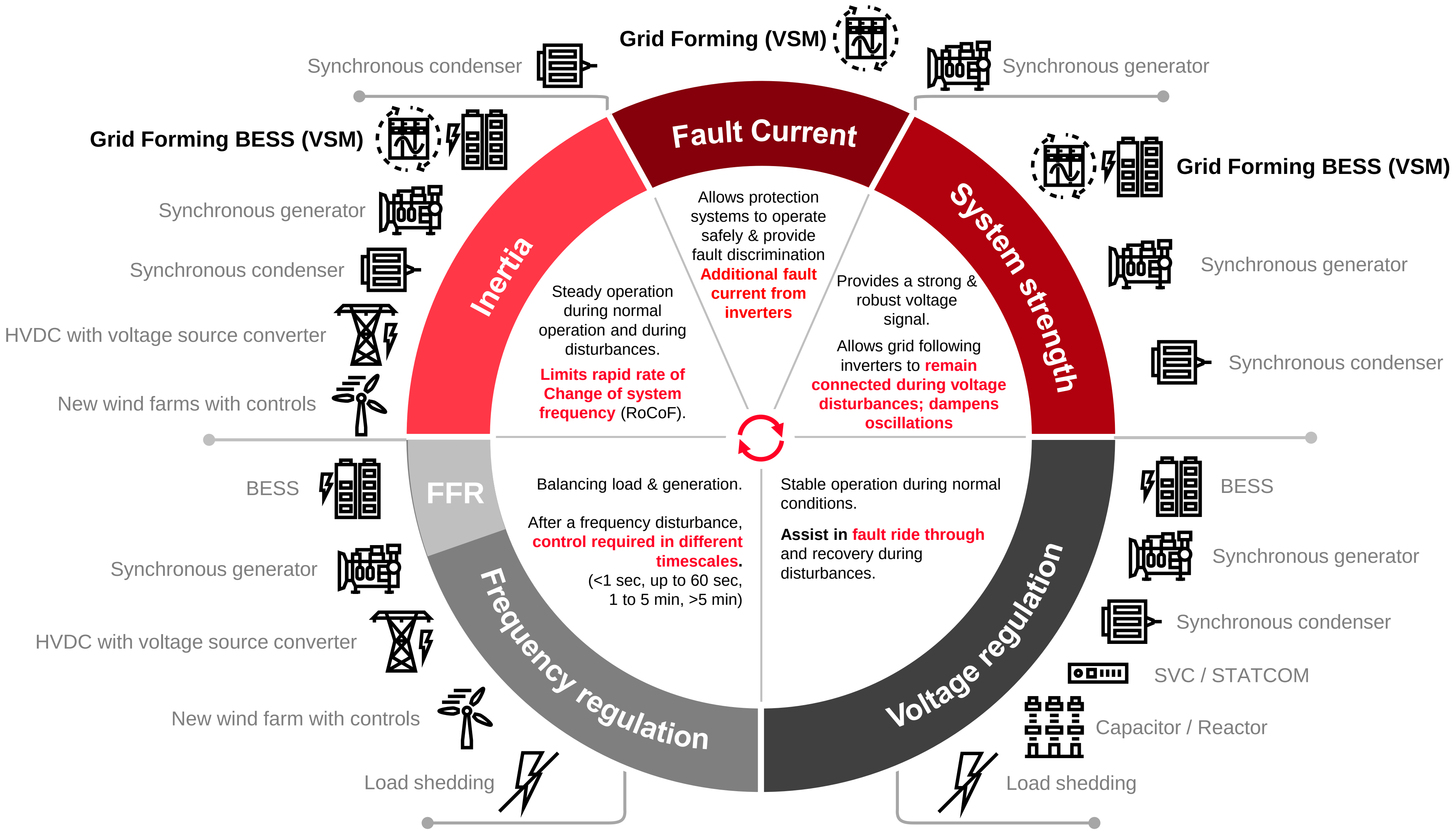

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Our Heritage - Evolved Knowledge & Technology over 30+ years

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1988

powercorp

1990

Energy efficiency

Diesel Battery Storage System

- PowerWater Corporation
- 10 sites across NT
- 60kW storage for spinning reserve

1998

40% RE penetration

Wind Diesel System

- Western Power
- Denham Power Station
- 3 x 230kVA wind turbines

2010

100% RE penetration

Solar Diesel Storage System

- Horizon Power
- Marble Bar & Nullagine Stations
- 300kW Solar PV; 500kVA flywheel

2011

ABB

2014

DNSP System Microgrid

Storage Diesel System

- AusNet Services
- 1MW/1MWh battery storage
- 1 MW diesel generator

2016

50% RE penetration

Solar Diesel Stabilizing System

- DeGrussa Mine, Western Australia
- 10MW Solar PV
- 4/6 MW battery stabilizing system

2017

Gas Turbine Spinning Reserve

Storage + Gas Turbine System

- Alinta Energy; WA
- 4 x Gas Turbines
- 35MVA/8MWh battery storage

2018

TNSP Connected Microgrid

ESCRI/Dalrymple

- Electranet; South Australia
- 30MW/8MWh battery storage
- 91 MW windfarm, 3MW distributed solar

2019

Off-shore Gas Turbine Spinning Reserve

Storage with Gas Turbine System

- Goodwin Woodside
- 2.8MVA/1.43 MWh battery storage
- Microgrid Plus Control System

2020

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2020

Phillip Creek Compressor Station

Spinning Reserve / Seamless Transition

- Jemena
- 1.5MW/1.5 MWh battery storage
- Microgrid Plus Control System

2021

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2021

Gas Turbine Spinning Reserve

BESS Spinning Reserve Project

- Rio Tinto, WA
- 45MW/12MWh battery storage VSM
- Integrating to Network Manager

2022

Darwin Kathrine BESS

NT High Spec. VSM BESS

- Territory Generation, NT
- 35MW/35MWh battery storage VSM
- E-mesh power management

Technology evolved from solving Power System Stability rather than Energy Conversion.

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Grid Edge Solutions Global Footprint

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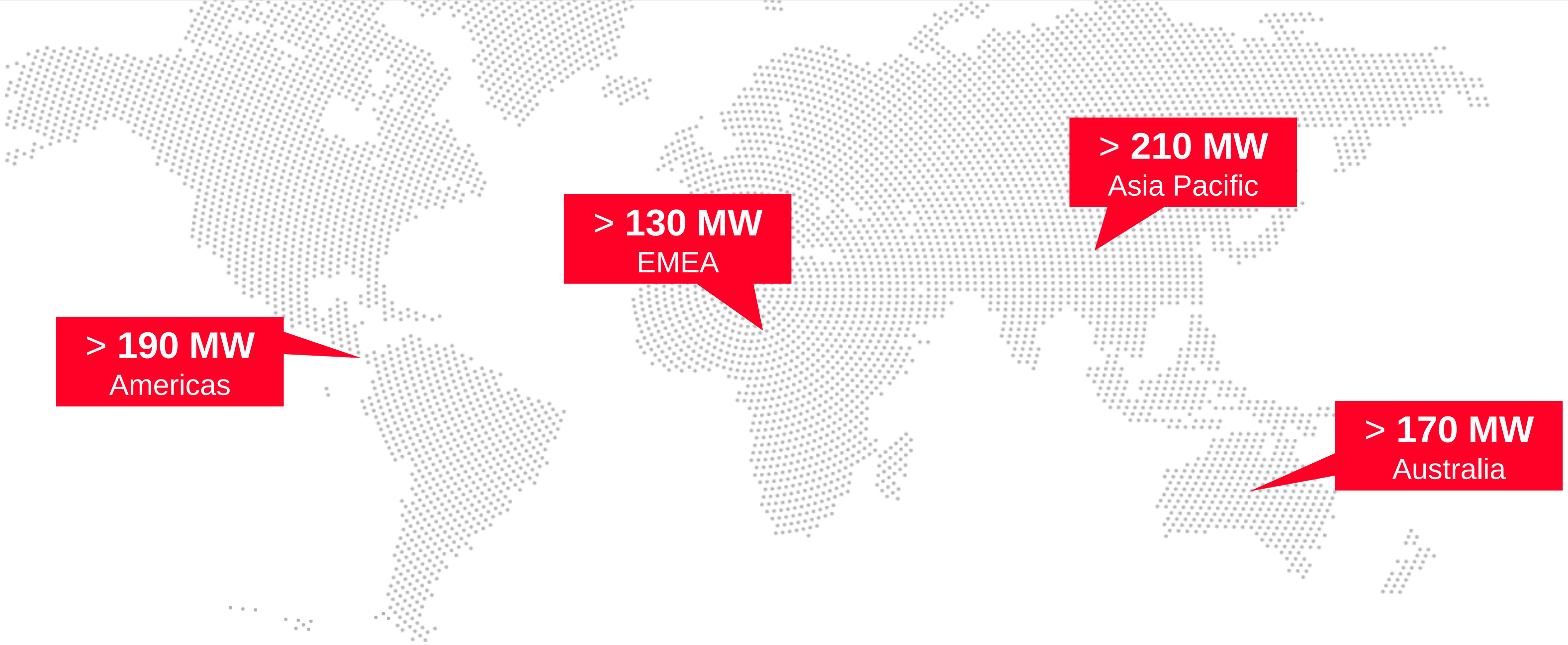
CUSTOMER CHALLENGES

Energy autonomy, reliability and resiliency; new economic opportunities; and effectively manage on increased portfolio of distributed energy resources (DERs).

CUSTOMER OUTCOMES

- ✓ Improved reliability and resiliency
- ✓ Reducing energy cost & CO_2
- ✓ Unlocking new revenue streams
- ✓ Maximizing renewable integration

Grid Edge Solutions Regional references



GLOBAL FOOT/PRINT

220+ Projects delivered worldwide

30+ Years of experience

700+ MW of microgrids and BESS installed base

90+ Countries supported with Service and Sales organizations

VALUE PROPOSITION

e-mesh™ portfolio is a scalable, vertically integrated digital ecosystem managing & optimizing energy at all levels with wide range of applications from the field to the boardroom, on cloud and on premises.

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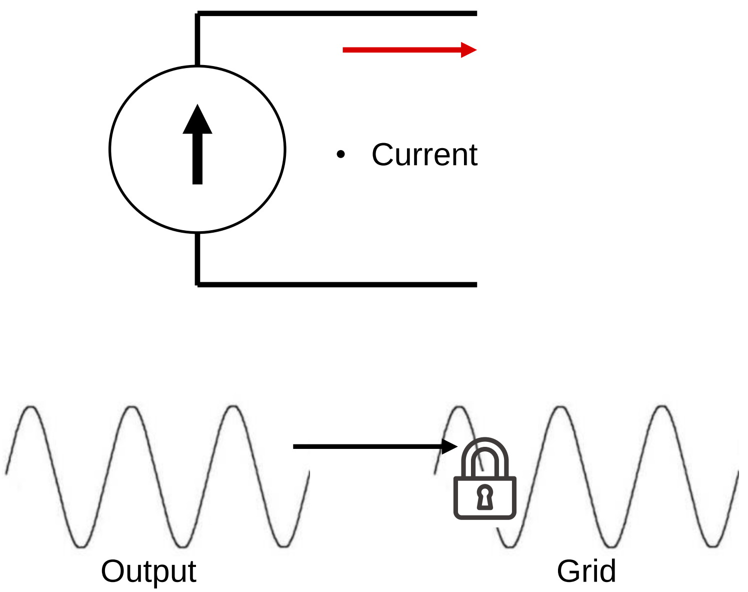
How PowerStore digitally stabilizes grids

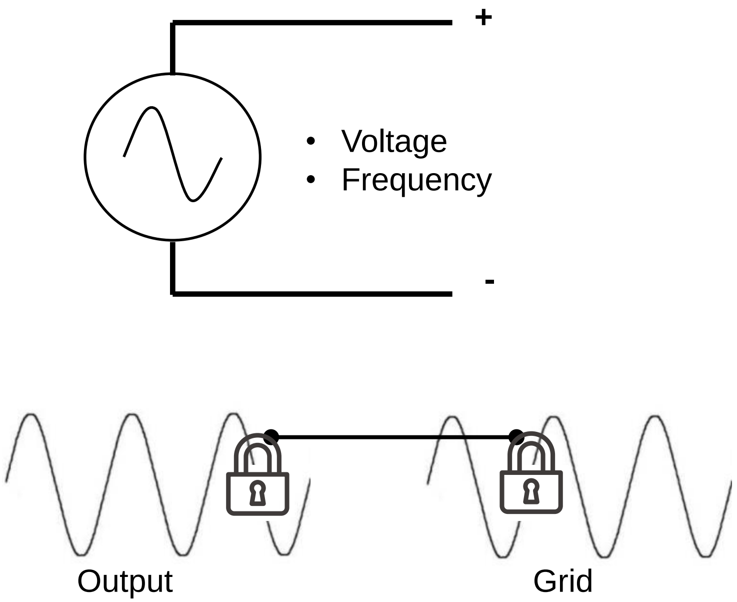
Grid following (GFL)

Current Source Inverter (CSI)



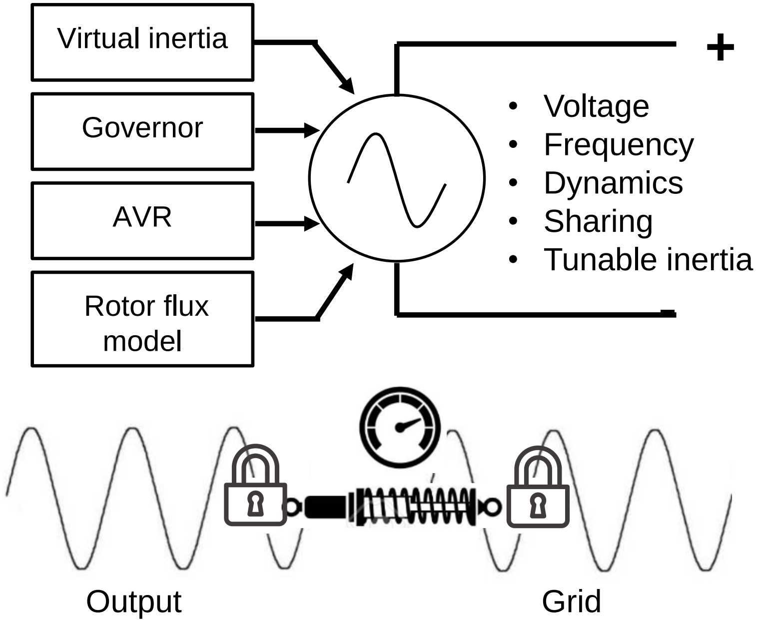
Grid forming (GFM)

Voltage Source Inverter (VSI)



Virtual Synchronous Machine (VSM)

PowerStore GFM BESS in VGM



The key to stabilizing grids and unlocking new revenue streams is digital automation and smart controls intelligently applied to grid forming (GFM) converters

Monetized Virtual Synchronous Machine **S**ervices (today)

No	Service Functions	Description	ISO/RTO/NEM	Microgrid (0.1-10 MW)
1	**S**inewave	Voltage Harmonic Filtering		$
2	**S**ystem Strength	Strengthen Weak Grids		$
3	**S**tatic Inertia	Inherent frequency support		$$$
4	**S**hort Circuit Current	Activating Protection System		$$$
5	**S**ystem Restoration	Energizing network sections		
6	**S**tarting from black	Blackstarting a dead bus		$$
7	**S**tabilising frequency (fast)	Fast Frequency Response		$$
8	**S**tabilising frequency (reserve)	Contingency Frequency Support	$$	$$
9	**S**tabilising frequency (regulation)	Secondary Frequency Regulation	$	$
10	**S**upport Voltage	Voltage regulation		$
11	**S**tandalone Operation	Grid reference for islanded Operation		$$$
12	**S**eamless Transition	Disconnection and reconnection of network sections without interruption		$$$

ISO = Independent System Operator (USA), RTO = Regional Transmission Operator (USA), NEM = National Electricity Market (Australia)

Monetized Virtual Synchronous Machine **S**ervices (future?)

No	Service Functions	Description	ISO/RTO/NEM	Microgrid (0.1-10 MW)
1	**S**inewave	Voltage Harmonic Filtering	?	$
2	**S**ystem Strength	Strengthen Weak Grids	$$	$
3	**S**tatic Inertia	Inherent frequency support	$$	$$$
4	**S**hort Circuit Current	Activating Protection System	$$	$$$
5	**S**ystem Restoration	Energizing network sections	?	
6	**S**tarting from black	Blackstarting a dead bus	?	$$
7	**S**tabilising frequency (fast)	Fast Frequency Response	$$	$$
8	**S**tabilising frequency (reserve)	Contingency Frequency Support	$$	$$
9	**S**tabilising frequency (regulation)	Secondary Frequency Regulation	$	$
10	**S**upport Voltage	Voltage regulation	?	$
11	**S**tandalone Operation	Grid reference for islanded Operation		$$$
12	**S**eamless Transition	Disconnection and reconnection of network sections without interruption	?	$$$

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VSM References

Inertia, Strength, and Security for Grids

Virtual Synchronous Machines & BESS in Australia

Hitachi Energy has over 200MVA operating or in construction since 2014

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Goodwyn (Woodside)

- 2.8MVA/1.43MWh VSM
- Offshore Platform
- Commissioned 2019

DK BESS (TGen)

- 35MVA/35MWh VSM
- NT
- Commissioning 2023

Northstar/Soloman (FMG)

- 30MVA/8MWh VSM &
- 20MVA/5MWh VSM
- NWIS/Private Network
- Commissioning 2022

Newman (Alinta)

- 35MVA/8MWh VSM
- NWIS/Private Network
- Operating since 2017

Kalbarri (Western Power)

- 5MVA/2.5MWh VSM
- SWIN
- Operating since 2021

Tom Price (Rio Tinto)

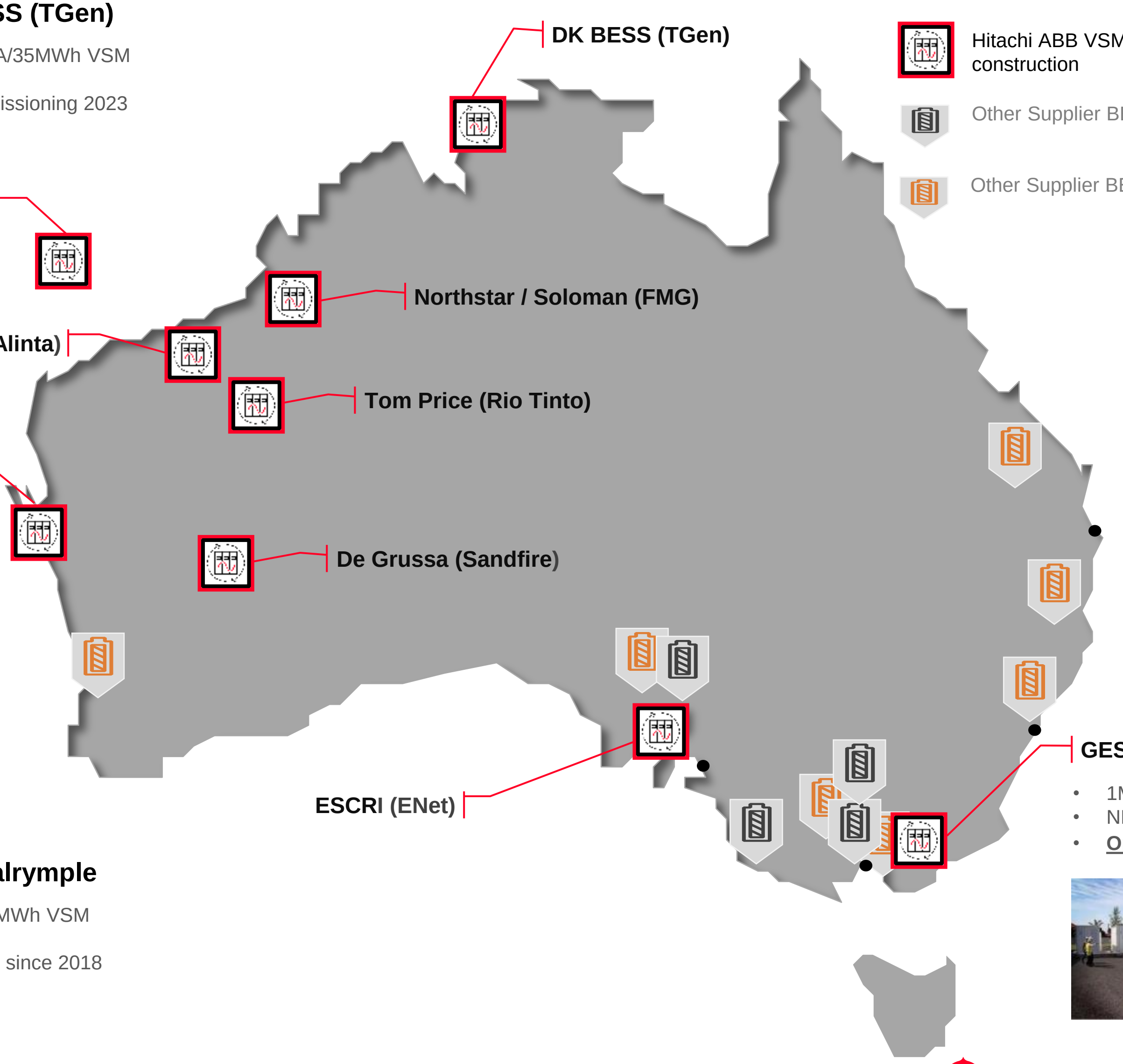
- 45MVA/12MWh VSM
- Private Network
- Commissioning 2022

De Grussa (Sandfire)

- 6MVA/2MWh VSM
- Private Network
- Operating since 2017

ESCRI/ Dalrymple

- 37MVA/8MWh VSM
- NEM
- Operating since 2018



GESS (AusNet)

- 1MVA/1MWh VSM
- NEM
- Operating since 2014

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Dalrymple substation: Unplanned Islanding

Sequence of events

Pre-event conditions

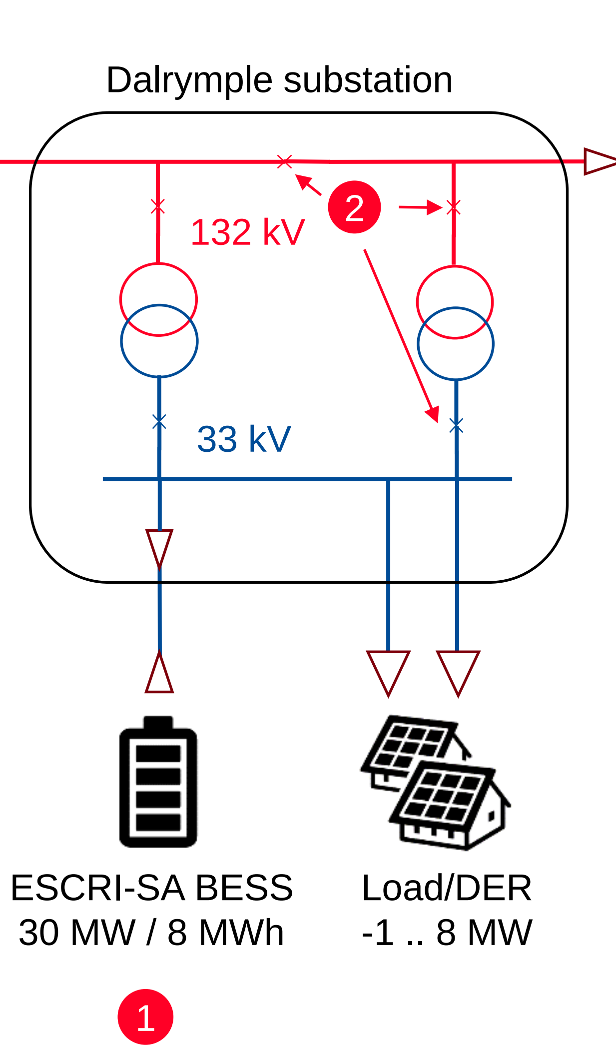
- Wind farm offline
- BESS running unloaded on the NEM
- Local load ~ 4 MW
- All breakers closed

Event

1 132 kV breaker at the upstream substation opens

1 BESS becomes the only grid forming source in the now islanded microgrid and instantaneously supplies the area

2 Some 80 msec later the protection system at Darlymple disconnects the upstream line



Wattle Point Wind Farm 91 MW

BESS and Dalrymple substation

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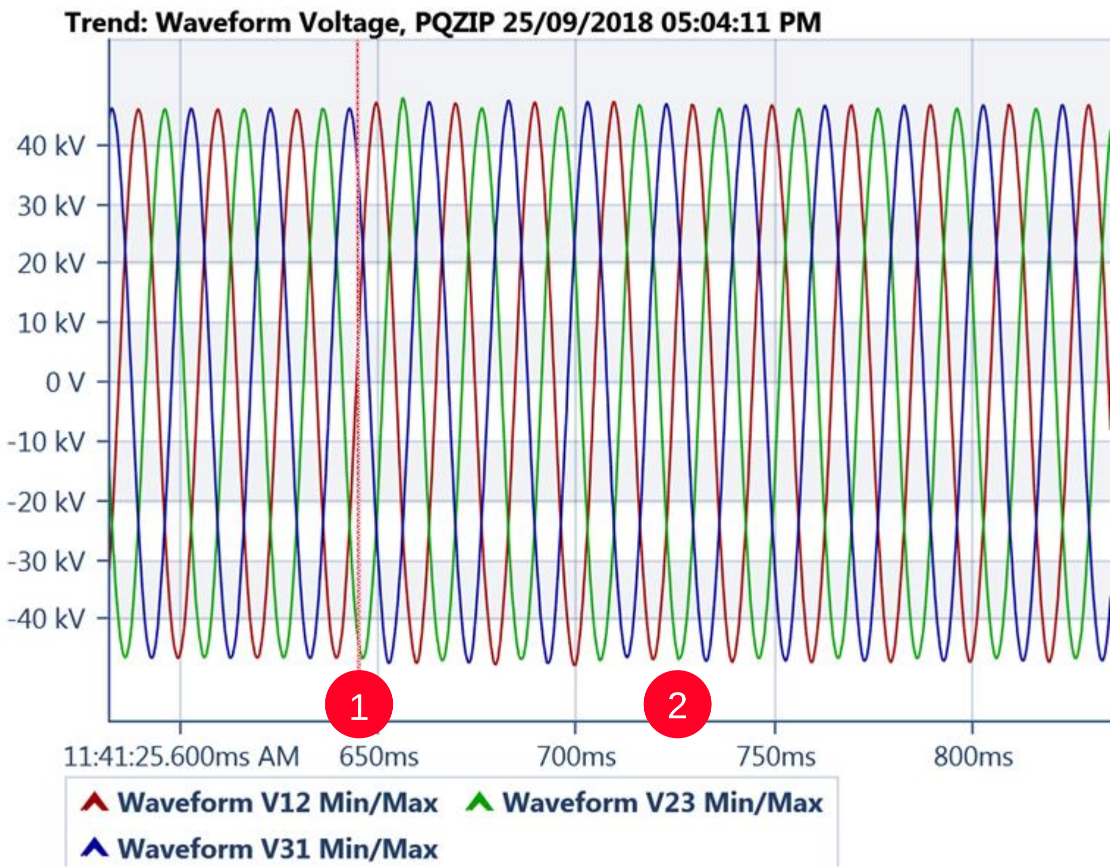
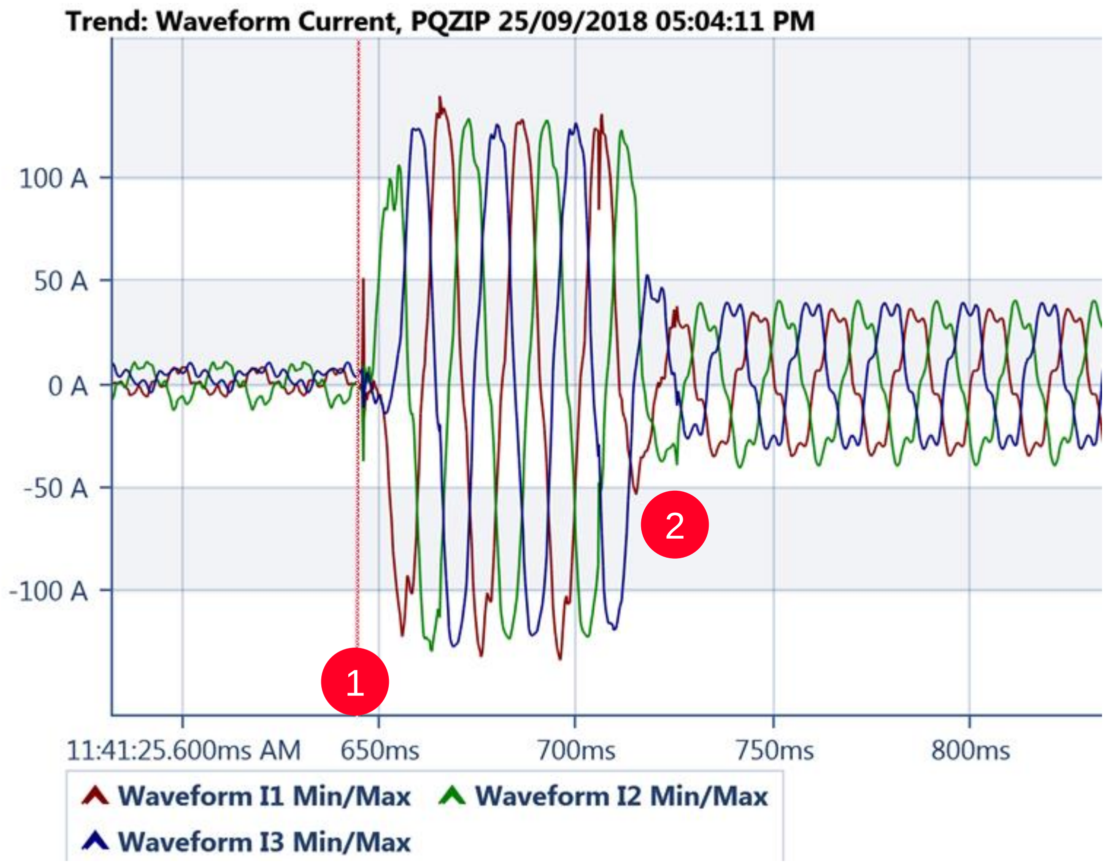
ESCRI/Dalrymple: Unplanned Islanding

The islanding instant – BESS voltage and current waveforms

1 132 kV breaker at upstream substation opens = islanding takes place

2 Upstream line is disconnected





Misconception: Dalrymple BESS does not switch modes from grid connected to islanded – it is always Grid Forming

South Australia Islanding Event: Inertia Response

VSM responds to frequency change prior to high-speed data recorder

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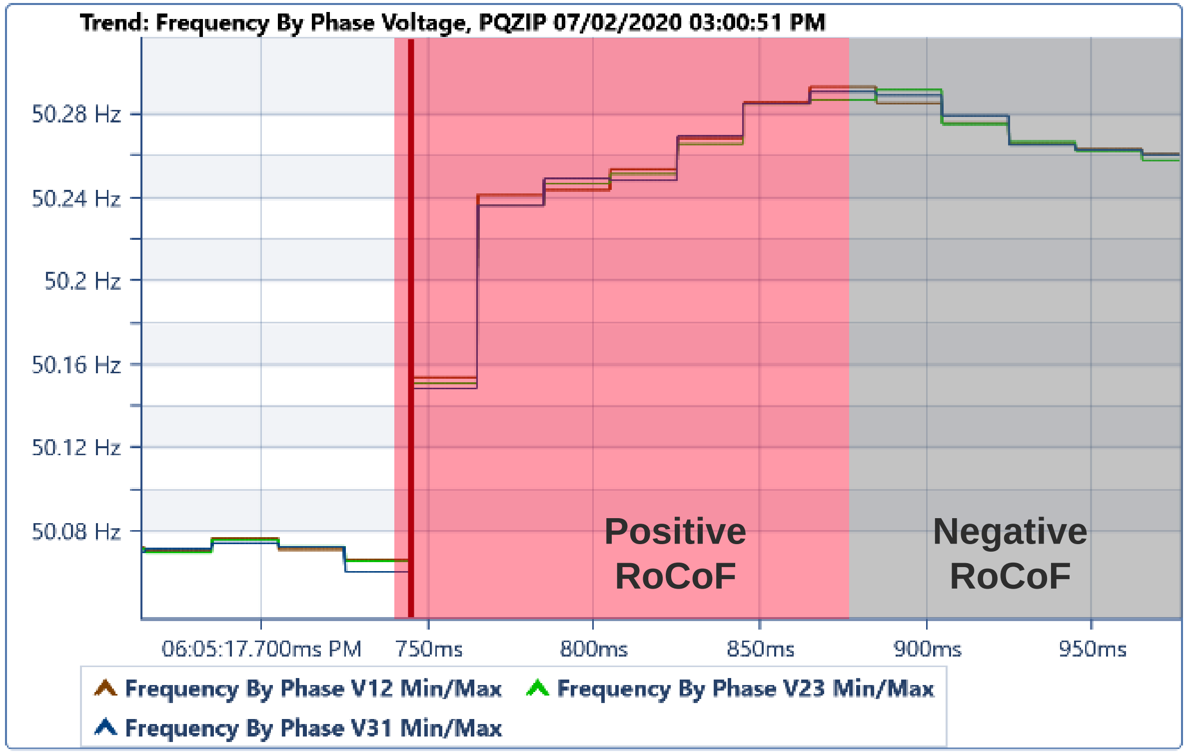
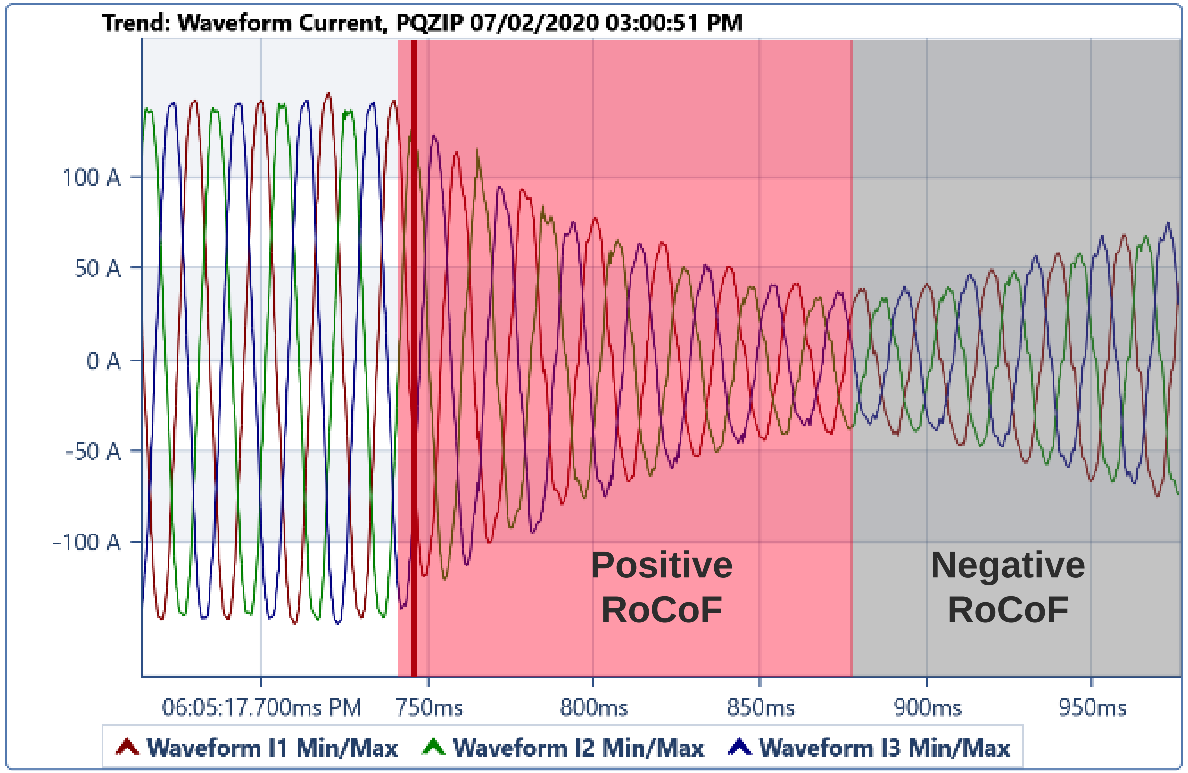
Frequency Measurement by high speed data recorder over 300ms



VSM Response – Current responds prior to frequency measurement (red vertical line) and the output (below) mirrors the grid frequency (left) as it resists the change in frequency



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Selected NAM projects – from small/isolated to large-scale systems

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2003

Gas Turbine Spinning Reserve

Ni-Ca Battery Storage System

- Golden Valley Electric Association
- 40MW / 10MWh battery storage
- Outages reduced by over 60%

2014

RE integration

Li-ion Battery Storage System

- Southern Cal Edison
- 8MW / 32 MWh
- Contingency support, V support

2019

Gull Bay Microgrid

Solar Diesel Storage System

- Gull Bay First Nations community
- 300kW / 555 kWh BESS
- 300kW Solar PV; 1 x 450kW,250 kW,180kW Diesel

2019

Cordova Microgrid

Hydro Diesel Storage System

- Cordova Electric Cooperative
- 1MW / 1MWh
- 2 MW diesel generator; 7.5 Hydro

2021

SnoPUD Arlington Microgrid

Solar EV Diesel Stabilizing System

- Snohomish Public Utility District
- 1MW / 1MWh
- V2G; Grid stabilization; RE integration; RE back-up

2021

Magens Junction Microgrid

Storage + PV + CHP System

- E-Finity
- 500 kW / 820 kWh
- Power quality & RE integration

Transitioning towards inverter-based grid by leveraging Microgrids know-how

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Key Takeaways

Summary

- **Virtual Synchronous Machines (VSM) are a proven technology to run grids on renewables.**
  - **VSM is the new grid**
- **VSM's have been successfully operating for over a decade**
- Hitachi Energy, the partner of choice and lowest risk option
  - Installed first Australian NEM connected VSM in 2014
  - First large-scale VSM registered on the NEM in 2018 (perhaps in the world)
  - Executed more than 200MW VSM projects globally

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