โครงการเพิ่มพูนความรู้ให้กับสมาชิกผ่านสมาคมวิชาชีพ
โดยคณะอนุกรรมการส่งเสริมความร่วมมือกับสมาคมวิชาชีพวิศวกรรม สภาวิศวกร

Grid Edge Solutions

Enabling the Future of Energy

สมาคมไฟฟ้าและพลังงานไอทริปเปิลอี (ประเทศไทย)

Dr. Praditpong Suksirithawornkul
IEEE Senior Member, Cigre Member
Senior Professional Engineer, Council of Engineers

สมาคมไฟฟ้าและพลังงานไอทริปเปิลอี (ประเทศไทย)

IEEE Power & Energy Society (Thailand)

IEEE Power & Energy Society (PES) develops standards and empowers the development of technology, software, and best practices in all areas of electric power and energy including generation, transmission, distribution and utilization to provide a reliable, resilient, safe, cost-effective and sustainable AC and DC electricity supply system to the end-user. PES focuses on current power system infrastructures and technological advancements in energy resources, smart grid and smart cities for the betterment of society.

https://www.ieeepes-thailand.org


IEEE PES
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Thailand Chapter
“การเดินทางสู่การเปลี่ยนแปลงทางดิจิทัลในภาคพลังงานนั้น
เราจะไม่เป็นเพียงแค่ผู้ตั้งรับความเปลี่ยนแปลง แต่จะต้องเป็นส่วนหนึ่ง
ของการกำหนดทิศทาง และเปลี่ยนแปลงตัวเราเอง เพื่อส่งต่อคุณค่าให้กับสังคม
และพัฒนาคุณภาพชีวิตของประชาชนให้ดีขึ้นในทุก ๆ วัน”
“Our journey to digitalization in energy sector is the excitement
that we are not only the defenders of change, but also the part of setting
the direction and disrupting ourselves to contribute value to the society
and improve people’s quality of life to be better every day.”
Mr.Wilas Chaloeysat (Govenor, Metropolitan Electricity Authority)
Chairman, IEEE Power & Energy Society (Thailand)

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Founded 1963

38
Other IEEE Societies

IEEE PES
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Global Regions

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GRID EDGE

IEEE BigData

IEEE BLOCKCHAIN™

IEEE brain

IEEE CLOUD COMPUTING

IEEE CYBER SECURITY

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IEEE Internet of Things

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IEEE Smart Cities

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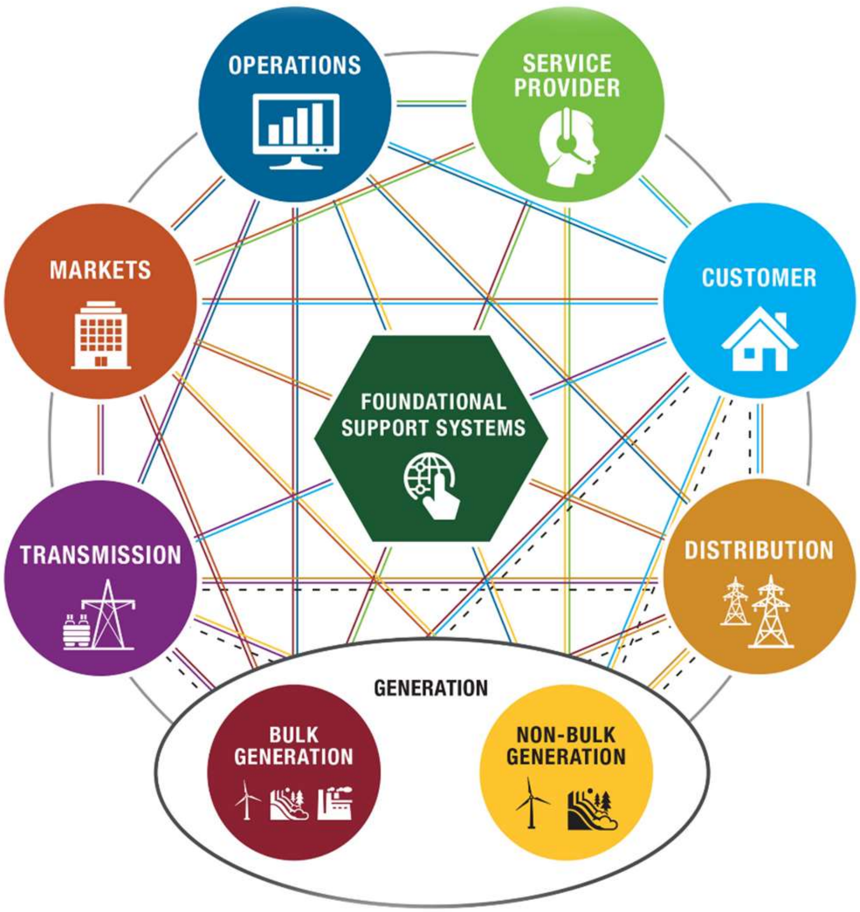

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IAS IEEE Industry Applications Society

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CSS

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The Mission of IEEE Smart Cities:

- To be recognized as the authoritative voice and leading source of credible technical information and educational content within the scope of smart cities identified below.
- To facilitate and promote both the collaborative and individual work of its Member Societies regarding smart city technology.

Our Vision: The IEEE Smart Cities Initiative will bring together IEEE's broad array of technical societies and organizations to advance the state of the art for smart city technologies for the benefit of society and to set the global standard in this regard by serving as a neutral broker of information amongst industry, academic, and government stakeholders.

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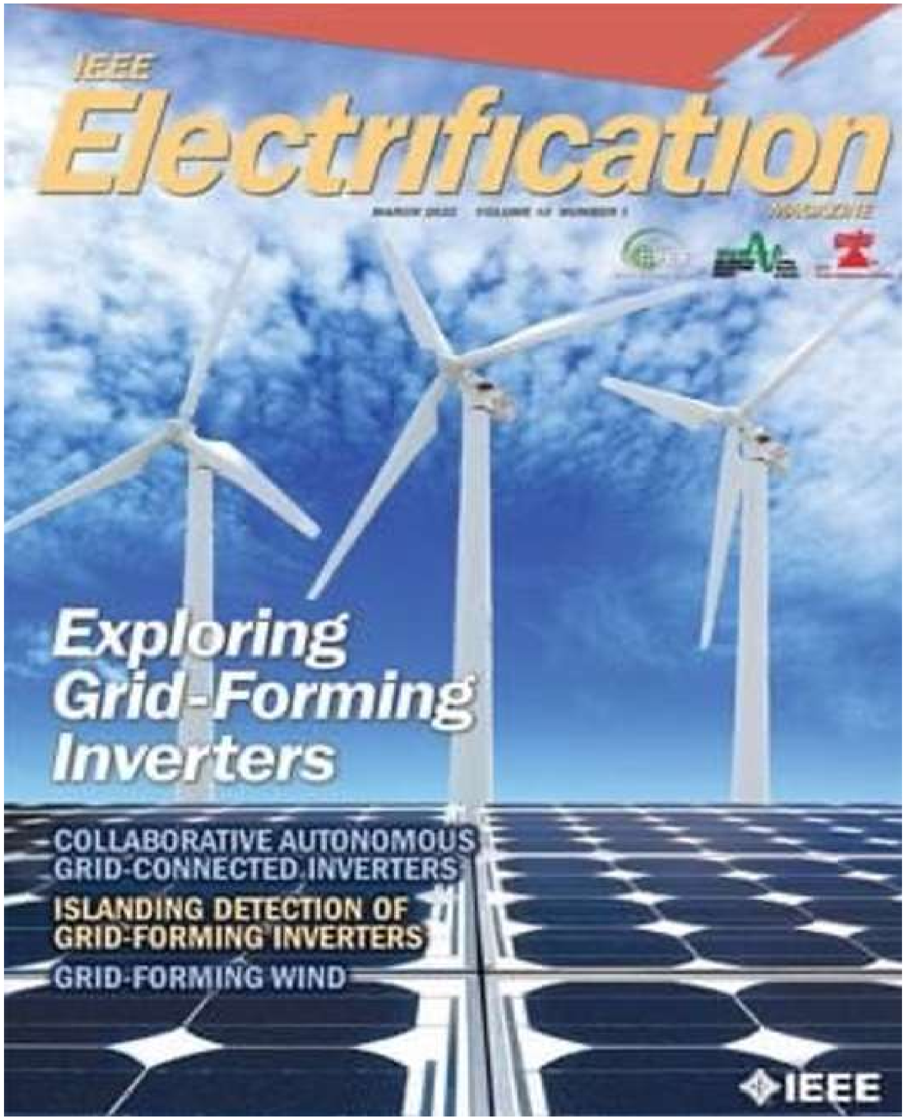


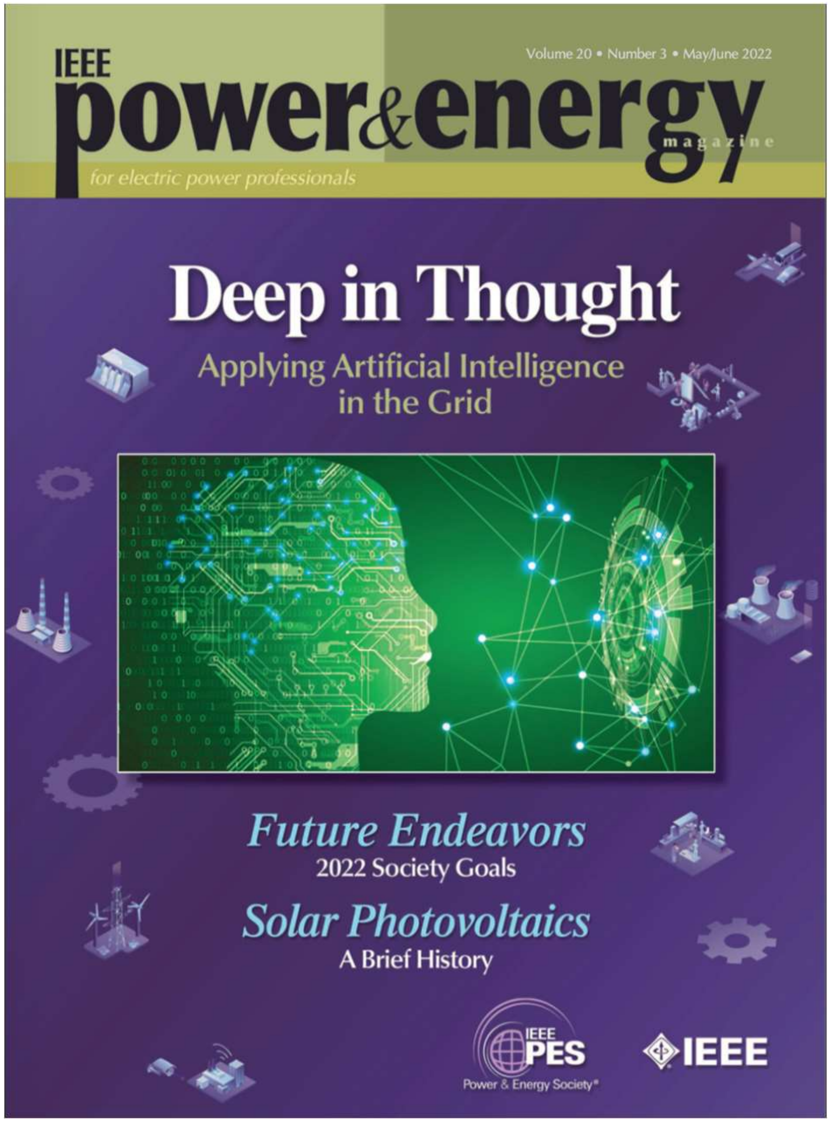


Table of Contents

The World in 2050

Climate change extremely urgent and important to limit global warming to

1.5°C

World population reaches

~10bn

(up from 7.8bn people in 2021)

Global demand for steel is projected to

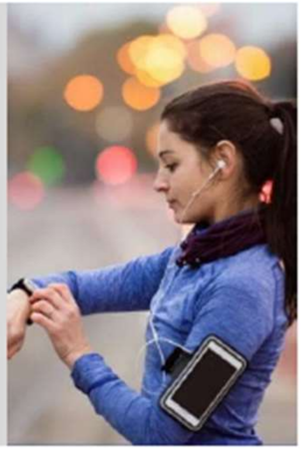
increase

by more than a third through to 2050

Internet of Things expands to

24bn

interconnected devices vs. 10bn connected devices today



Rapid growth in EV sales rises to

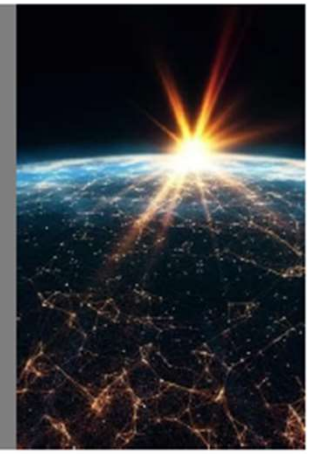
62M

units p.a. globally – up from 6.4M in 2021

Global electrification will be more than

50%

of total energy demand – up from around 20% today



Urbanization increases with

68%

of world population living in cities – up from 55% in 2018

Source : Hitachi Energy

Towards Carbon Neutrality

Carbon Neutrality

Business as usual, leading to further calamity

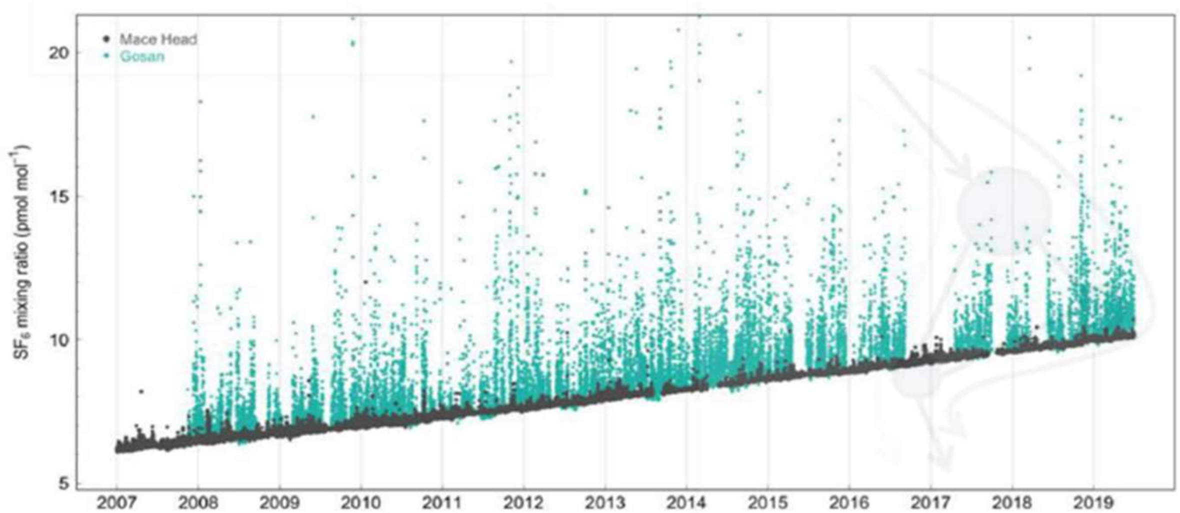
Real opportunities to put the world on a sustainable path

Source : Hitachi Energy

Sulfur Hexafluoride (SF6) - A Greenhouse Gas

SF6 is needed in switchgear but has some **global environmental impact**

Photo: NASA



Sources: IPCC AR6 (2021), Simmonds (2020)

Contribution to warming today	Atmospheric concentration	Annual rise	Quantity in installed equipment
0.22%	10 parts per trillion (260'000 tons)	0.3 parts per trillion (8'500 tons)	200'000 tons

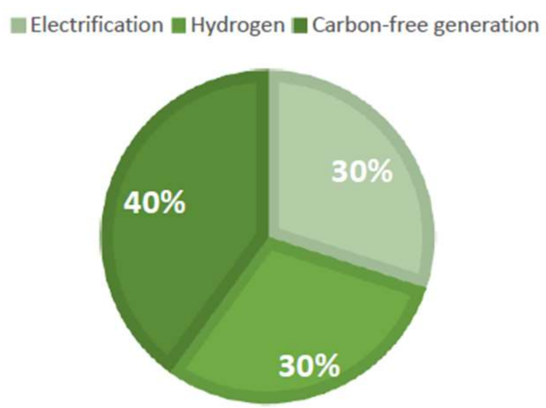
Source : Hitachi Energy

Role of Electrification and H2 in Decarbonizing

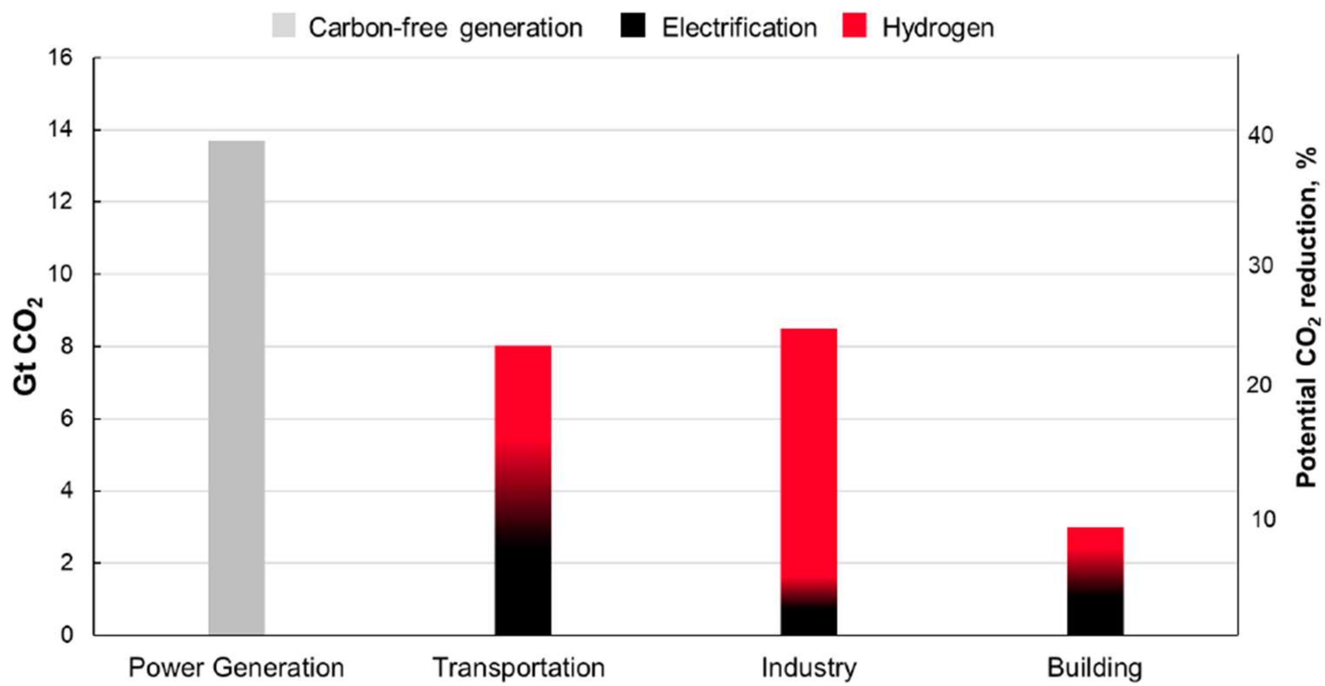
INDICATIVE

Impact on CO_2 emissions

- Electrification of many processes is feasible in most industrial sectors, cutting sectors' emissions by 30%
- Green H_2 used as industrial feedstock or fuel for shipping and aviation can further reduce the emissions with 30%



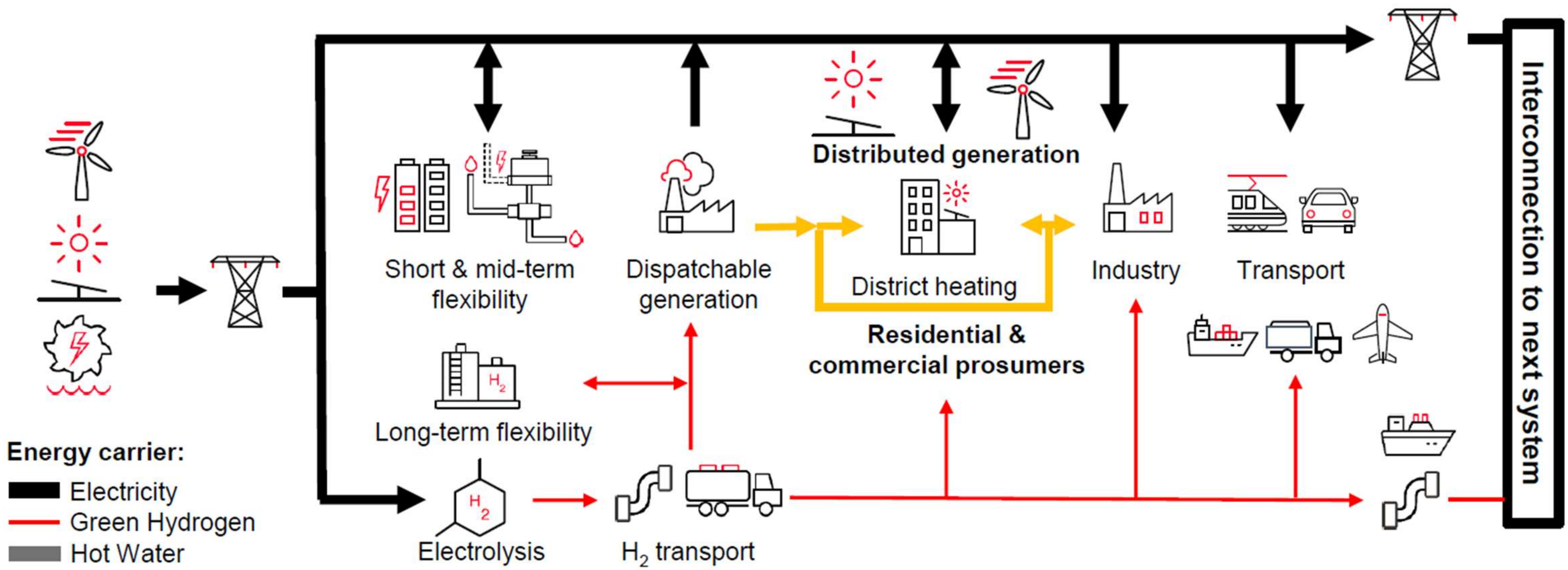
How electrification and H_2 can reduce CO_2 emissions across sectors



Electricity alone might not be enough to fully decarbonize

Source : 1: Focusing on potential of electrification and hydrogen to fully reduce CO2 emissions – not considering alternatives such as biofuels, nor considering increased power use and efficiency gains Source: HAPG Power Systems of the Future

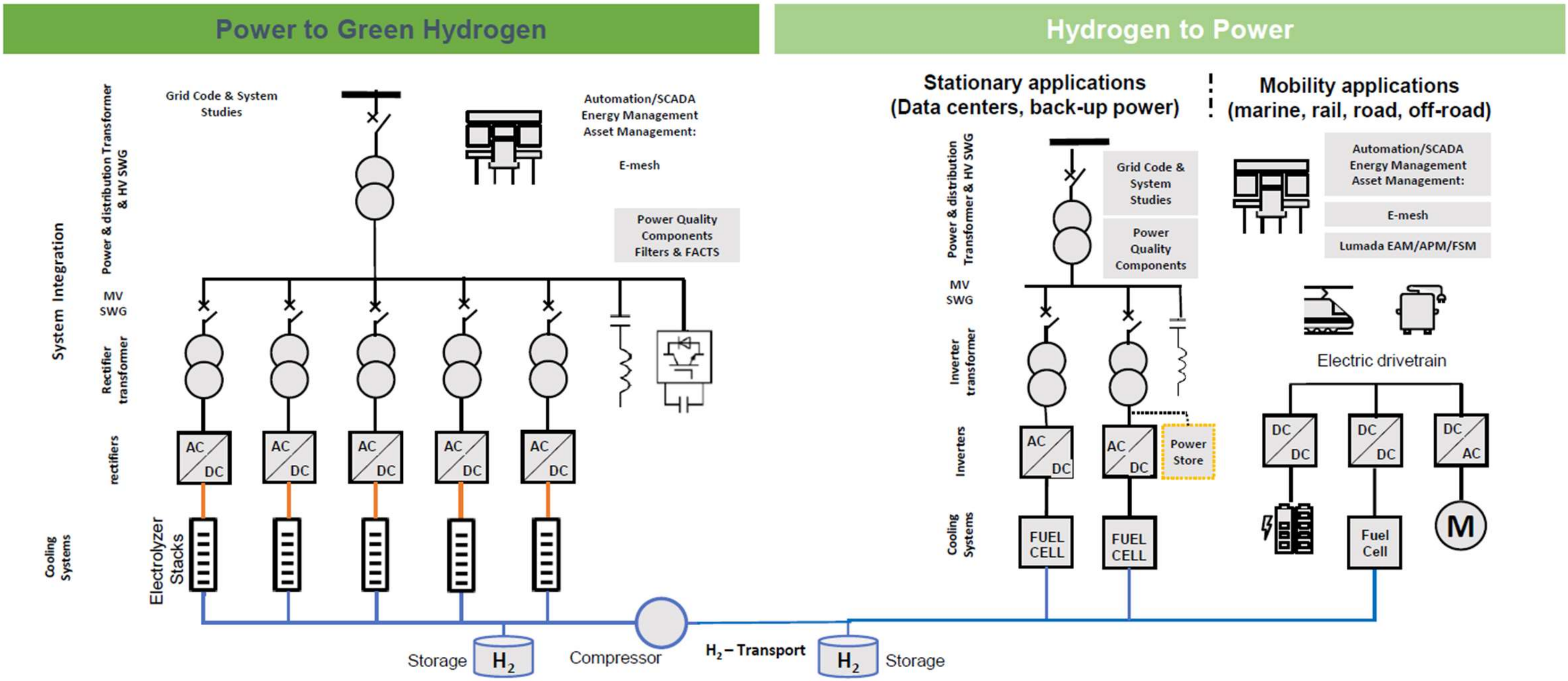
Towards a Carbon-Neutral Energy System



"Any energy unit will have been electrical at least once – electricity will be the backbone of the entire energy system."

Source : Hitachi Energy

Green Hydrogen Connection Challenges



Source : Hitachi Energy

Large-scale eMobility – Market Dynamics
eMobility is moving to mainstream

E-mobility will need a lot of clean electricity…

e-cars:
- **33%** of global car fleet to be electric by 2040
- **559 million EVs** on the road by 2040
- **551 TWh** by 2040[1]

e-buses:
- **80%** of global municipal bus fleet to be electric by 2040
- **2.3 million e-buses** on the road globally by 2040[1]
- **1,500TWh** by 2040[2]

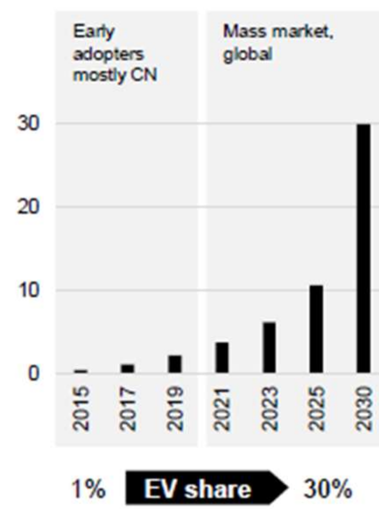
e-trucks:
- **15%** of global truck sales by 2030
- e-trucks: **1,000TWh** by 2050[3]

e-trains:
- As of 2014, ~25% of world's rail lines were electrified
- In North America, only 1% of rail lines were electrified[4]

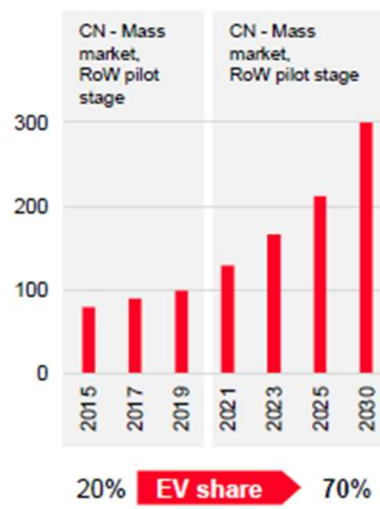
World Electricity Production[5] in 2018 ~26'000 TWh

…as it moves mainstream

New e-car sales, millions



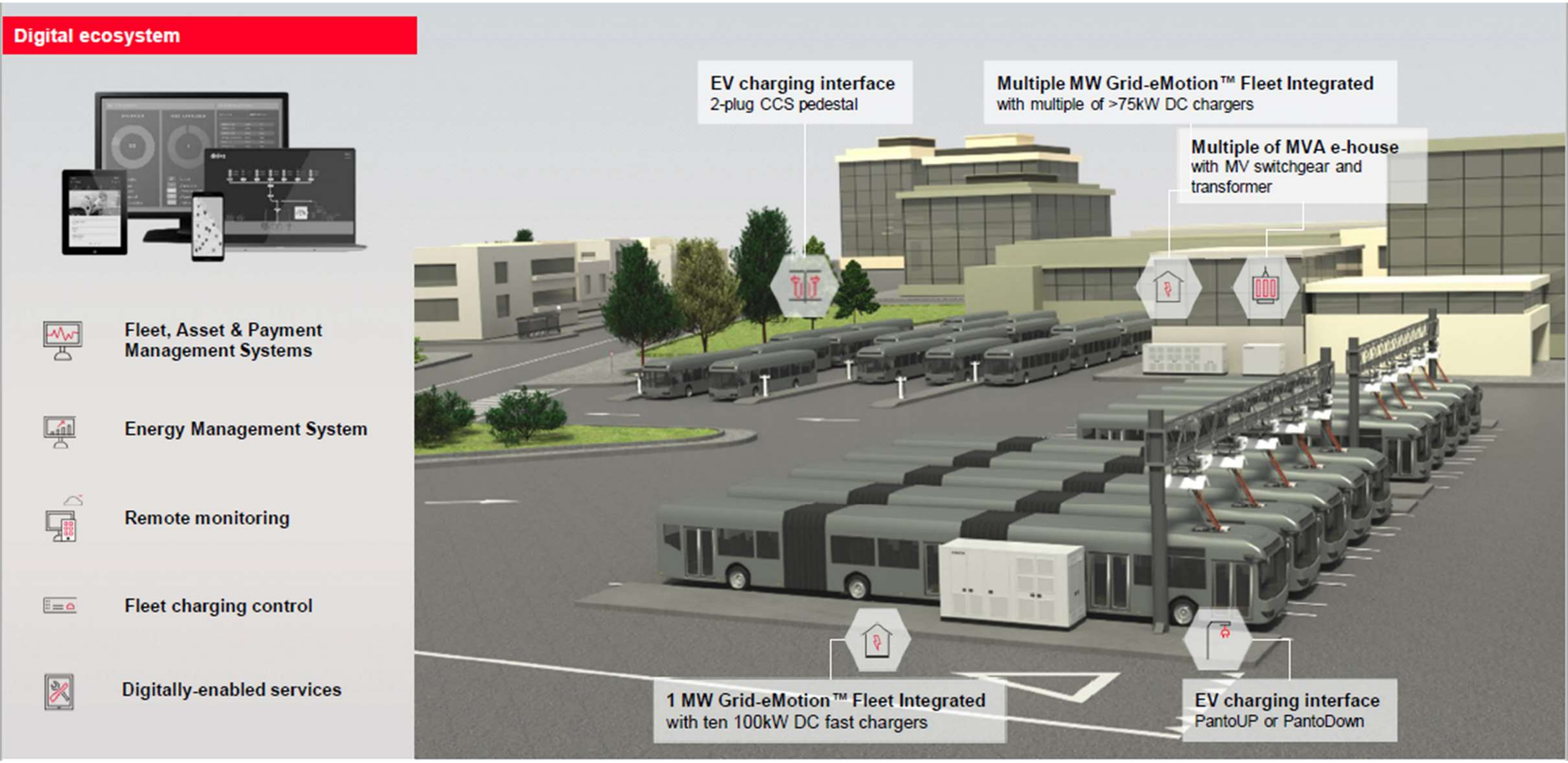
New e-bus sales, thousands



Coupling of eMobility with the energy sector is around the corner

1 – Electric Vehicle Outlook 2018, Bloomberg NEF, 2018
2 - https://www.bloomberg.com/professional/blog/eBuses-surge-even-faster-evs-conventional-vehicles-fade/
3 - https://www.mckinseyenergyinsights.com/insights/new-reality-electric-trucks-and-their-implications-onenergy-demand/
4.https://www.sci.de/fileadmin/user_upload/presse/pdf_downloads/Press_Release_Railway_Electrification.pdf
5 - https://yearbook.enerdata.net/electricity/world-electricity-production-statistics.html

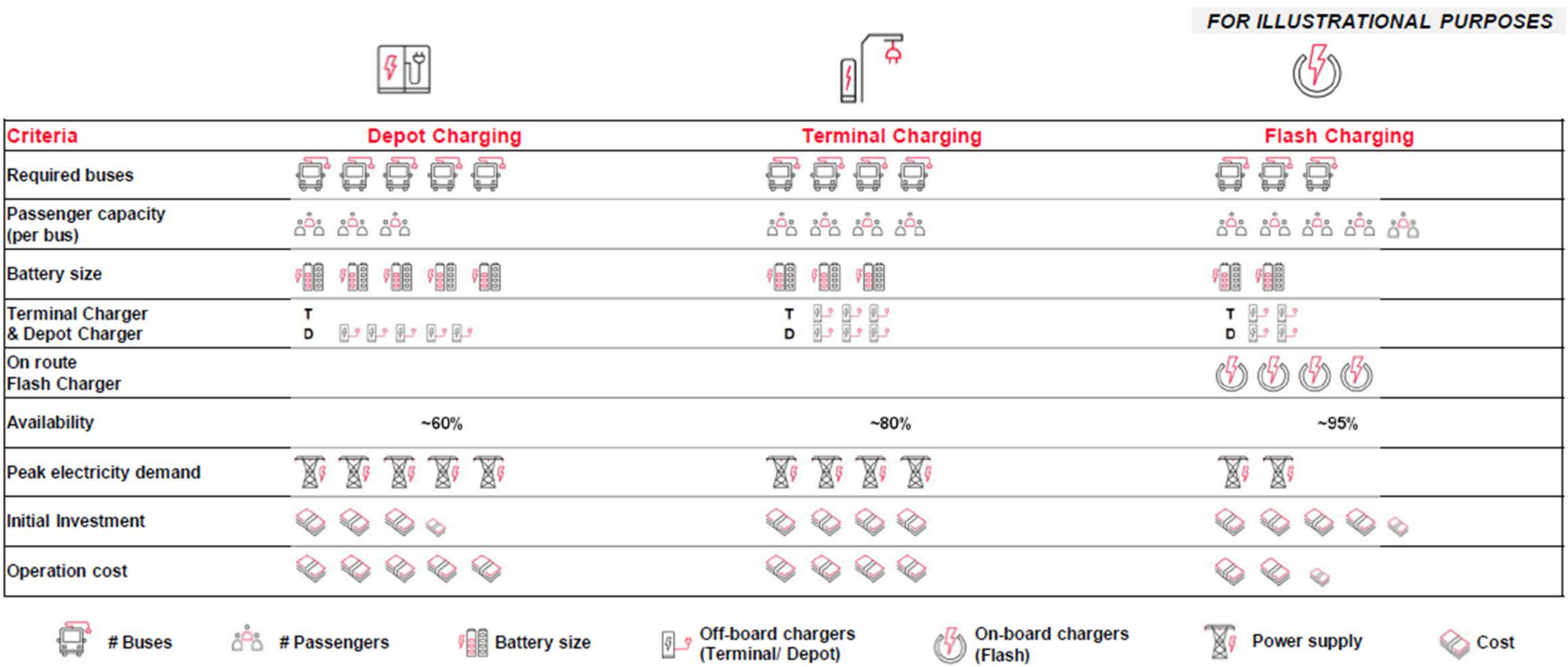
Large-scale eMobility – Technology Trends
Backbone elements for large-scale electrification



Source : Hitachi Energy

Large-scale eMobility – Technology Trends

Charging strategies

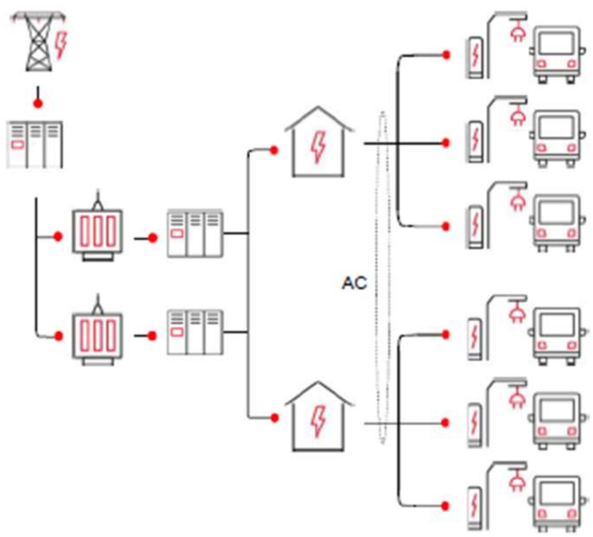


Source : Hitachi Energy

Large-scale eMobility – Technology Trends

From AC to DC electrification for scale-up

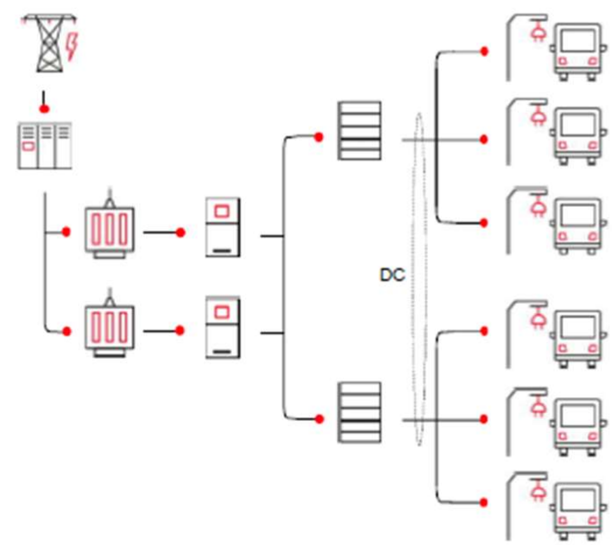
From AC distribution grid



Additional burden: MV/LV substation

Chargers with Plugs

To DC distribution (Grid-eMotion™)



Grid

LV or MV Grid Connection with Chargers and Plugs

Up to

60%

Footprint reduction* of EV chargers at site

- ✓ Containerised, fully assembled and tested in controlled environment, ready to install
- ✓ Integrated with SCADA, smart energy management, battery storage or solar
- ✓ Reduced cabling, interface complexity
- ✓ Lighter installation at parking places
- ✓ Improved reliability, availability and maintainability
- ✓ Less site work, less project delay risk

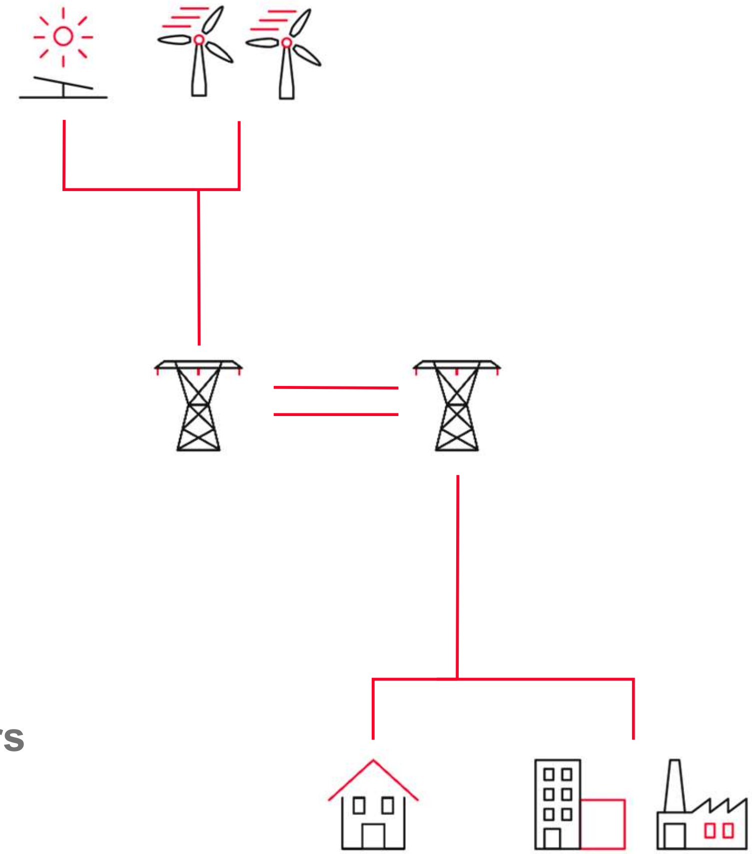
As scales grow to MW grid connection, reconsider your charging system strategy

Source : Hitachi Energy

New Energy Ecosystem

New energy ecosystem

Generation mix



Renewable share: ~40% of capacity by 2035

Greater volatility, less predictability

More feed-in nodes

Power transmission and distribution

Increasing complexity

Control/ information flow is key value driver

Transmission: Longer distances, higher voltages

Consumers and prosumers

Growth in distributed energy resources

Control & optimization at “local” level

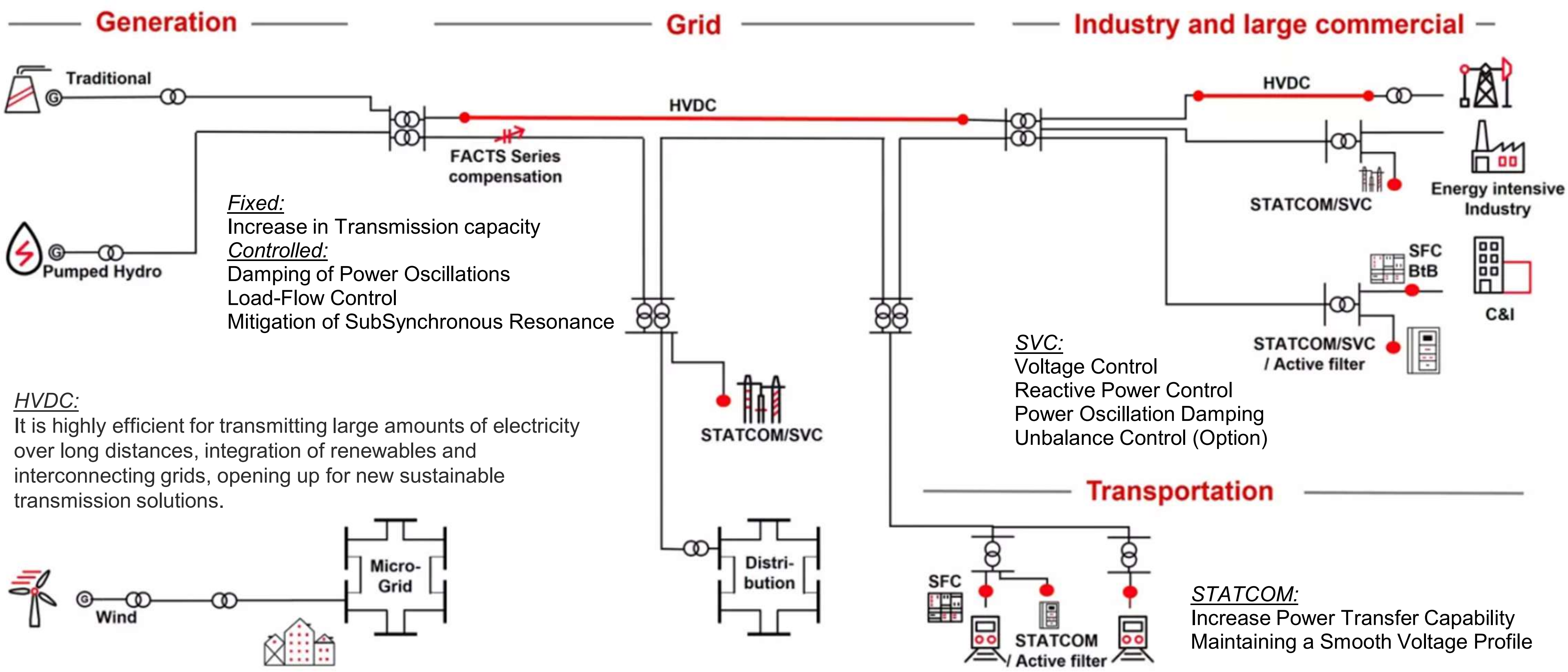
Customer profile change from static to dynamic

Maximum value extraction & flexibility from distributed assets

Big shift in the electrical value chain

Source : Hitachi Energy

Power Electronics is unlocking Social Benefits



Fixed:
Increase in Transmission capacity
Controlled:
Damping of Power Oscillations
Load-Flow Control
Mitigation of SubSynchronous Resonance

HVDC:
It is highly efficient for transmitting large amounts of electricity over long distances, integration of renewables and interconnecting grids, opening up for new sustainable transmission solutions.

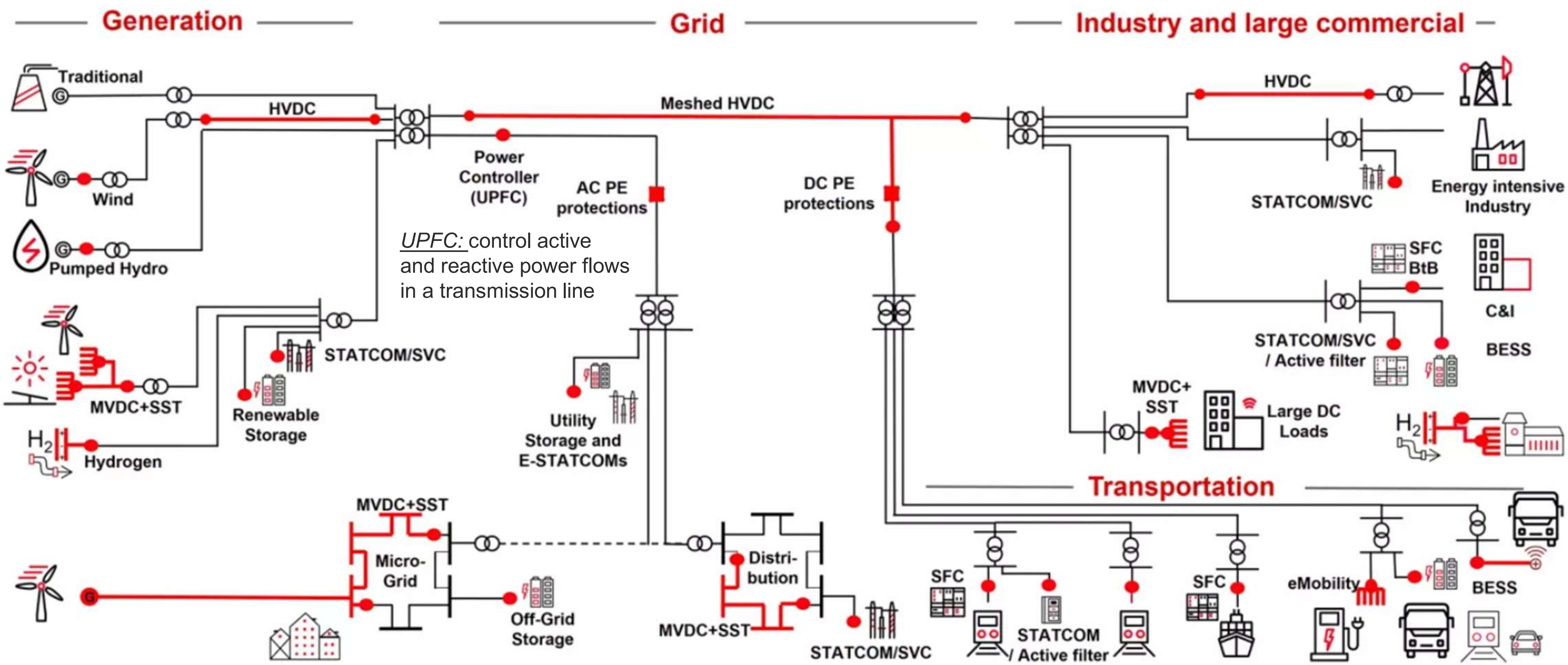
SVC:
Voltage Control
Reactive Power Control
Power Oscillation Damping
Unbalance Control (Option)

STATCOM:
Increase Power Transfer Capability
Maintaining a Smooth Voltage Profile

Power electronics is more relevant today than ever before

Source : Hitachi Energy

70% of electricity is processed by Power Electronics



UPFC: control active and reactive power flows in a transmission line

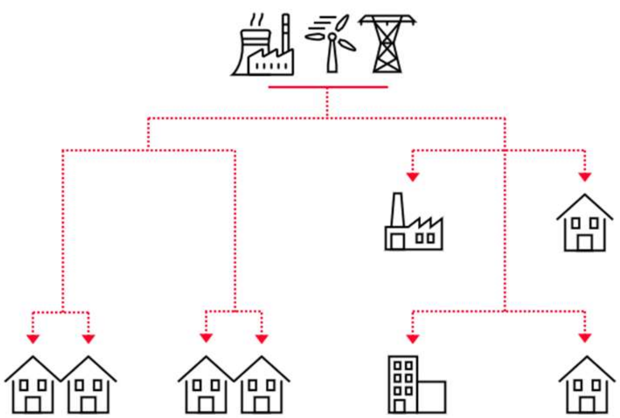
SFC: robust and loss optimized semiconductors ensures highest efficiency for railway

Power electronics is more relevant today than ever before

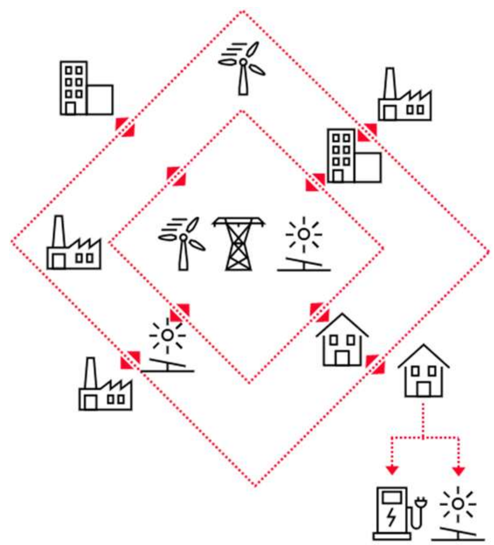
Source : Hitachi Energy

New energy ecosystem

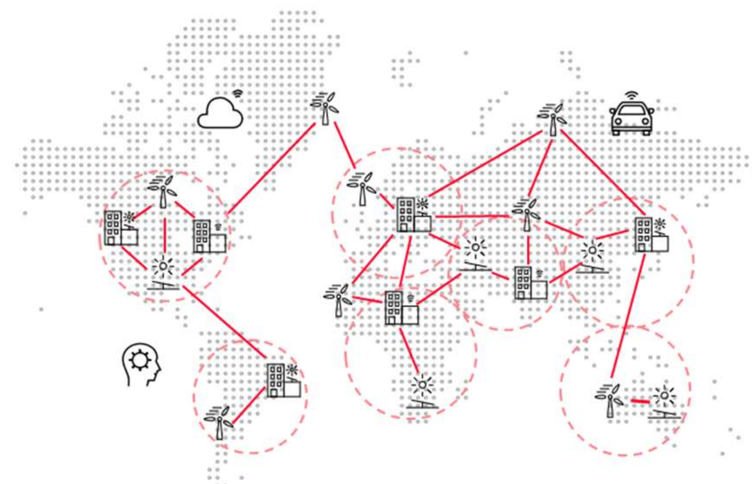
Yesterday



Today



Tomorrow

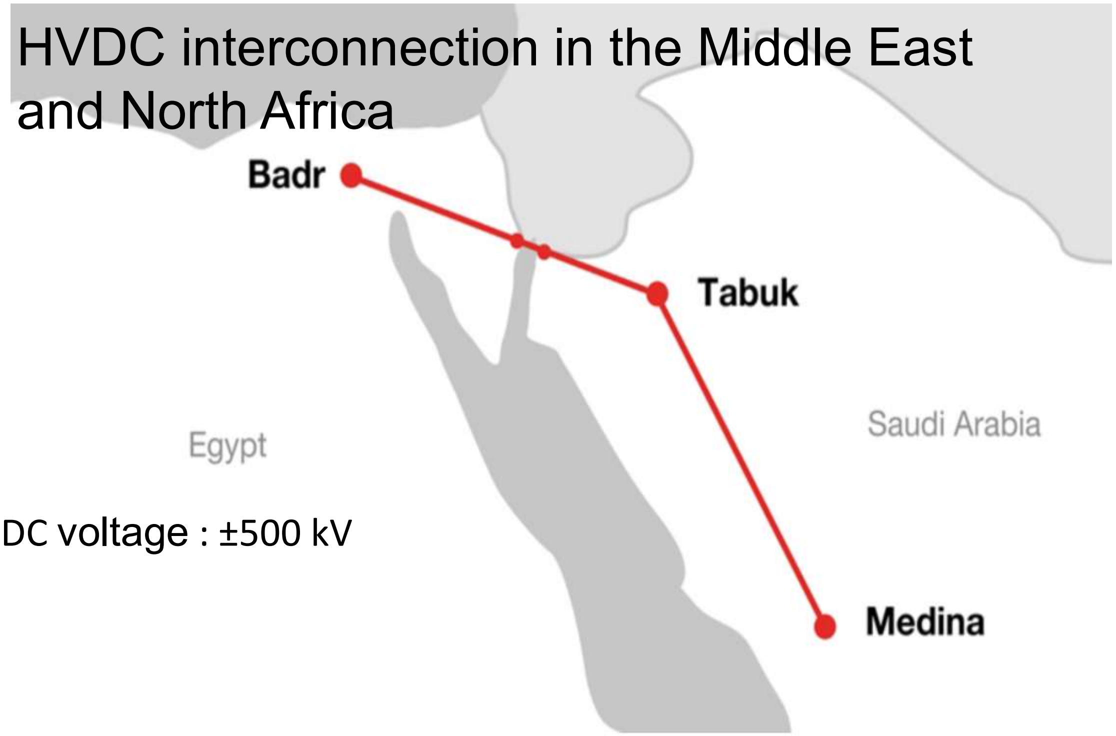


Renewables, grid edge technologies and digitalization drive the evolution of future power systems

Source : Hitachi Energy

New energy ecosystem : Not Tomorrow → But Today

HVDC interconnection in the Middle East and North Africa



DC voltage : ±500 kV

3,000 MW (multi-terminal)
Madinah 2 *1500 MW (Saudi Arabia)
Tabuk 2 *750 MW (Saudi Arabia)
Badr 2 *1500 MW (Egypt)

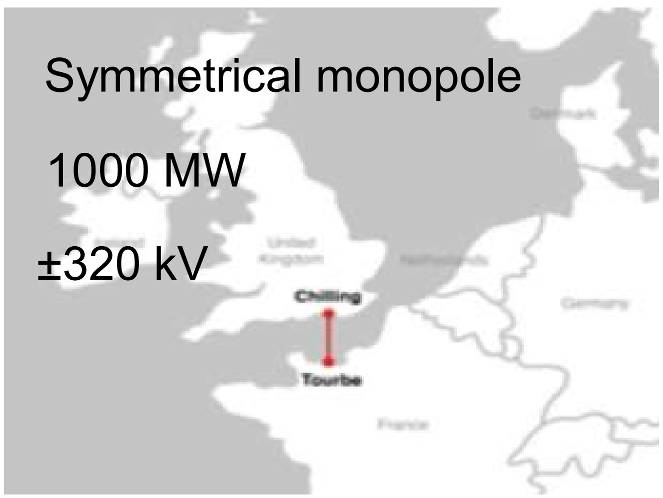
The Kingdom of Saudi Arabia is working to increase the share of natural gas and renewable energy sources to approximately 50% by 2030, and the Arab Republic of Egypt intends to increase the supply of electricity generated from renewable sources to 42% by 2035.

HVDC interconnection in the Middle East and North Africa

The Saudi Electricity Company (SEC) and the Egyptian Electricity Transmission Company (EETC) will benefit by connecting their two grids with strengthening grid resilience, power supply security, optimization of energy production at their power plants and addressing their power consumption peaks by exchanging the surplus power with each other.

New energy ecosystem : Not Tomorrow → But Today

The link between Norway and Germany expand the stable, large-scale integration and exchange of renewable power in the European Union.

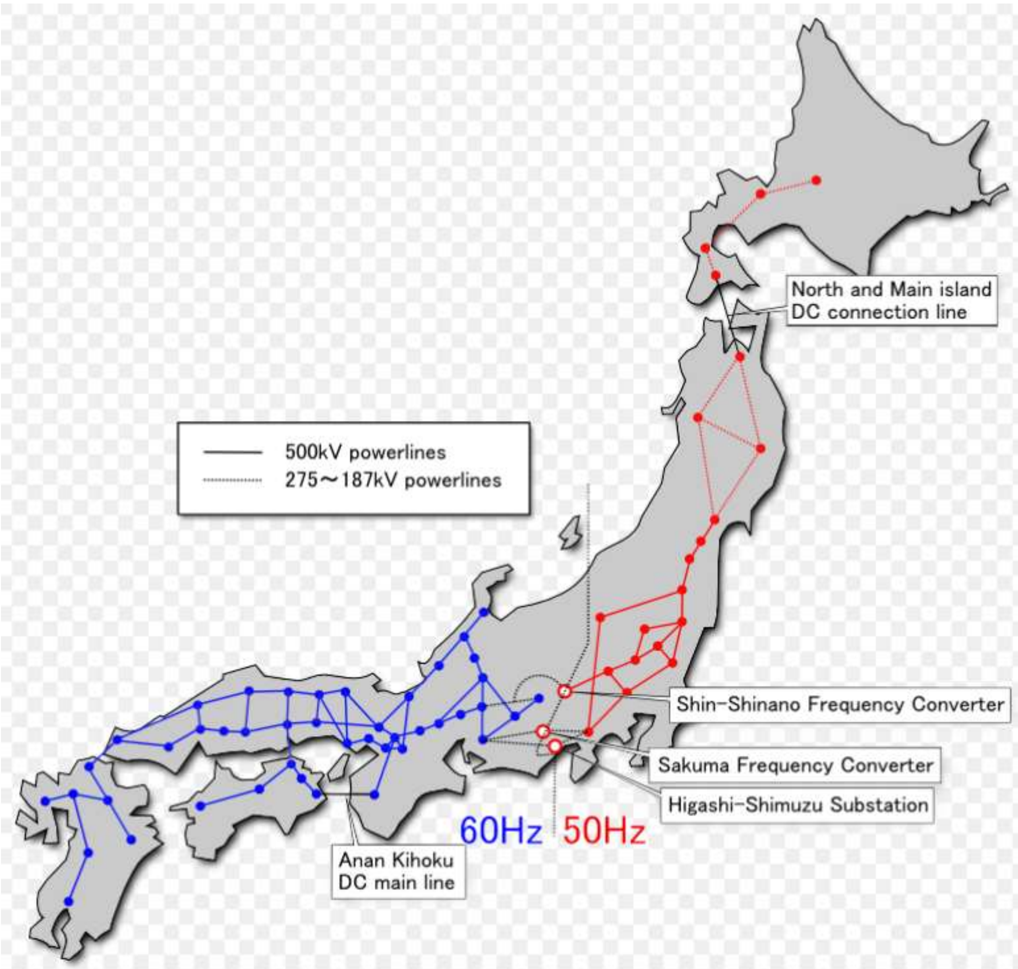


The interconnection of the British and French power networks and strengthens the integration of renewable energy.

HVDC interconnection in the European

Source : Hitachi Energy

New energy ecosystem : Not Tomorrow → But Today



The Higashi-Shimizu project will reinforce the connection between the 50 Hz network in Eastern Japan and the 60 Hz network in Western Japan.

Commissioning year: 2028

Back-to-back

600 MW

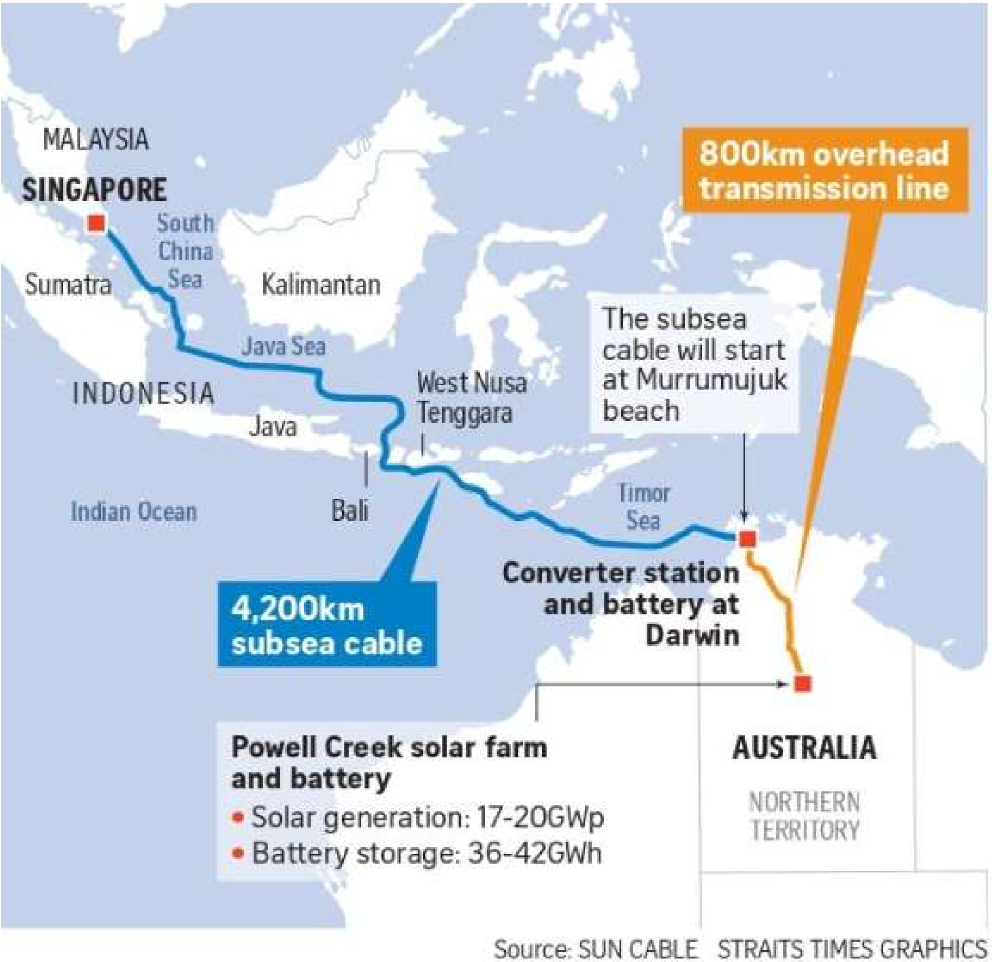
The connection is expected to significantly strengthen and help develop electricity transfer and increase power reliability. It will also enhance integration of the Japanese grid.

HVDC interconnection in the Japan

Source : Hitachi Energy

New energy ecosystem : Not Tomorrow → But Today

Australia-Asia PowerLink, Australia-Singapore



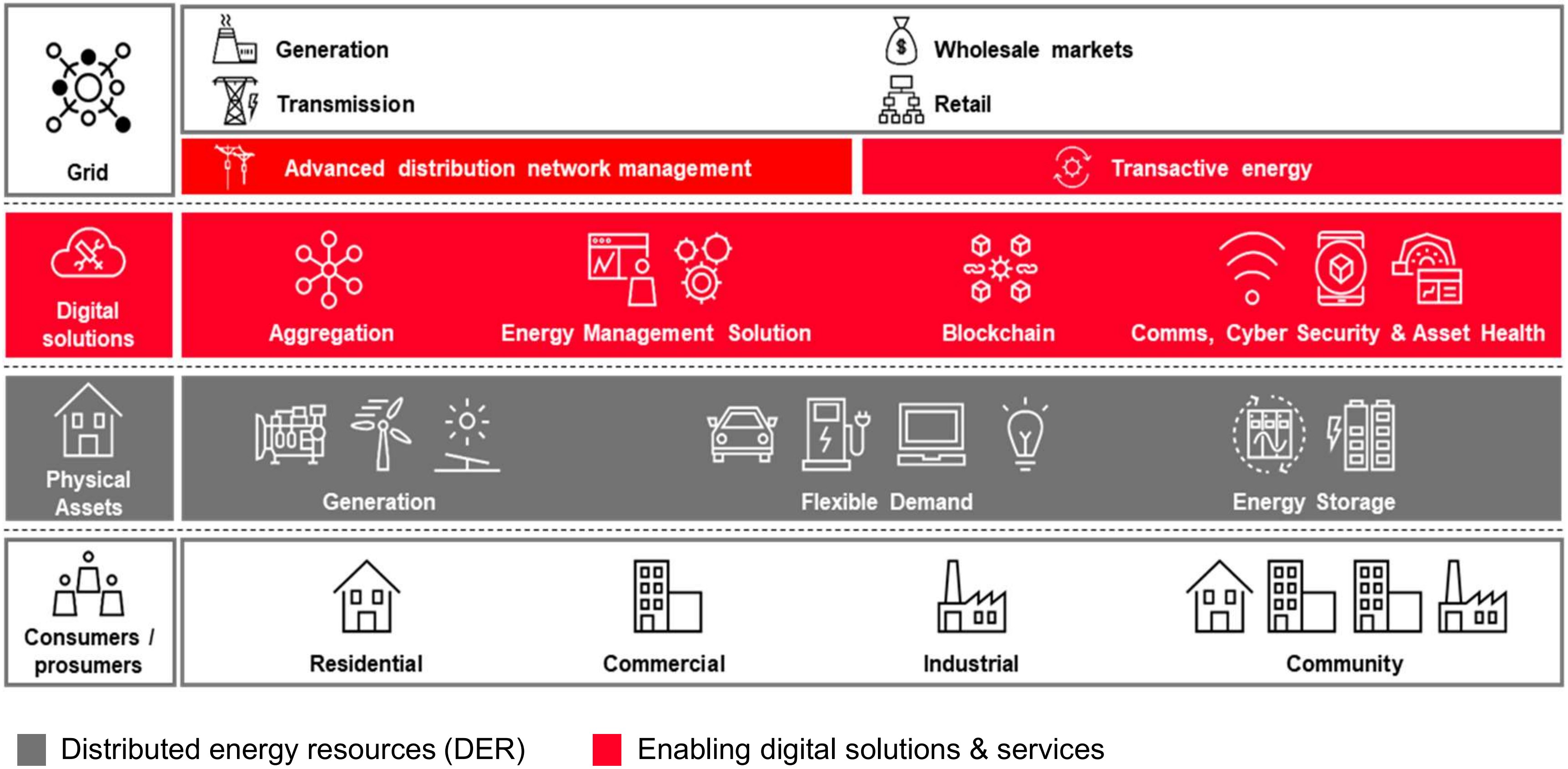
Australia-Asia PowerLink will comprise the world's biggest solar farm and longest undersea power cable.

Source : Sun Cable

HVDC interconnection in the Asia - Pacific

The AAPowerLink project is estimated to involve an investment of A$30bn ($22.54bn). The financial closure for the intercontinental power grid project is expected in the fourth quarter (Q4) of 2023.

New energy ecosystem : Not Tomorrow → But Today



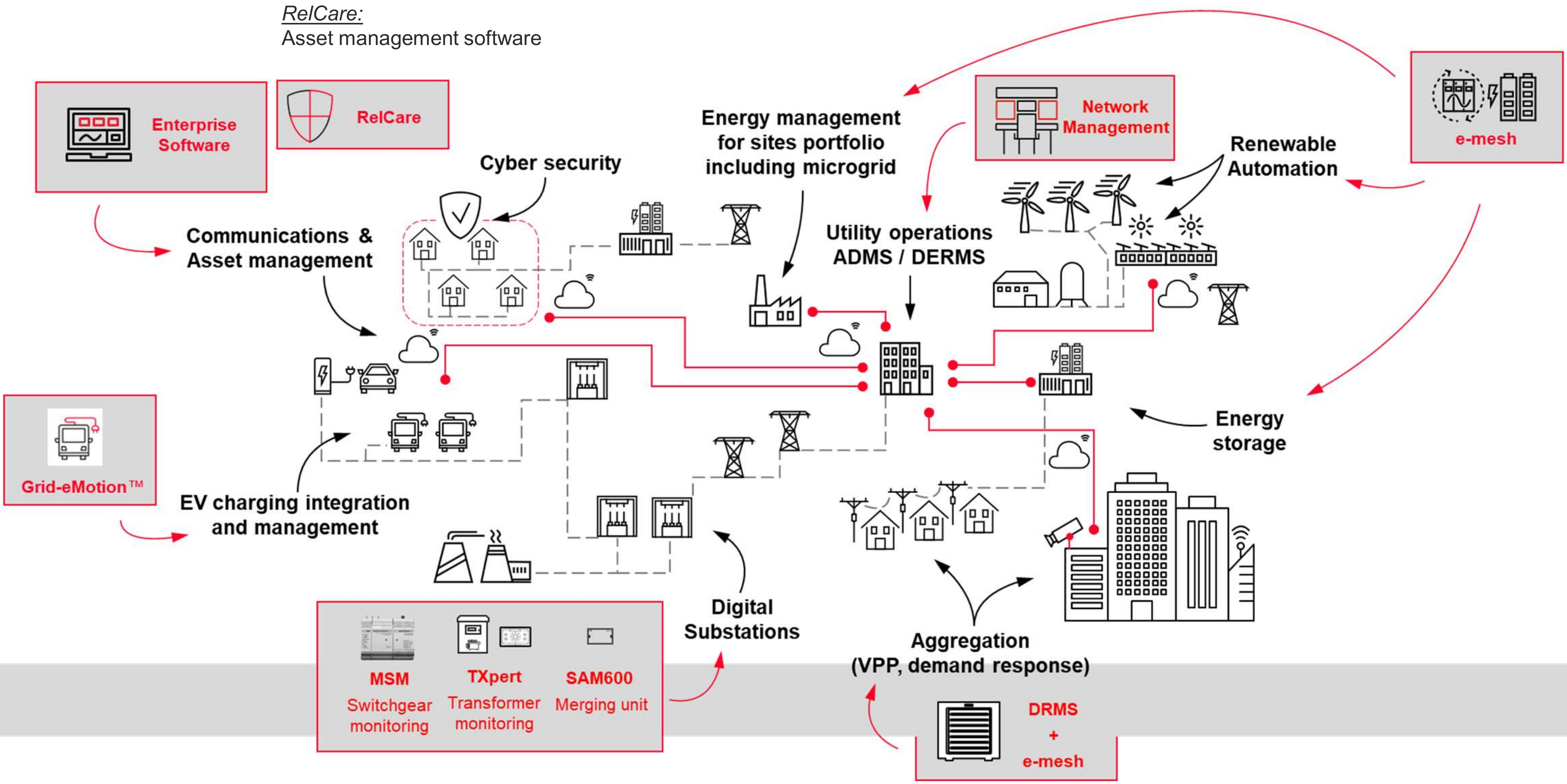
Digital solutions enable:

- Maximized customer value
- System performance optimization
- Grid reliability
- Energy services
- New business opportunities for energy providers

Evolving ecosystem due to growth in distributed capabilities

Source : Hitachi Energy

Grid Edge Solutions : Digital Portfolio



Source : Hitachi Energy

Grid Edge Definition Challenges, Opportunities and New Technologies

Grid Edge Definition

Technologies working near or at the end of electrical grids. The grid edge comprises technologies, solutions and business models supposing the transition toward to a de-centralized, distributed and transactive in electrical grids.

Ref : Grid Edge : Utility Modernization in the Age of Distributed Generation

Technical Report, Magdalena Klemun, Massachusetts Institute of Technology

Grid Edge Challenges

Regulatory challenges

Lack of homogenous standard

- ❑ Standardization in each region have the different details

Business challenges

Engaging the customer at optimal level

- ❑ Allowing customers to select from among an array of energy services

Ref : Grid Edge : Utility Modernization in the Age of Distributed Generation
Technical Report, Magdalena Klemun, Massachusetts Institute of Technology

Grid Edge Challenges

Technological challenges

Interoperability

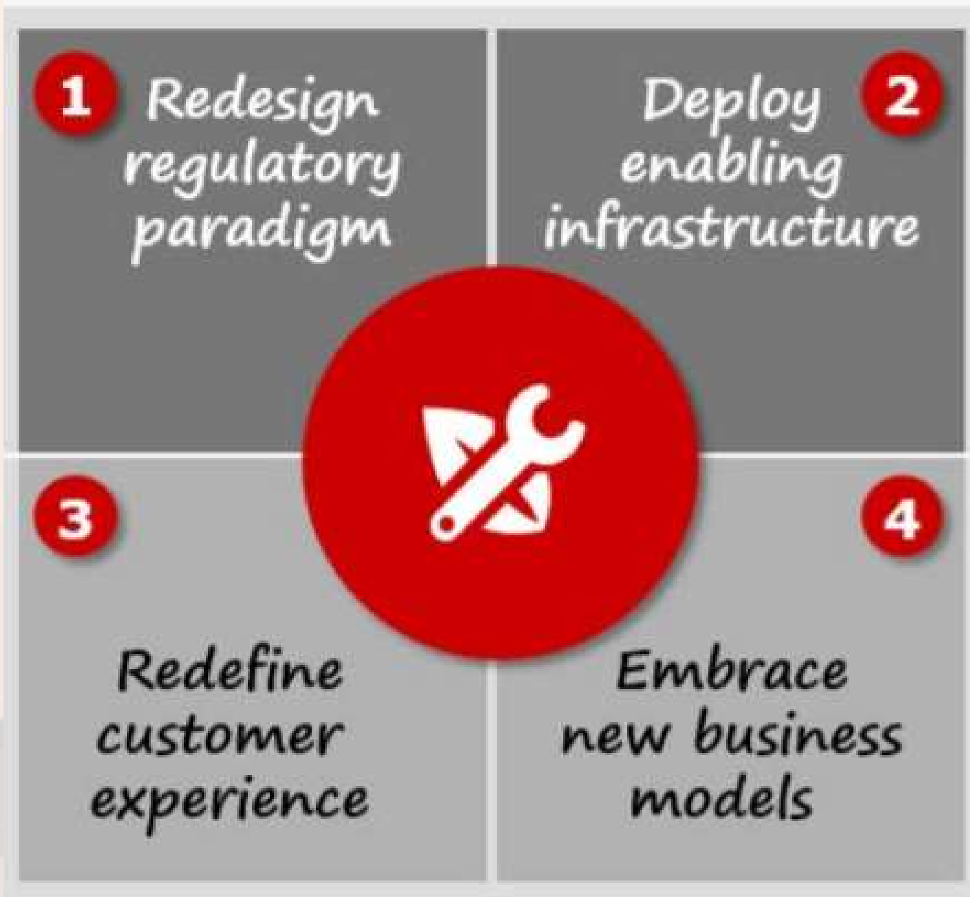
- ❑ Standards for AMI communication
- ❑ Distribution automation interoperability
- ❑ Software integration standards
- ❑ Interconnection standards
- ❑ Standard demand response signals

Large-scale integration of renewable energy

Ref : Grid Edge : Utility Modernization in the Age of Distributed Generation
Technical Report, Magdalena Klemun, Massachusetts Institute of Technology

Grid Edge Actionable Framework

Change the rules of the game, reforming regulation to enable new roles for distribution network operators



Ensure timely deployment of the infrastructure to enable new business models

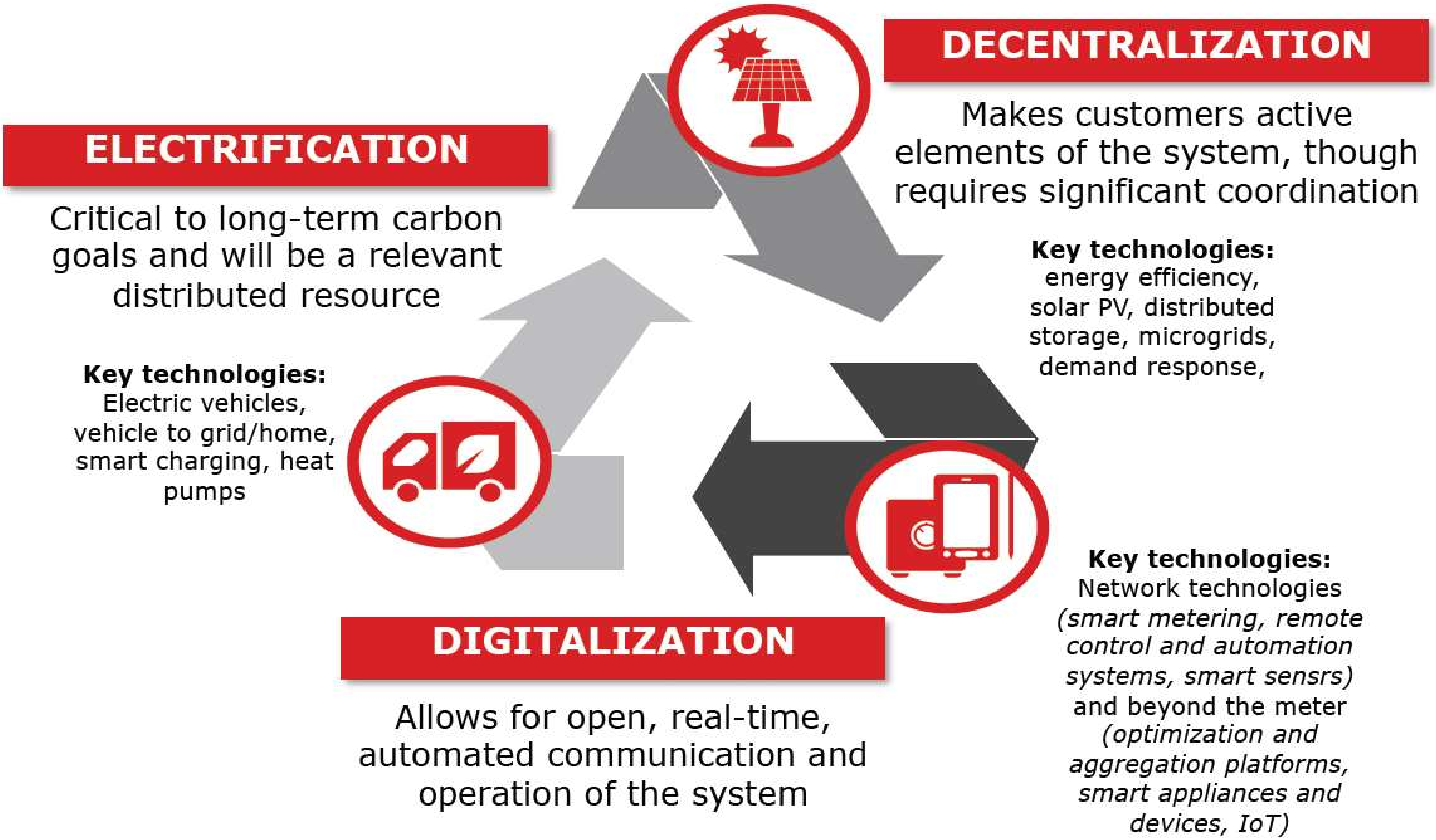
Incorporate the new reality of a digital, customer empowered, interactive electricity system facilitating customer engagement

Pursue new revenue sources from innovative distribution and retail services

Ref : World Economic Forum, The Future of Electricity New Technologies Transforming the Grid Edge,
In collaboration with Bain & Company

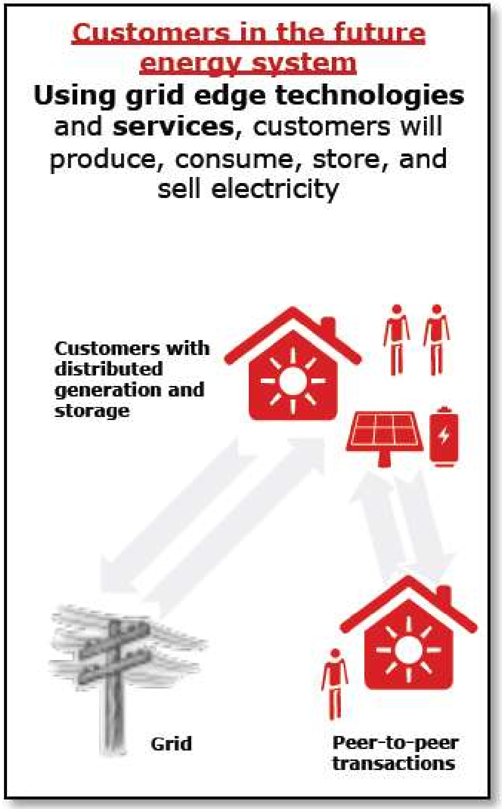
The Future of Electricity
New Technologies Transforming the Grid Edge

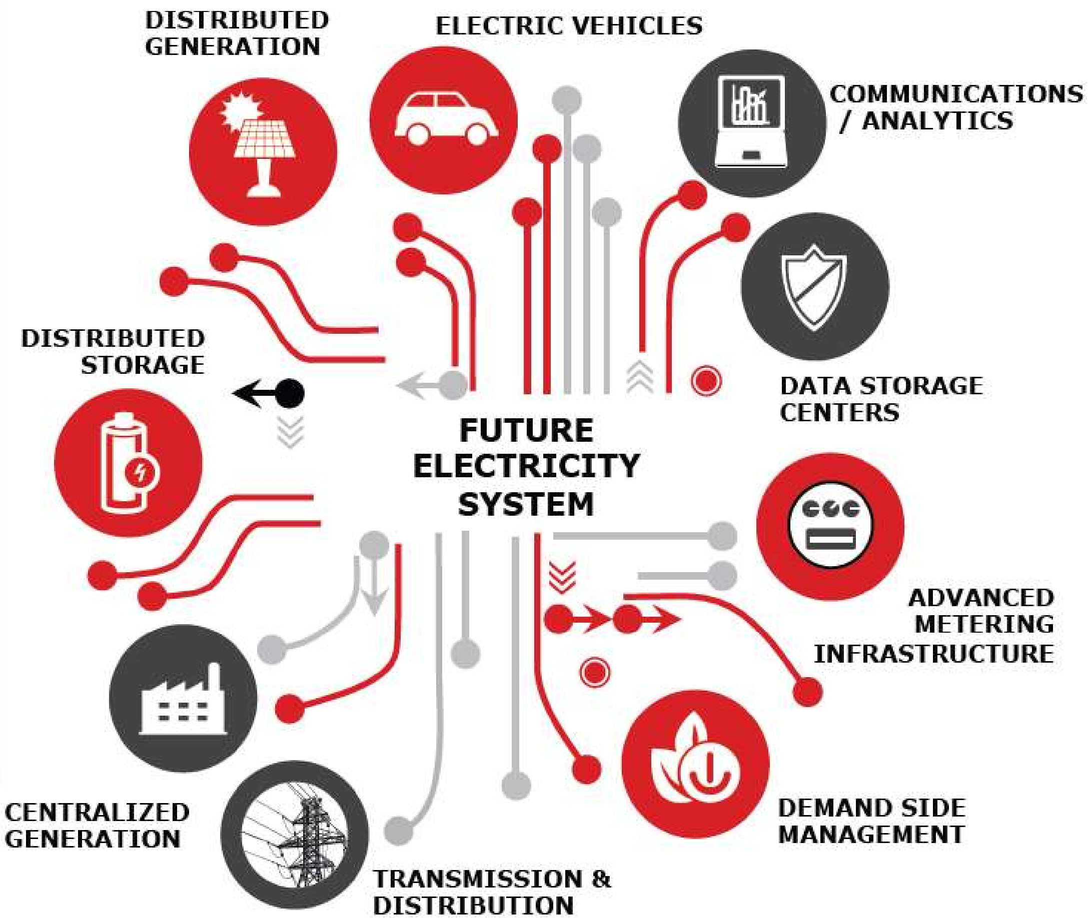
Three Trends of the Grid Edge Transformation

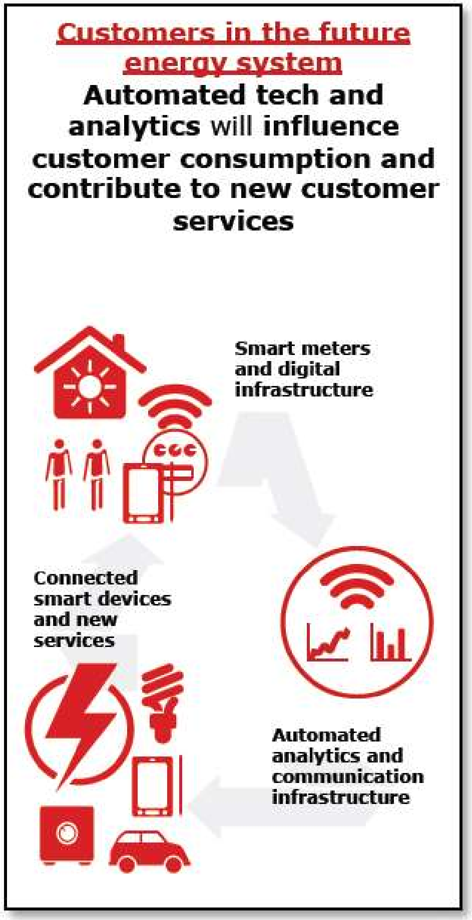


Ref : World Economic Forum, The Future of Electricity New Technologies Transforming the Grid Edge,
In collaboration with Bain & Company

The Additional Roles for the Grid and Incorporate Many Customer Technologies



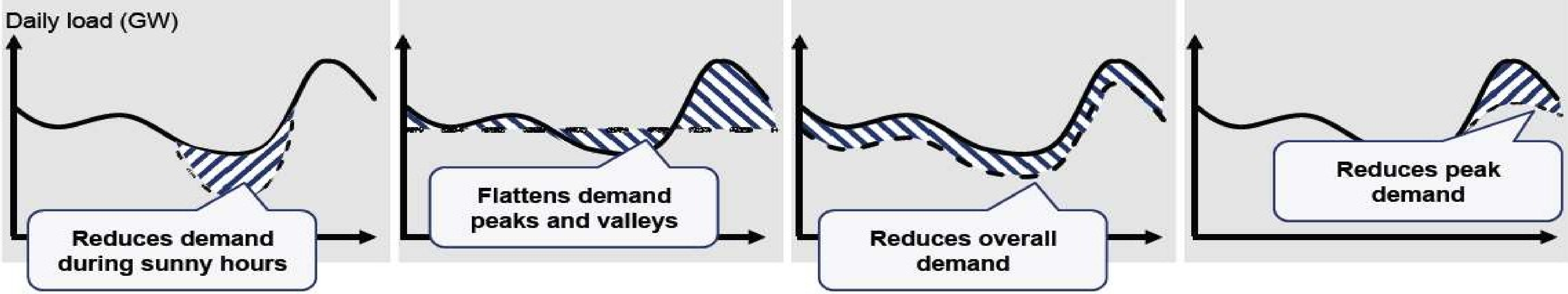




Ref : World Economic Forum, The Future of Electricity New Technologies Transforming the Grid Edge,
In collaboration with Bain & Company

Decentralization refers to several technologies with different implications for the grid

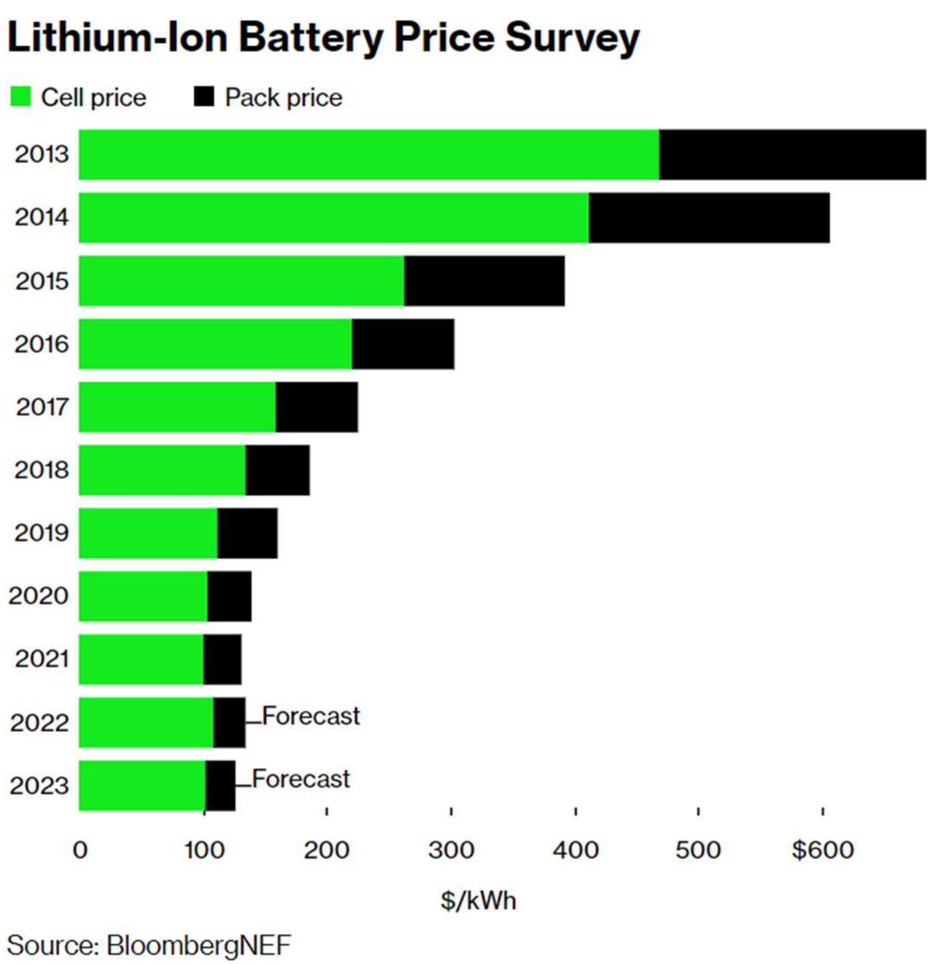
Distributed Generation	Distributed Storage	Energy Efficiency	Demand Response
Distributed generation from renewable sources—primarily PV	Devices that store electrical energy locally for use during peak periods or as backup	Any service or device that allows for reduced energy use while providing the same service	Technology that enables control of energy usage during peak demand and high pricing periods

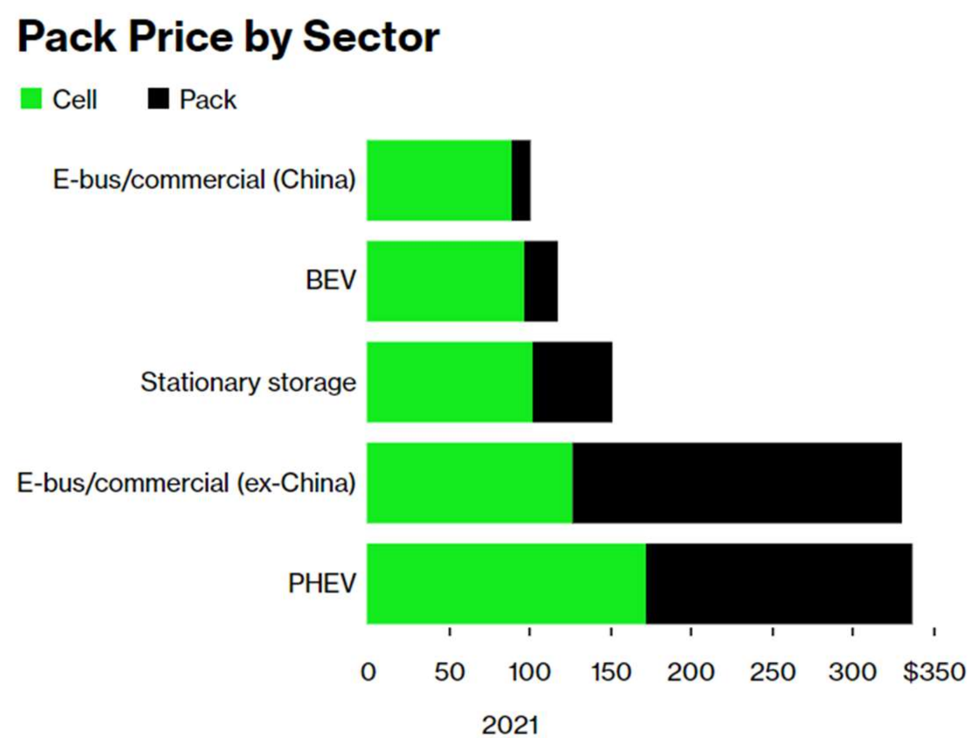


Ref : World Economic Forum, The Future of Electricity New Technologies Transforming the Grid Edge,
In collaboration with Bain & Company

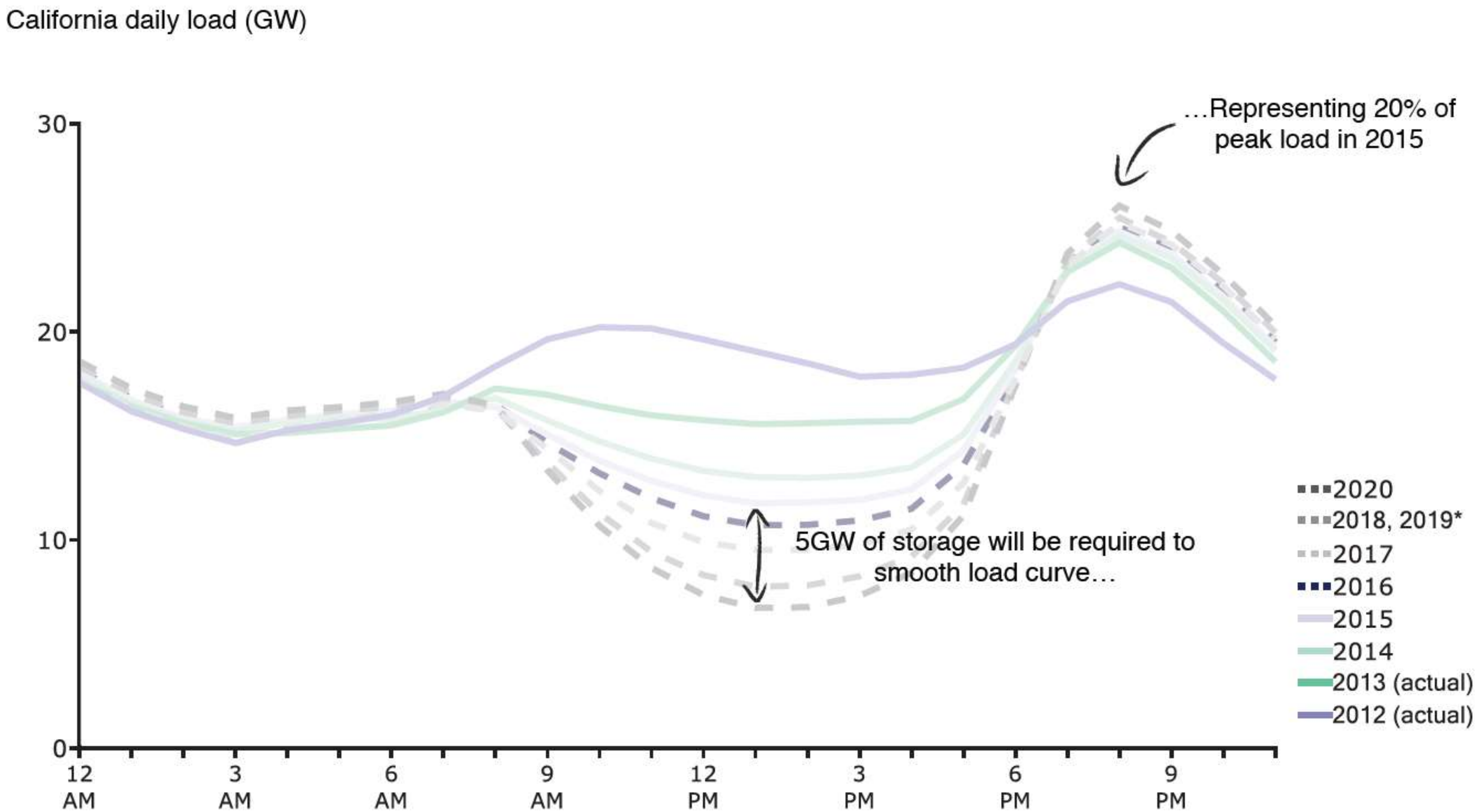
Lithium-Ion Battery Price Survey

Declining cost of batteries, from $680 per kWh in 2013 to $135 kWh in 2022 (Forecast), has helped encourage adoption of EVs and storage





As Renewable Generation Increases, the Disconnect between Supply and Demand



*Note: *CAISO forecast of 2018/2019 duck curve is nearly identical. Represents March 31.*
Source: CAISO

Grid Edge Solutions

Application: e-mesh PowerStore

Pattasit Wachirapornpruet
Senior Specialist, IEEE PES Working Group

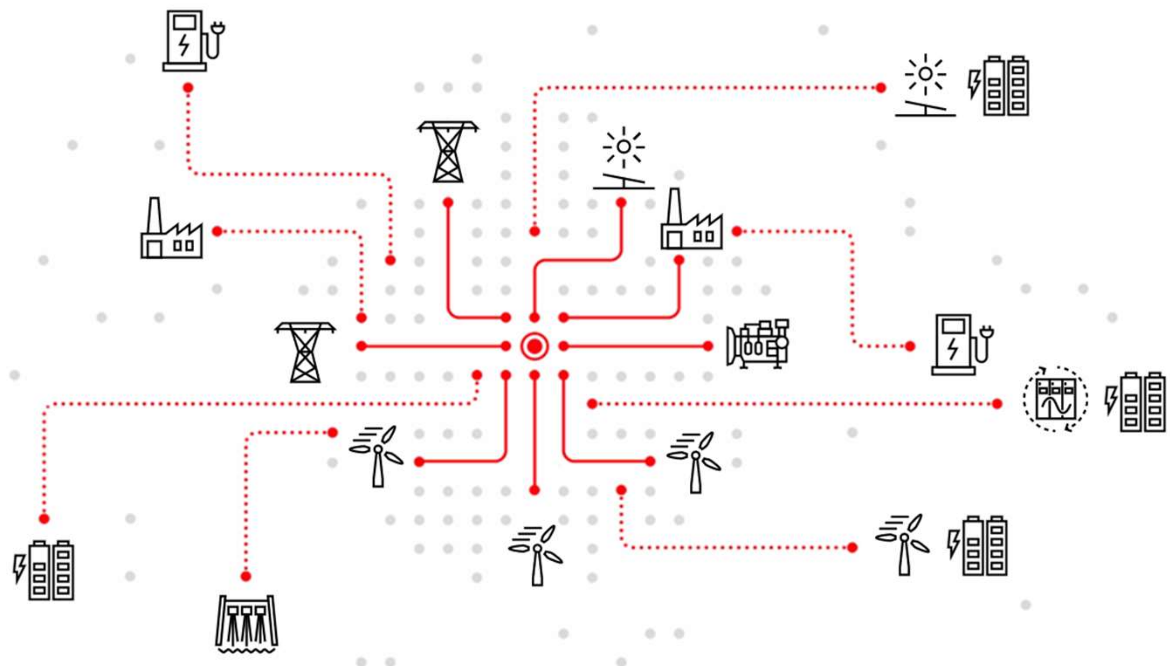
Grid Edge Solutions

e-mesh value proposition

Scalable vertically integrated digital ecosystem managing and optimizing energy at all levels with wide range of applications from the field to the boardroom, on cloud and on premises.

e-mesh enables:

- Availability of reliable and resilient power
- Reduction in carbon footprint
- Improved energy costs
- Maximizing integration of renewables
- Enhanced revenue and ROI through "value stacking"



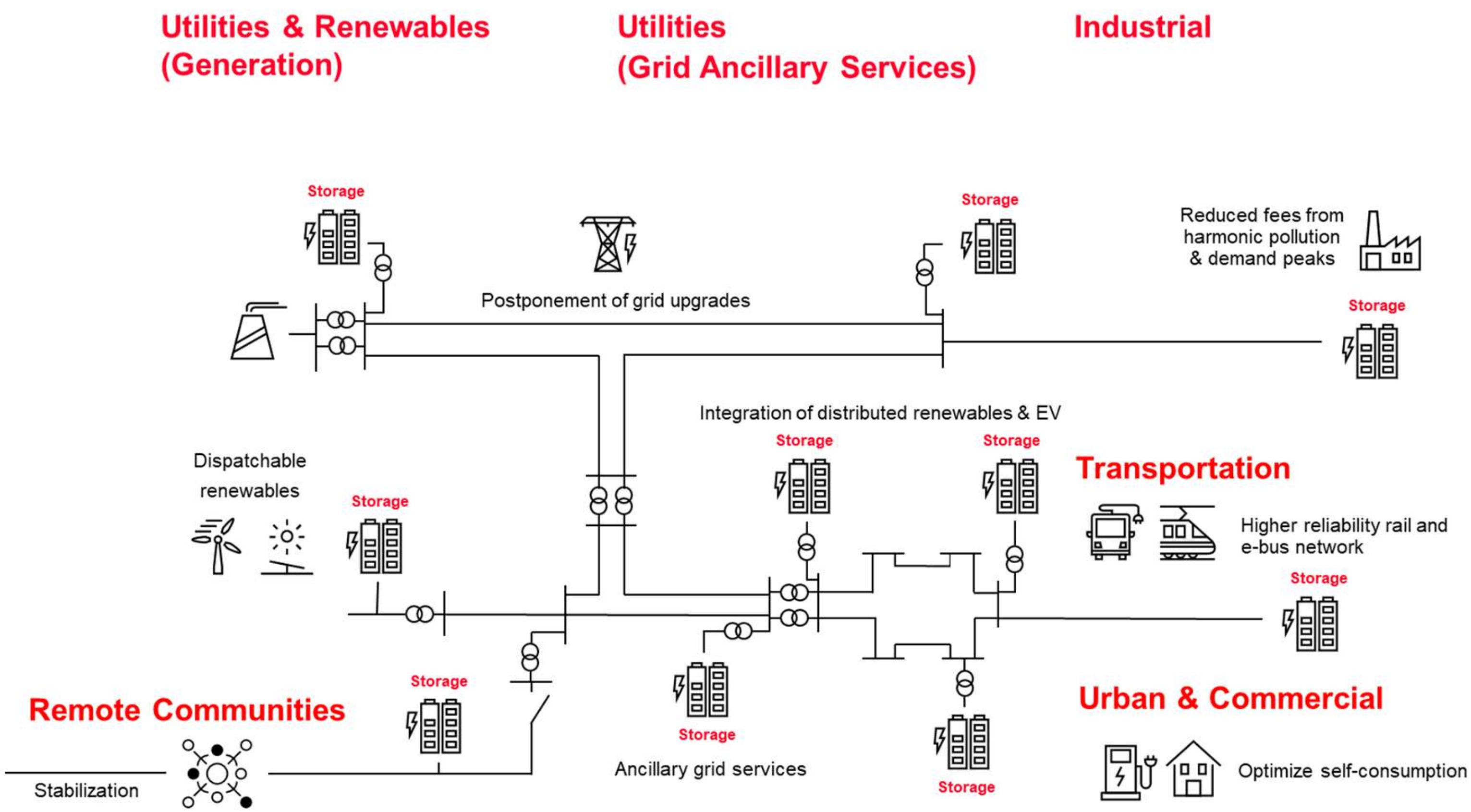
Enabling energy management and optimization with e-mesh portfolio

Source : Hitachi Energy

Serving customers across multiple segments

Summary

- Applications across multiple segments
- Improved economic viability
- Key enabler of new business models
- Value stacking increases ROI
- Digital capabilities enable advanced applications
- Enabling further renewables deployment



Source : Hitachi Energy

e-mesh portfolio

Applications
SaaS Apps for improved performance

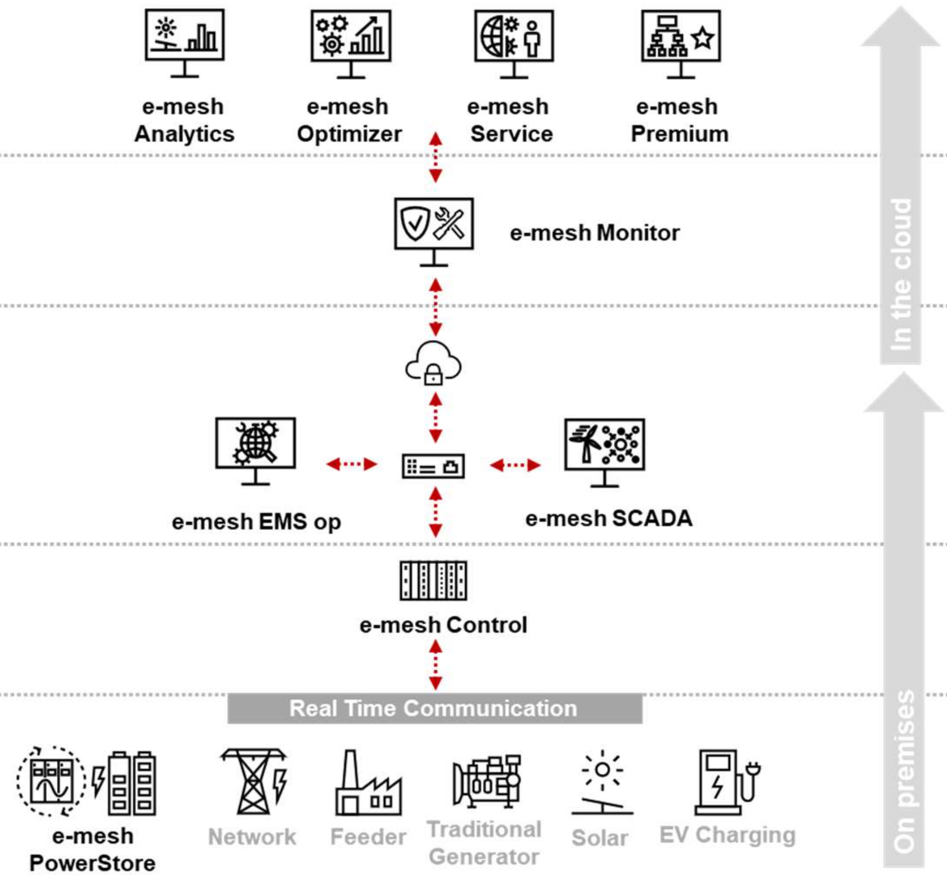
Monitor
Cloud enabled remote monitoring and control

EMS
On-premises energy management solution

SCADA
On-premises plant automation solution

Control
Intelligent and efficient power management

PowerStore
Smart battery energy storage solution



- Energy forecast, production and optimization planning
- Business KPI dashboards and reports
- Improved productivity and profitability

- Monitoring and control
- Bi-directional data flow
- Remote access

- Monitoring & control
- Optimal energy production
- Operational & maintenance cost reduction

- Renewable power generation grid code compliance
- Network voltage control
- Feeder & Load demand management

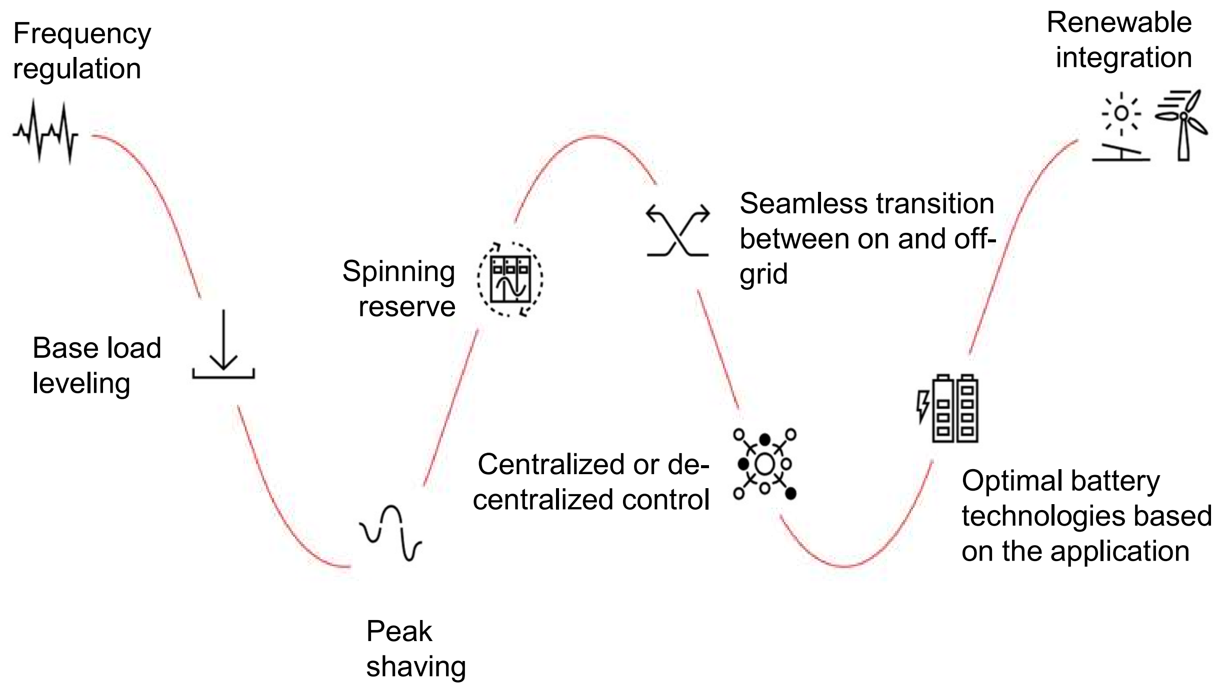
- Smart battery energy storage solution
- Support for various applications including islanding, seamless transition, black start, spinning reserve, etc.

Source : Hitachi Energy

e-mesh PowerStore

Highlights

- Designed for both grid-connected and off-grid applications
- Grid codes and standards compliant
- Intelligent and efficient power management system
- Pre-configured automation functionalities
- Productized design allows faster implementation
- Assures high level of cyber security
- Available in different sizes and configurations, based on two variants: Integrated and Modular



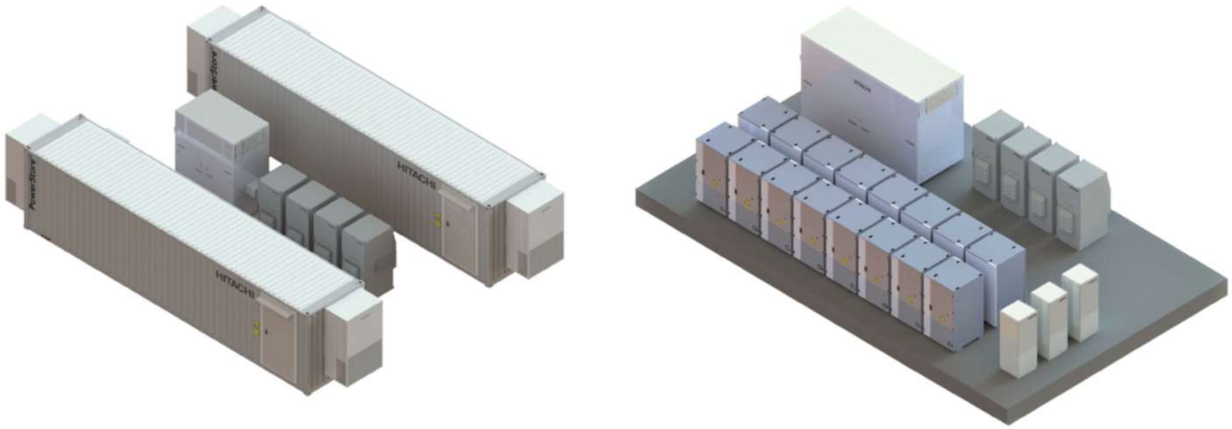
Energy storage system – enabling resilient and cost-effective access to power

Source : Hitachi Energy

e-mesh PowerStore

PowerStore Modular: PS1000

The PCS and battery are housed in separate enclosures* to achieve flexible power and energy ratings.



PCS: Power Conversion System

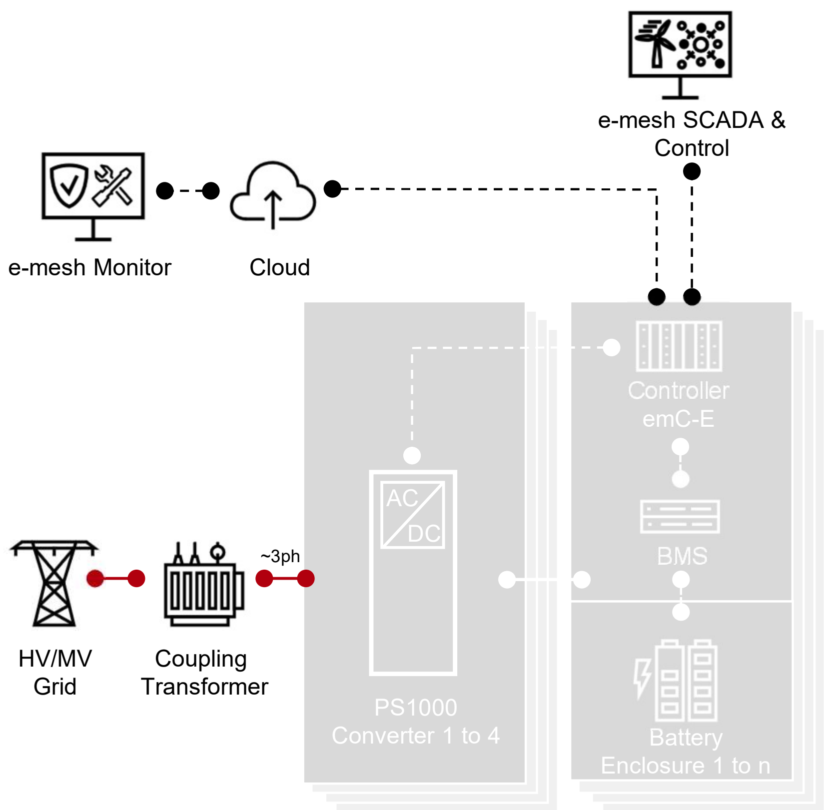
* Enclosure images for illustrative purposes only.

** In the outdoor batteries option, the controller is delivered in a separate enclosure

Source : Hitachi Energy

e-mesh PowerStore

PowerStore Modular



Highlights

- Modular systems in 1MW blocks, up to 100 MW+
- 2 battery enclosure options depending on technology: containerized or outdoor cabinets
- Individual selection based on application and customer requirements
- Can connect to all voltage levels via external transformer
- Cloud-based remote monitoring and control system
- Fulfill health, safety and environmental requirements

Key components

- e-mesh Control
- Grid-forming power converter
- AC and DC protection
- Battery racks and BMS
- Fire detection and suppression

Flexible & scalable energy storage system

* In the outdoor option, the controller is delivered in a separate enclosure

Source : Hitachi Energy

e-mesh PowerStore

Seamless Transition

Seamless transition from grid connection to islanded mode

Meet the challenges for robust power supply in isolation from national grid infrastructure and gain control of your power needs on 'local' level

Grid Stabilization

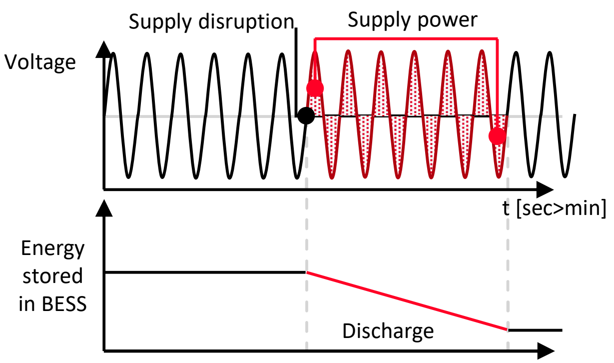
Reliable and affordable flow of power whenever it is required

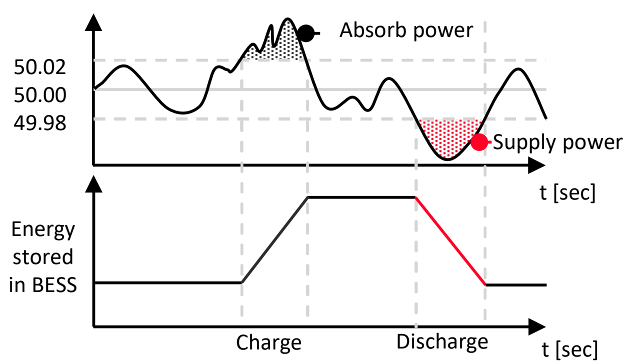
Stabilizes an electricity network by rapidly absorbing power surges or by injecting power to make up for short-term decline, in order to maintain high quality

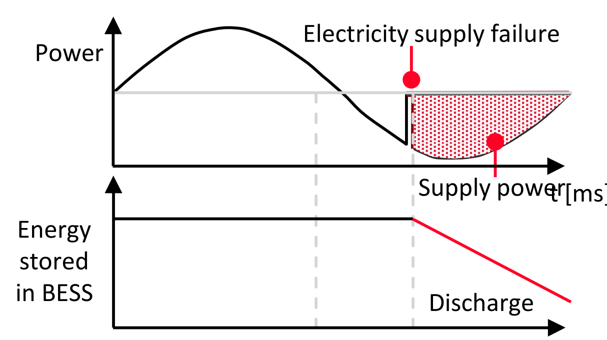
Standalone

Driving the transition to a carbon neutral tomorrow, today

Acts as "Virtual Generator" and can form the grid, handling up to 100% renewable energy.



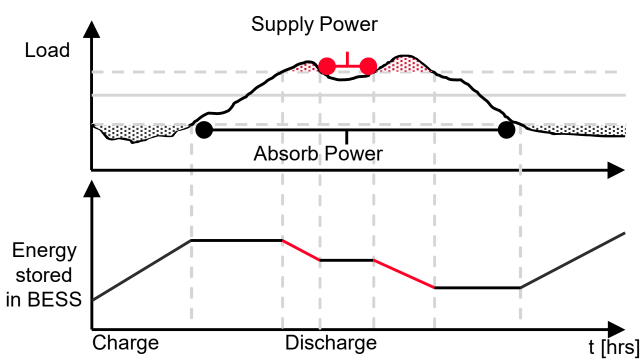




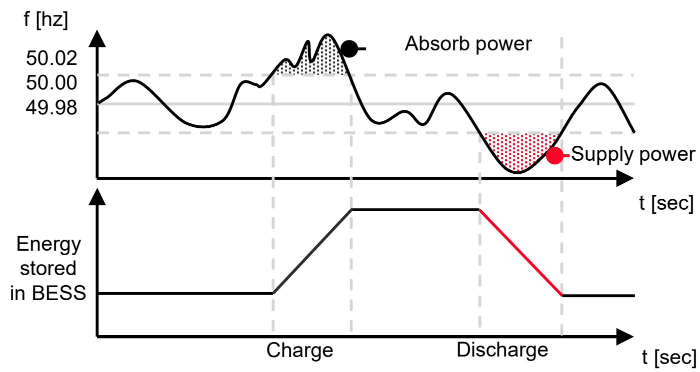
Advanced control algorithms enabling revenue stacking to maximizing return on investment

Source : Hitachi Energy

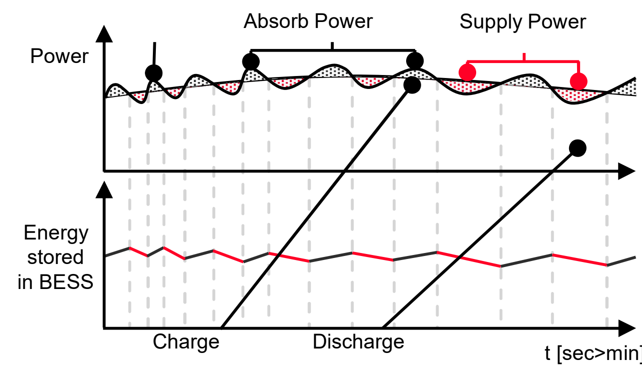
e-mesh PowerStore



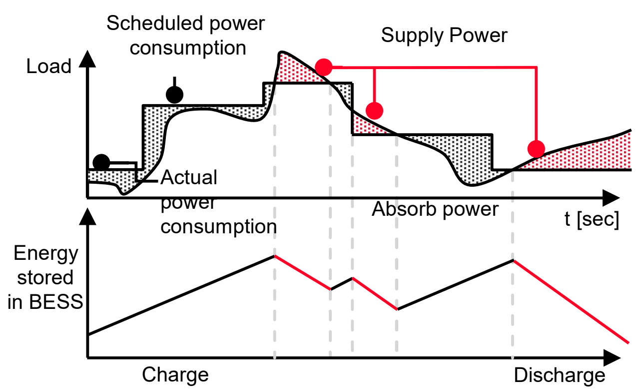
Load leveling



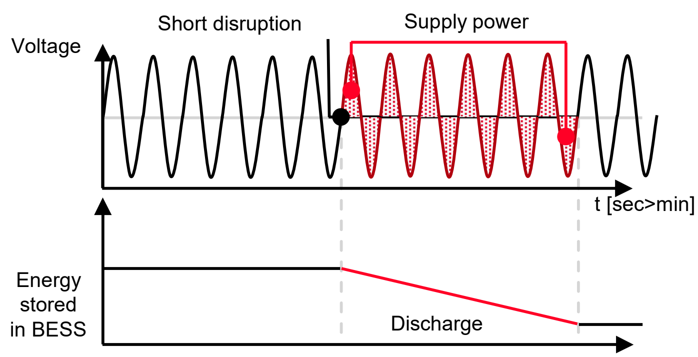
Ancillary services



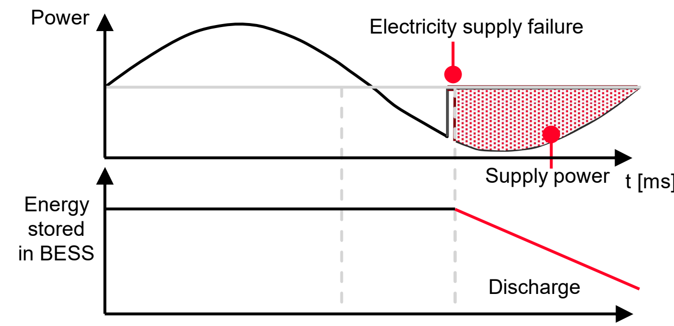
Integration of renewable resources



Peak shaving



Power quality



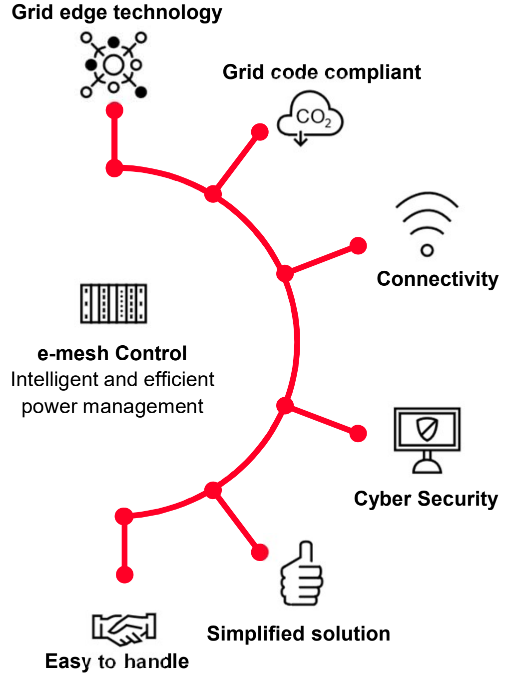
Spinning reserve

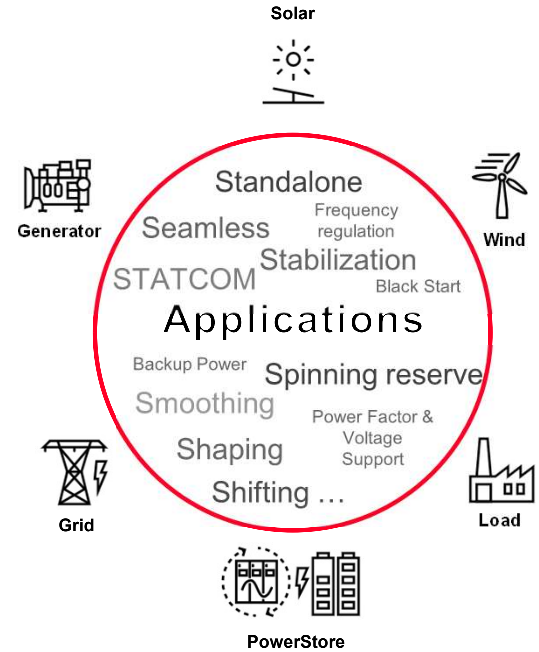
Source : Hitachi Energy

e-mesh Control

Highlights

- Asset control ranging from renewable power plants, microgrids, energy storage and substations
- Productized libraries and application customization
- Seamless integration into existing substations with RTU500 technology
- Network voltage control, feeder & load demand management
- Resilient cyber security features
- Complies with major communication protocols (3rd party equipment)
- Implements IEC 61131 standard for PLC languages
- Ensure asset grid code compliance





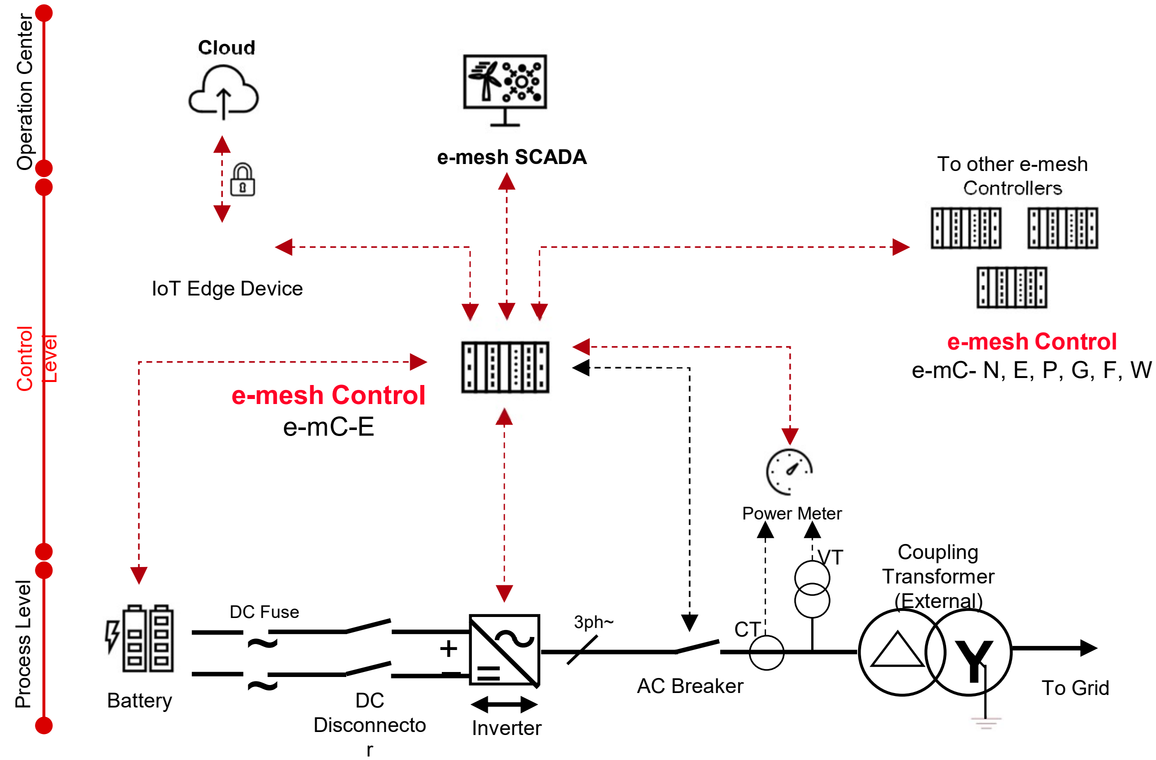
Ensuring reliable and economical power supply with reduced carbon footprint

Source : Hitachi Energy

e-mesh Control

Benefits

- Max efficiency of traditional & distributed energy assets
- Platform scalability to reduce cost of future expansion
- Reduces cost of operation
- Maximizes renewables utilization
- Standard, pre-tested configurations to save commissioning time
- Secure and authorization authentication for energy assets access



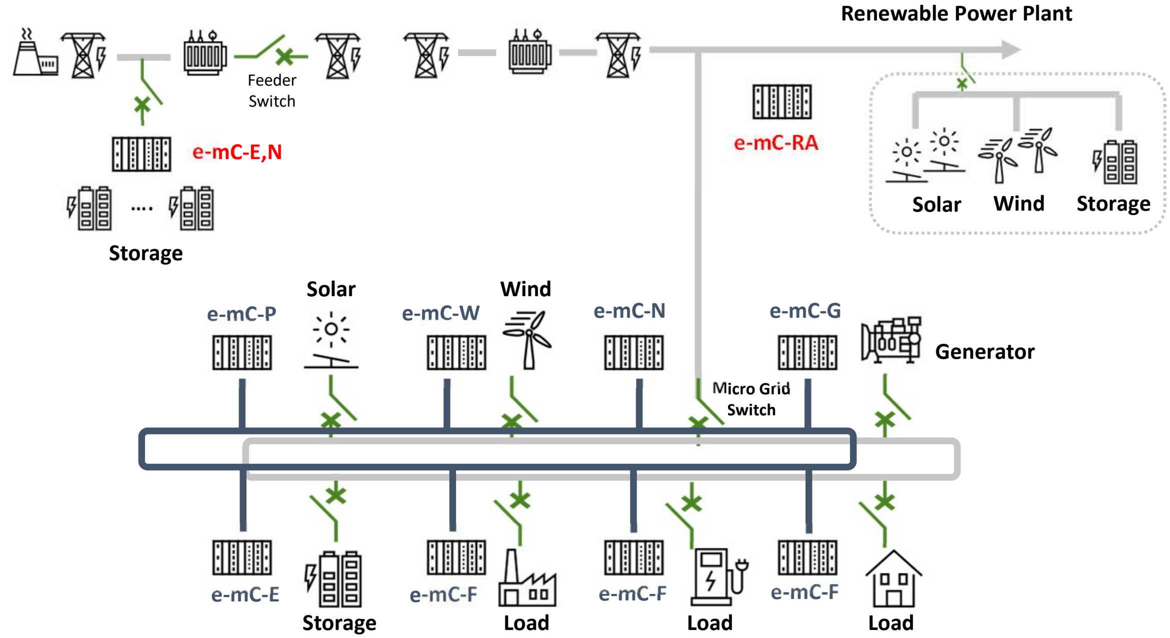
Ensuring reliable and economical power supply with reduced carbon footprint

Source : Hitachi Energy

e-mesh Control

Dedicated controller for any type of asset

Energy Assets	Controller	Application
	e-mC-P	PV inverters
	e-mC-E	BESS*
	e-mC-G	Fossil fuel generators
	e-mC-W	Wind turbines
	e-mC-F	Load feeders
	e-mC-N	Grid / network interface
	e-mC-RA	Renewable Power plant control

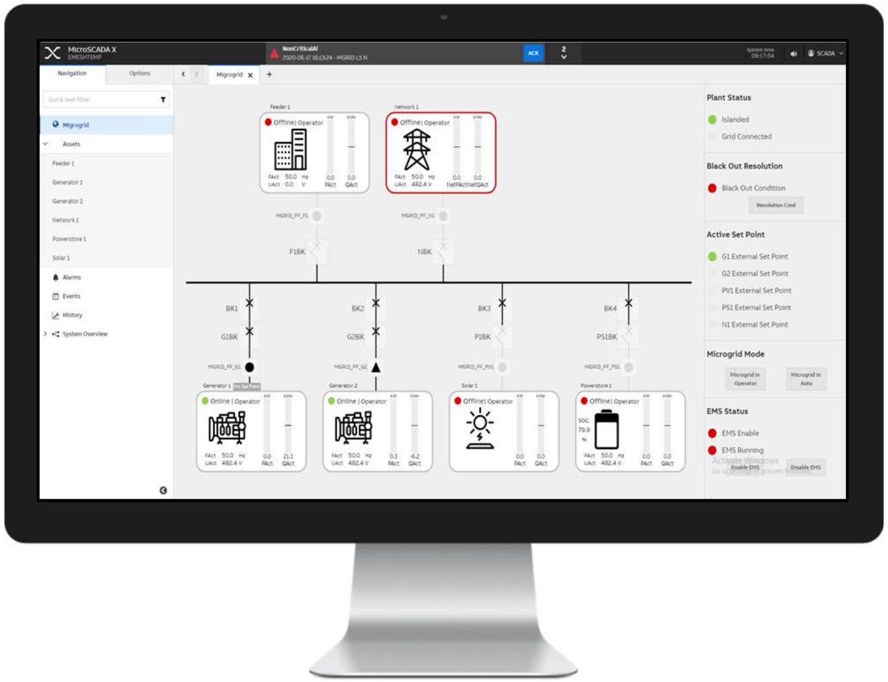


Source : Hitachi Energy

e-mesh SCADA

Highlights

- Provides real-time control and monitoring of all your assets
- Data acquisition from field assets such as BESS, EVs, renewables and other distributed resources.
- Productized libraries simplify application customization
- Compliance with major communication protocols
- Quickly locates issues in the plant
- Maximizes safety and allows reduction in operator error

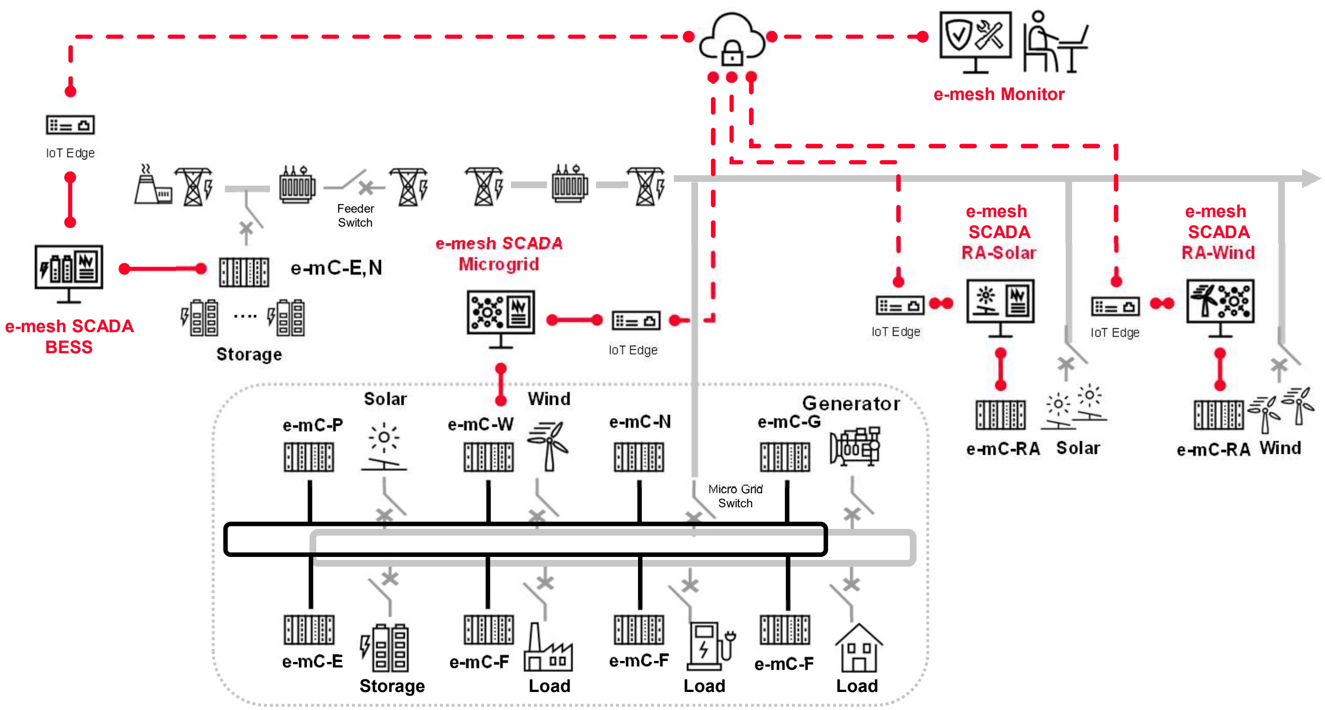


Simplify site energy operations & maximize return on investments

Source : Hitachi Energy

e-mesh SCADA

SCADA	Application
RA-Solar	Renewable Automation: Solar PV
BESS	Battery energy storage solutions
RA-Wind	Renewable Automation: Wind
MG	Microgrid solutions



Source : Hitachi Energy

e-mesh EMS

Highlights

e-mesh Energy Management System (EMS), an optimizer suite that provides additional features for **optimal energy management of distributed energy resources**.

- Minimize OPerating Expenses and CO2 emissions through day-ahead and intra-day optimal dispatch
- Take full advantage of renewables power generation and loads power consumption forecast data
- Enables the creation of insightful and handy reports for business executives
- Enhanced visibility into energy saving methods compliant with ISO 50.001
- Supports market participation and energy trading

Site energy management optimization

Source : Hitachi Energy

e-mesh EMS

Optimize

- Helps in planning, scheduling and setting of operating profiles for sites and DERs
- Evaluate custom optimization scenarios and implement the best solution
- Available planning horizons include intra-day and day-ahead

Forecast

- Collects and harmonizes forecast data for the EMS Optimize module
- Supports energy trading and bid generation by providing actionable insights

Report

- Provides operational and business reports such as revenues from energy sales, cost of energy purchased, carbon emission, business-as-usual benchmark, etc.
- Past, current & next-day KPIs are stored locally and can be accessed through a web user interface or secured web APIs

Connect

- Provides connectivity for integration to SCADA and other 3rd party systems such as forecast providers and trading systems

Four modules to optimize performance, improve energy efficiency and minimize costs

DER: Distributed energy resources / KPI: Key Performance Indicator / API: Application Programming Interface

e-mesh Digital Solutions

How we offer it?

Software as a Service (SaaS)

Is it black box?

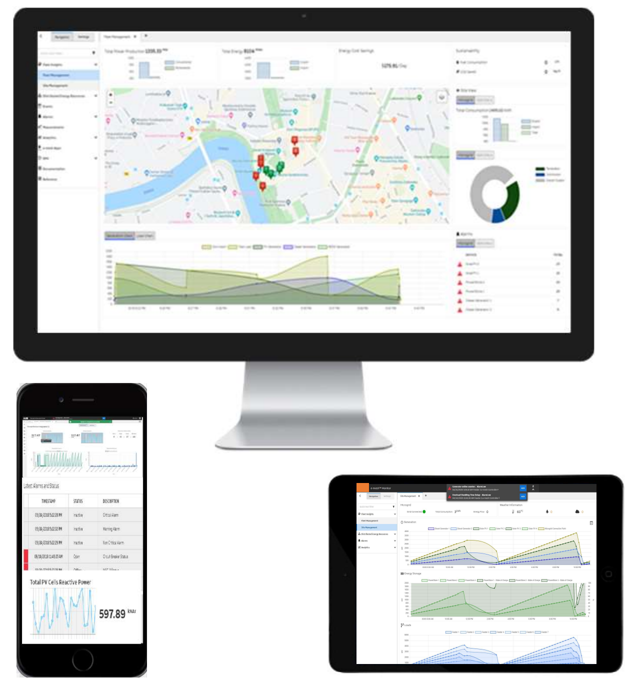
Interoperable and secured

Web API interfaces

e-mesh Monitor & e-mesh Apps

- Transition from time based to predicting optimal operational actions
- Reduced IT infrastructure CAPEX & OPEX
- Flexibility to select service tier matching your needs
- No more manual data reporting, all managed by one click
- Benefit from our continuous delivery of features updates and e-mesh App Store without operation interruptions

Which are your benefits?



Informative Insights for certain uncertainty management

Source : Hitachi Energy

e-mesh Monitor

Highlights

e-mesh Monitor is a **cloud-based digital platform**, exclusively designed to aggregate data from distributed energy assets and turn it into actionable business insights.

- Data collection & aggregation from assets using an IoT edge device
- Data analysis & storage in a secured cloud Real-time monitoring of distributed energy assets from anywhere, anytime
- Alarms, historical analysis and performance analytics reporting
- Act as the hosting platform for the e-mesh Software as a Service (SaaS) Applications
- Handle multiple DERs
- Extend using it on your handheld devices and interface through secured APIs

Asset insights

Source : Hitachi Energy

e-mesh Applications

Analytics

Diagnose and understand real-time performance of distributed energy assets

- Perform quick health check
- Detect micro faults anywhere in the site
- Analyze deeper root cause
- Predict failures in advance

Optimizer

Optimize microgrids, commercial & industrial and renewable sites

- Improve productivity and economical gains
- Maximize power generation
- Reduce operational costs
- Minimize CO_2 emissions
- Optimal decision making

Manage

Monitor and manage multiple sites at once – for large utilities and IPPs

- Forecast and optimal planning
- Business intelligence reporting
- Geographical information system
- Fleet management

Service

Improve field service activities by visualizing site level information in no time

- Mobile access to site details
- Increase longevity of assets
- Faster response time to faults
- Extended secure interfaces with other systems

Digitalization of grid edge operations

IPP: Independent Power Producer

e-mesh Applications

Highlights

e-mesh Applications are a set of **SaaS-based solution suites** that transforms data into insights to help improve business performance with the help of cloud technology, machine learning and predictive analytics.

- Extends the functionalities of e-mesh Monitor
- Available as four different suites – Analytics, optimizer, Service and Premium
- Easy-to-deploy, extendable and scalable SaaS applications
- High-end web user interface to visualize data
- Power packed features leveraging machine learning and data analysis
- Dashboards, analytics and reports for all relevant stakeholder
- Management of multiple fleets at once
- Secure deployment

Cloud, analytics and machine learning to accelerate business performance

Source : Hitachi Energy

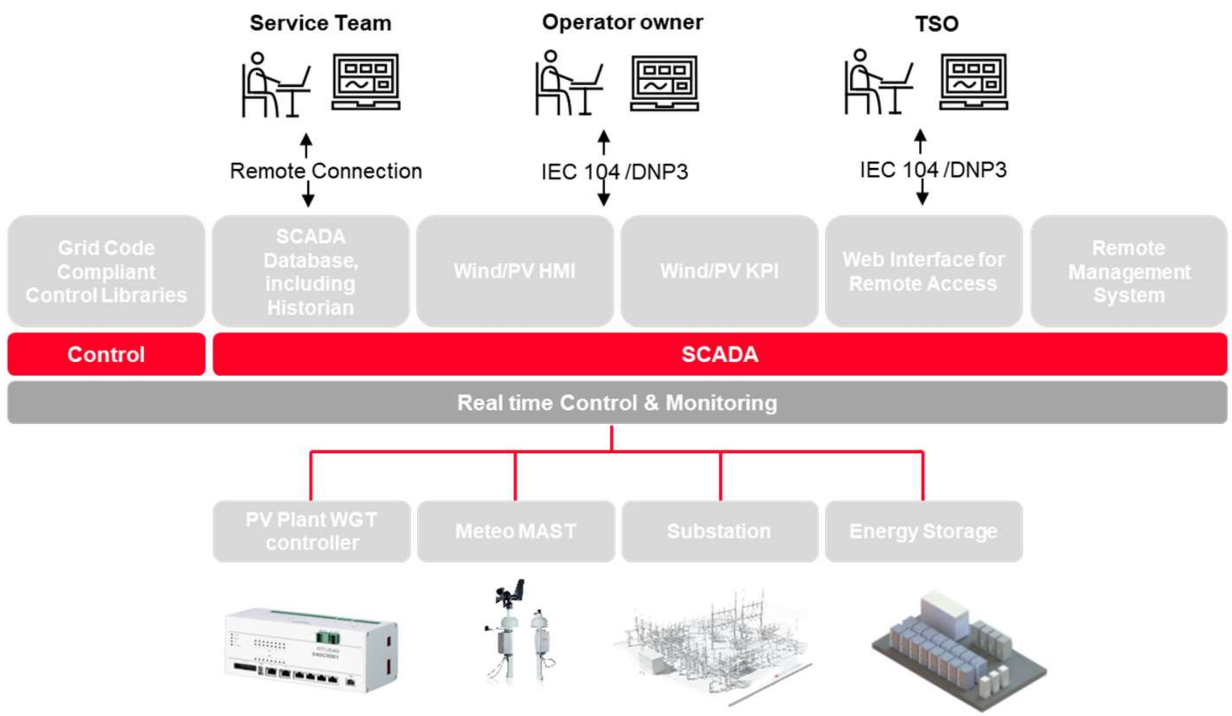
e-mesh Control & SCADA for Renewables

e-mesh Control

- Single point of control for the entire plant or fleet
- Ready-to-use, pre-configured and type-tested for wind and PV applications
- Standardized protocols to connect all the assets into a single system
- A common hardware platform, resulting in cost reduction and minimal spare parts handling
- Scalable for future operations

e-mesh SCADA

- Simple and intuitive HMI that provides real-time updates and meaningful data display
- Quickly locates issues in the field
- Maximizes safety, allowing reduction in operator error



Optimized solution for renewables plants & remote-control centers

PV: Solar Photovoltaics / TSO: Transmission System Operator / HMI: Human-Machine Interface

Source : Hitachi Energy

e-mesh Service Level Agreements

Protection for your investment

Rapid response
We guarantee fast and flexible response to maximize your equipment uptime

24/7 support

Software & firmware lifecycle
We optimize connectivity, reliability and efficiency of your assets to increase speed and yield.

Spare parts
We offer smart spare parts pool for grid edge products and solutions

Training
We offer customized training programs and tailored courses at your site

Cyber security
We enable smarter system protection to make your utilities more efficient, more productive, and more economic

Source : Hitachi Energy

e-mesh Advisory Services

Grid edge market analysis

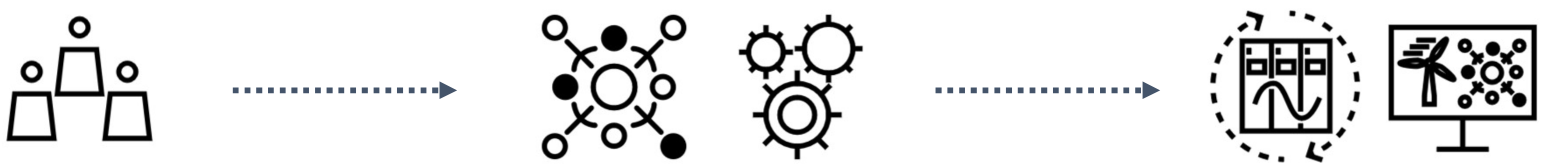
- Trends in energy price, tariffs
- Drivers for energy storage applications.
- Market participation revenues streams

Grid edge financial analysis

- Financial metrics, IRR, and payback
- Fuel savings
- environmental impacts
- Sensitivity analysis
- Value stacking
- Ownership models

Grid edge technical analysis

- Comprehensive portfolio of simulation models for e-mesh PowerStore & Control
- Stability and dynamic studies
- Contingency analysis
- Power quality and reliability
- Frequency and voltage ride though



Grid Edge Consulting and Advisory Services

Grid Edge Solutions

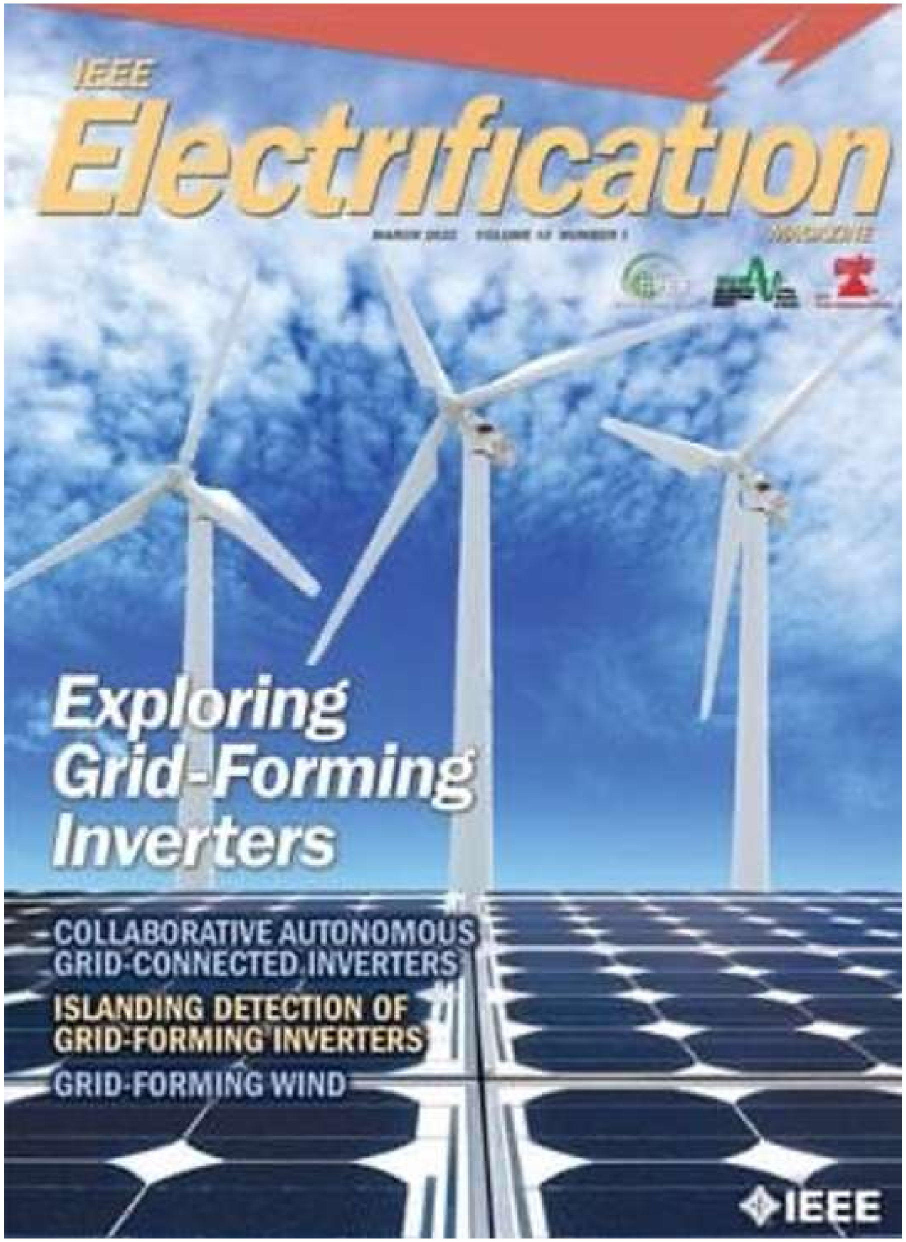
Grid Edge Products

End-to-end Grid Edge decision solutions

Source : Hitachi Energy

Exploring Grid-Forming Inverters

Exploring Grid-Forming Inverters



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FREE Open Article: Grid-Forming Inverters for Grid-Connected Microgrids▶
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Solar–diesel–flywheel microgrid power generation at Marble Bar, Western Australia

Source : IEEE Electrification Magazine / March 2022

Figure : Solar–diesel–flywheel microgrid power generation at Marble Bar, Western Australia. (Source: Hitachi Energy; used with permission.)

Energy Storage Helps Solve Weakness

Table : A comparison of grid characteristics of SG – dominant & renewable generation

Characteristics	Traditional SG Dominant	Low Renewable Penetration	High Renewable Penetration
Inertia	High	Medium	Low
SCR	High	High	Low
Protection	Traditional	Traditional	Adaptive
Frequency Stiffness	High	High	Low
Voltage Stiffness	High	High	Low

Source : IEEE Electrification Magazine / March 2022

Grid and Microgrid Perspectives

Microgrid Perspective	Grid Perspective
✓ Access to grid energy at lower tariffs ✓ Capacity trading ✓ Reliability ✓ Voltage disturbance shaping	✓ Reducing load ✓ Firm capacity with schedulable generation ✓ Frequency control ancillary services ✓ Normal and special network support ✓ Stability ✓ Damping at end of volt-ampere reactive injection ✓ Feeder shedding as a service without a local outage

Source : IEEE Electrification Magazine / March 2022

Comparison of Grid-following and Grid-forming Inverters

	Advantages	Disadvantages
Grid-following inverter (Current source)	✓ Simple controls ✓ Very fast response time ✓ Suitable for RE grid interface ✓ Available in rotating and stationary frames ✓ Automatically limits current during faults	• Does not contribute to grid strength • Requires a stiff grid • PLL loses track of grid frequency during faults • Cannot be grid master • Limit to percentage on a grid
Grid-forming inverter (Voltage Source)	✓ Grid master ✓ Can run in stand-alone mode ✓ Can run in weak grids ✓ Handles load changes without disturbances	• Desynchronizes during faults • Too stiff in pure form • Does not share with legacy SGs

Source : IEEE Electrification Magazine / March 2022

VSM Control System

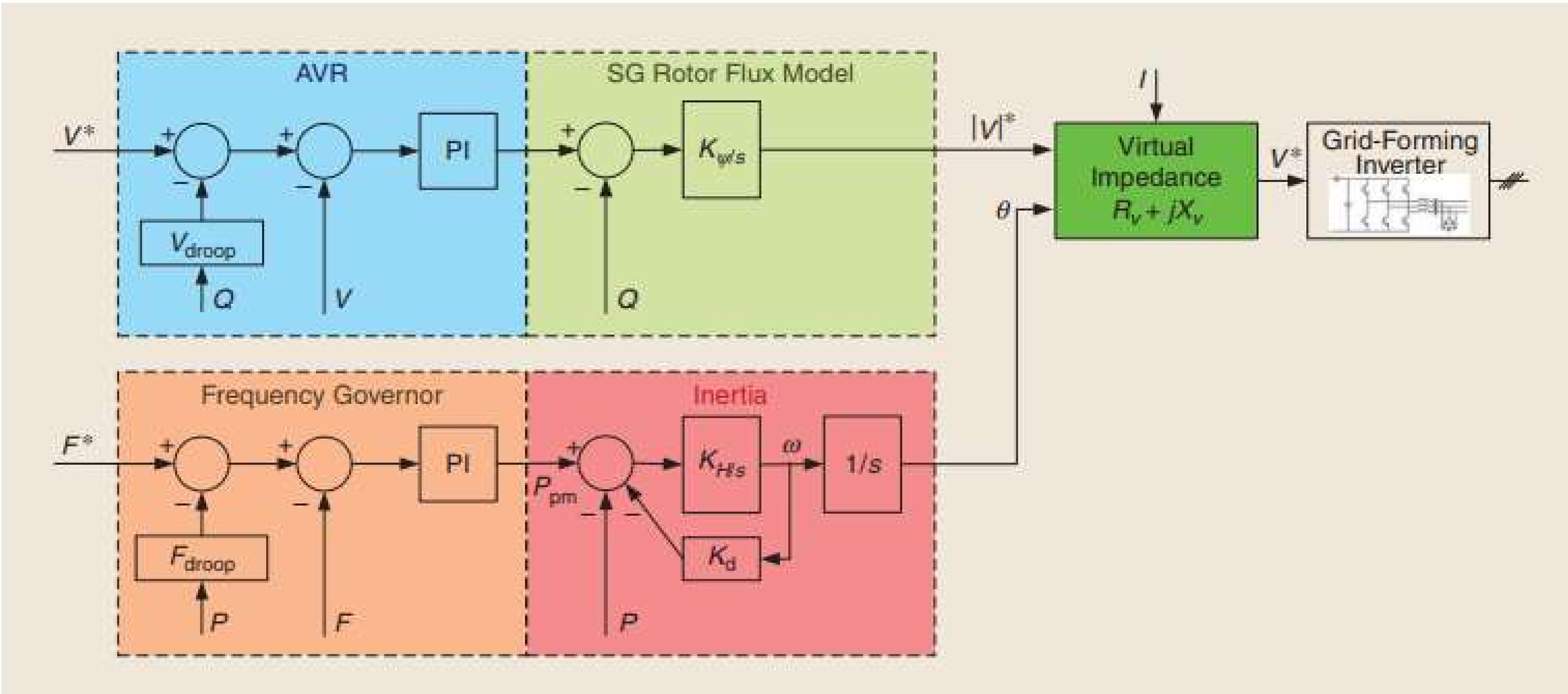


Figure : A VSM control system consisting of five parts: an automatic voltage regulator (AVR), a rotor flux model, a frequency governor, inertia, and virtual impedance

Source : IEEE Electrification Magazine / March 2022

Grid-Forming Inverters With VSM Functionality in Operation

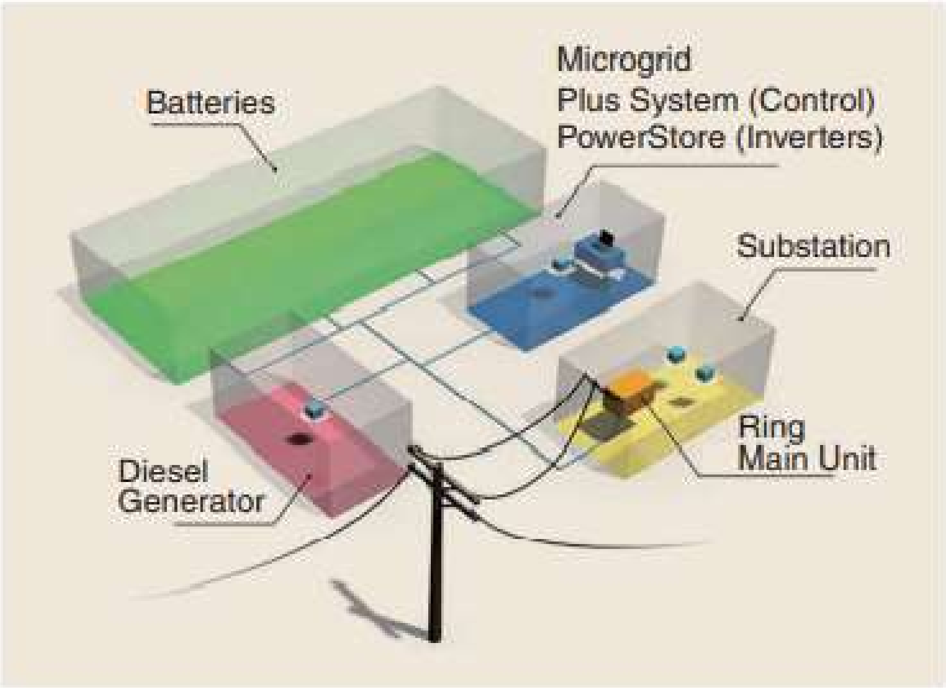


Figure : A grid-forming inverter BESS was installed in an industrial estate in northern Melbourne to support a local end-of-line feeder

Figure : A grid energy storage system for end-of-line distribution feeder grid support

Source : IEEE Electrification Magazine / March 2022

A Fast Future Grid Without the SG Legacy

- As we have seen, the grid is in transition, with generation moving from mechanically driven to electronically driven sources, due to the demand to integrate renewable energy.
- What of the future, when a large percentage of the total generation is from inverters and there is even a full inverter-based grid? Does it make sense to emulate SGs?
- Inverters have much faster dynamics, as they are not dependent on mechanical characteristics, so an inverter-based grid could respond more quickly to changes.
- One of the advantages of inverters is that they are software-controlled. Therefore, the software can be updated to change its behavior, and the control parameters can be adapted to changing grid conditions.
- As the number of inverters in the grid increases, it may be that SGs will change so that they act as slow baseload generators.

Source : IEEE Electrification Magazine / March 2022

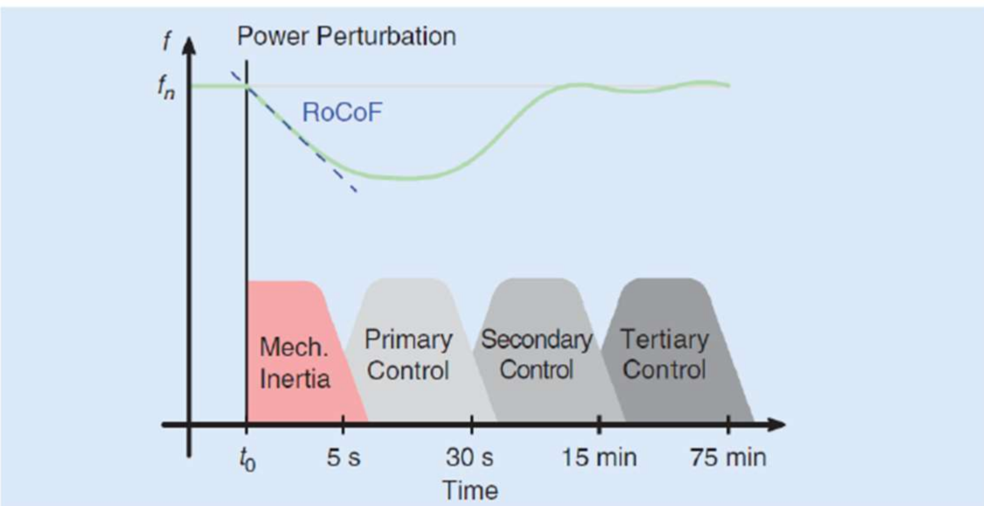
Grid Forming Energy Storage

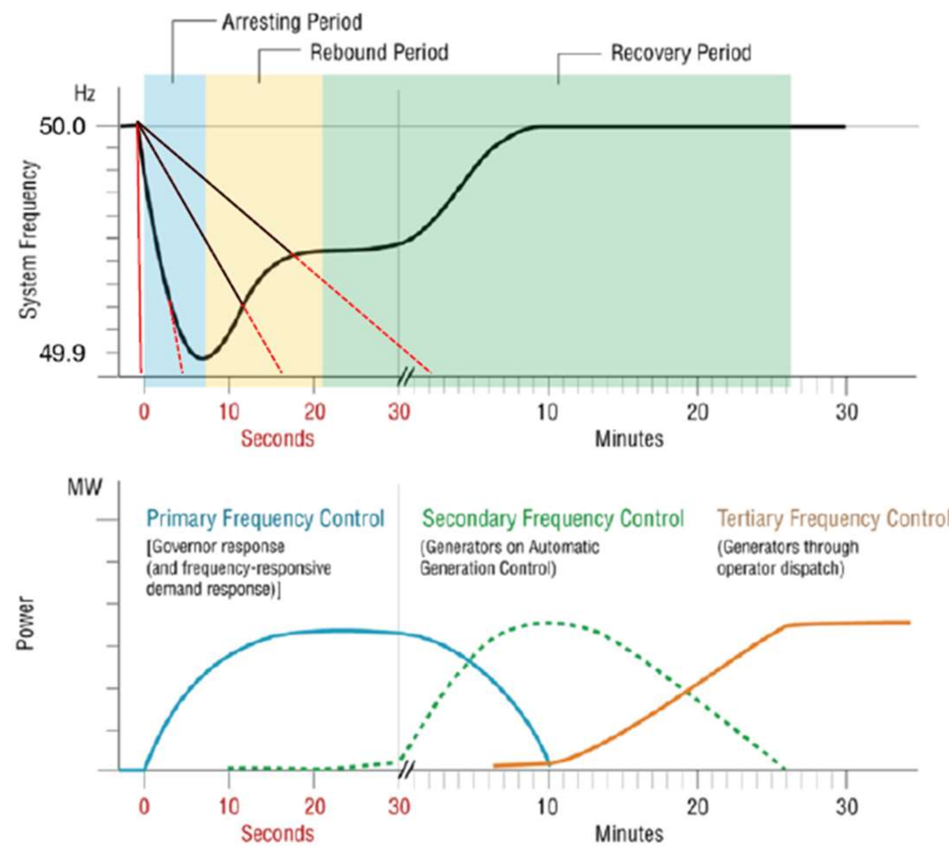
Provides Virtual Inertia, Interconnects Renewables and Unlocks Revenue

What is inertia?

Capability of the power system to resist changes in frequency by means of an inertial response from a generating unit, network element or other equipment that is electro-magnetically coupled with the power system and synchronised to the frequency of the power system.

*Inertial response from synchronous generators is **inherent**, **uncontrolled**, and independent of output level.*





Source: E. Unamuno, J. Paniagua, J.A. Barrena "Unified Virtual Inertia for ac and dc Microgrids. And the role of interlinking converters.", IEEE Electrification Magazine, December 2019
Source: CAISO, Source: NER , Source: https://www.nrel.gov/docs/fy20osti/73856.pdf

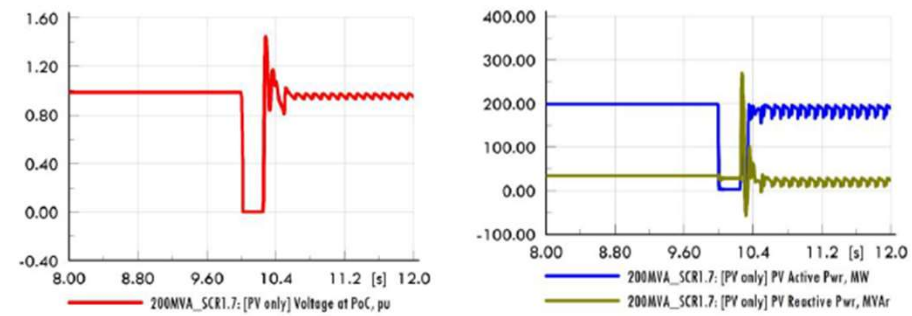
What is system strength?

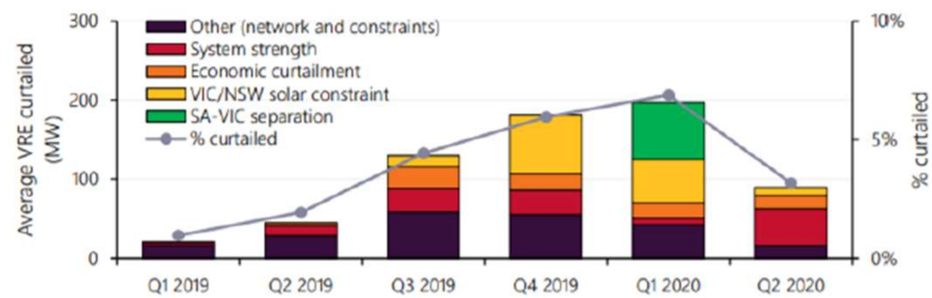
Definition

“System strength is the ability of the power system to maintain the voltage waveform at any given location, with or without a disturbance.”

- High fault levels = high system strength
- Short Circuit Ratio (SCR) associated with system strength
- Phase Lock Loop (PLL) of grid following plants require high system strength for stable operation
- PV plants may not recover post fault on low SCR network; oscillatory behavior post fault
- Fast response doesn’t cut it, needs to provide fault current and inertia (high inverter overload important)

Lack of system strength prevents interconnection and increases renewable curtailment





Grid Forming inverters do not need a PLL – they generate their own waveform

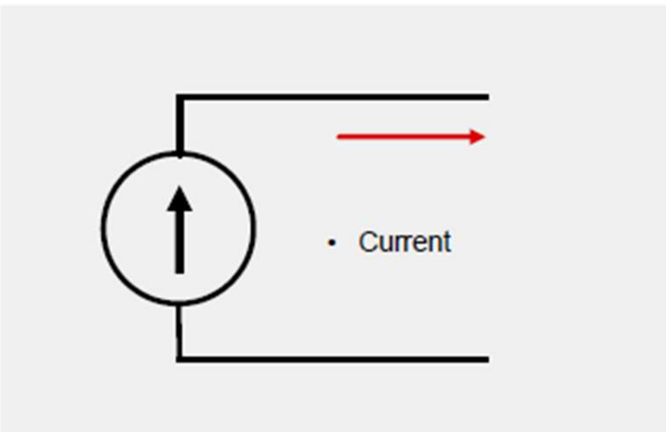
Source: https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf?la=en, https://aemo.com.au/-/media/files/major-publications/qed/2020/qed-q2-2020.pdf?la=en&hash=D1A82334D16E915FCB1B628640A05223 Source: https://aemo.com.au/-/media/files/major-publications/qed/2020/qed-q2-2020.pdf?la=en&hash=D1A82334D16E915FCB1B628640A05223

Converter technology

Grid Following, Grid Forming and Virtual Synchronous Machine

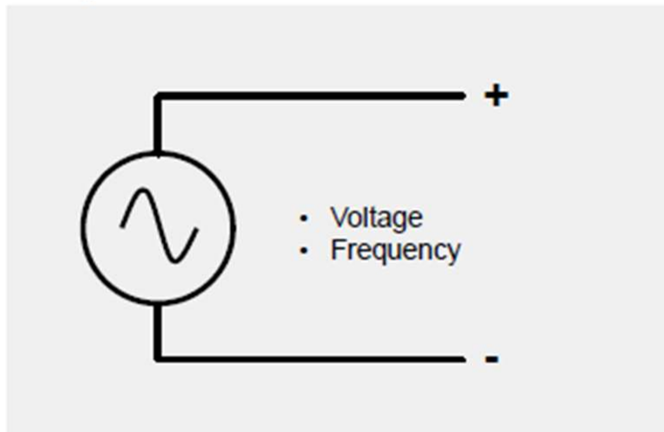
Grid Following - CSI

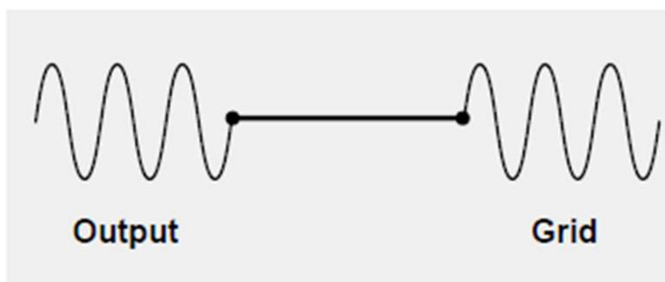
Current Source Inverter



Grid Forming - VSI

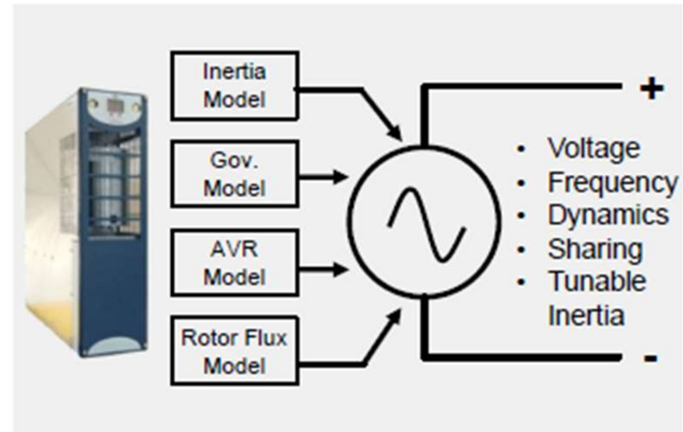
Voltage Source Inverter

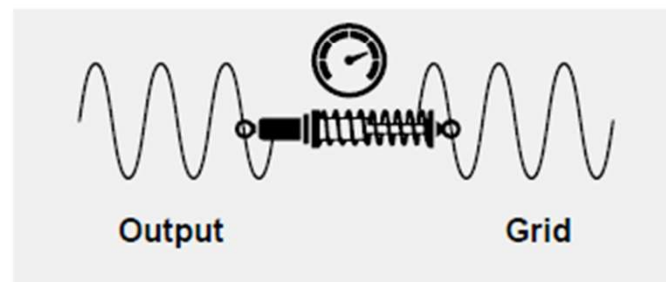




Virtual Synchronous Machine - VSM

Hitachi ABB PowerStore™





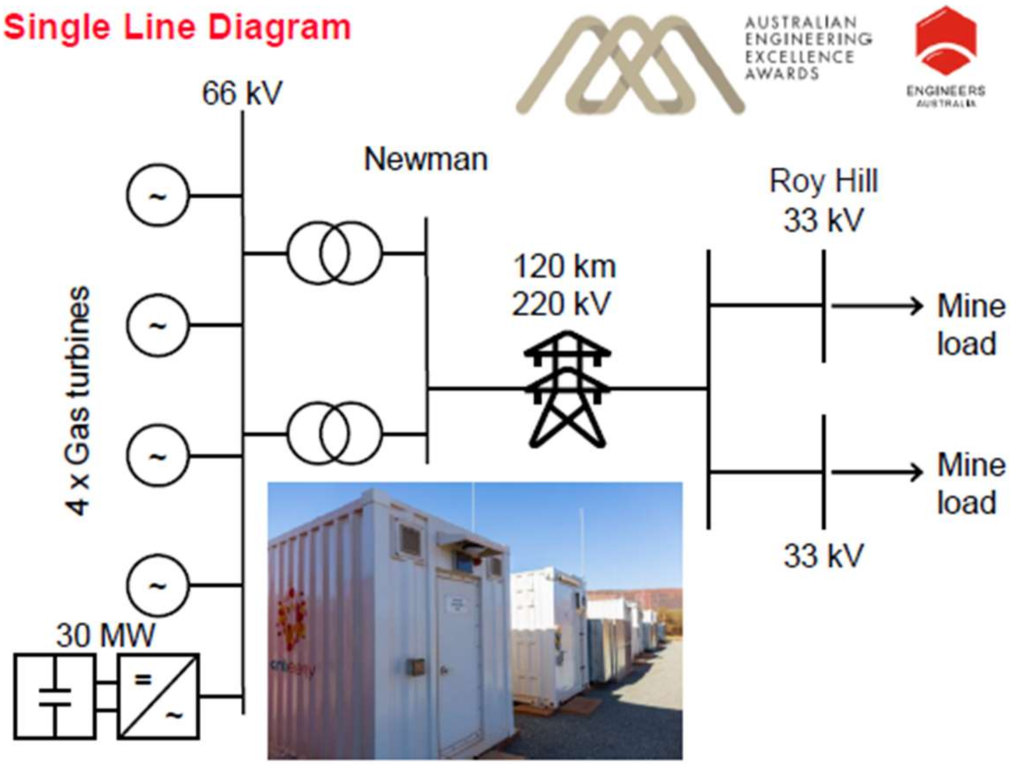
CSI = Current Source Inverter (Current controlled)
VSI = Voltage Source Inverter (Voltage controlled)

Source: Hitachi Energy

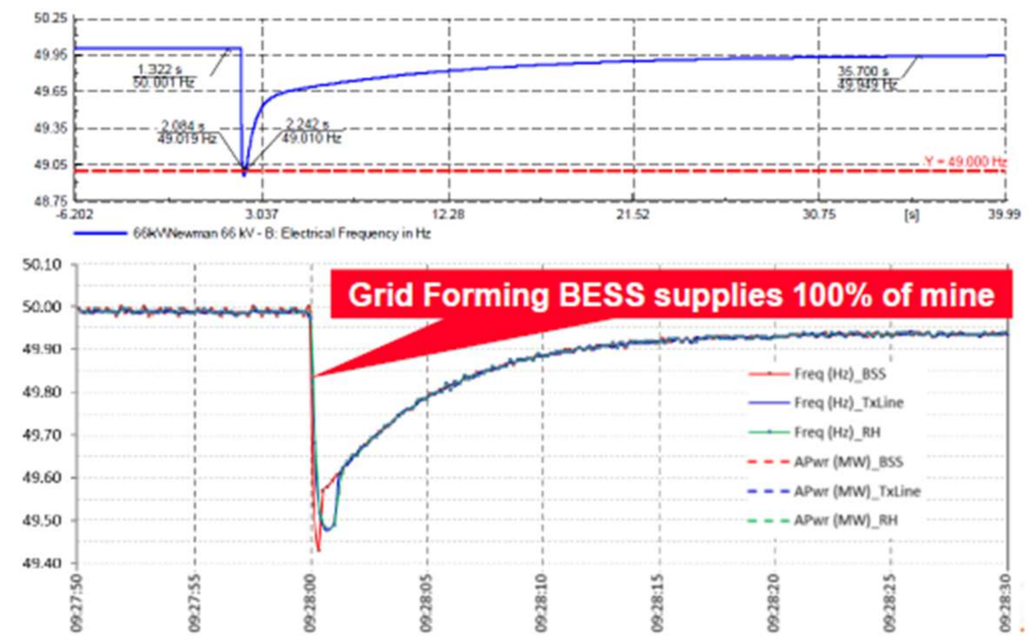
Alinta Newman 30MW / 8MWh PowerStoreTM

How do we switch off the last generator?

Single Line Diagram



Last gas turbine trips off – simulated vs. actual response



Virtual Synchronous Machines are critical to allow Synchronous Machines to switch off

Source: Hitachi Energy

Case Study

Dalrymple – World’s first large scale utility connected Grid Forming BESS

Dalrymple ESCRI-SA BESS

Business Case & Commercial Arrangements

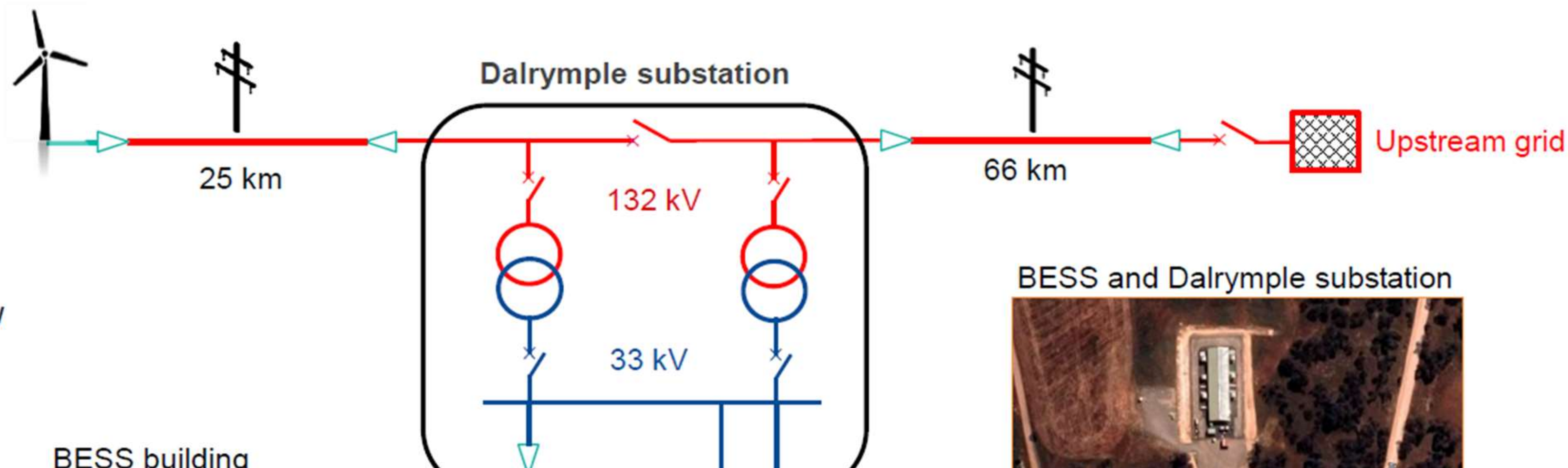
Innovation Awards

Energy Networks Australia:
2019 Industry Innovation Award

South Australia Premier's Award:
2019 Energy Sector - Transformational Innovation

Integration at ElectraNet's Dalrymple substation

Wattle Point Wind Farm 91 MW
(55 x Vestas V82 directly
coupled induction generators)



BESS building

BESS and Dalrymple substation

Images (left to right): Wind farm: Flickr https://www.flickr.com/photos/daveclarkecb/
BESS: Courtesy ElectraNet
BESS and substation: Courtesy Google Maps

Virtual Inertia vs Fast Frequency Response (FFR)

What is the difference and why does it matter?

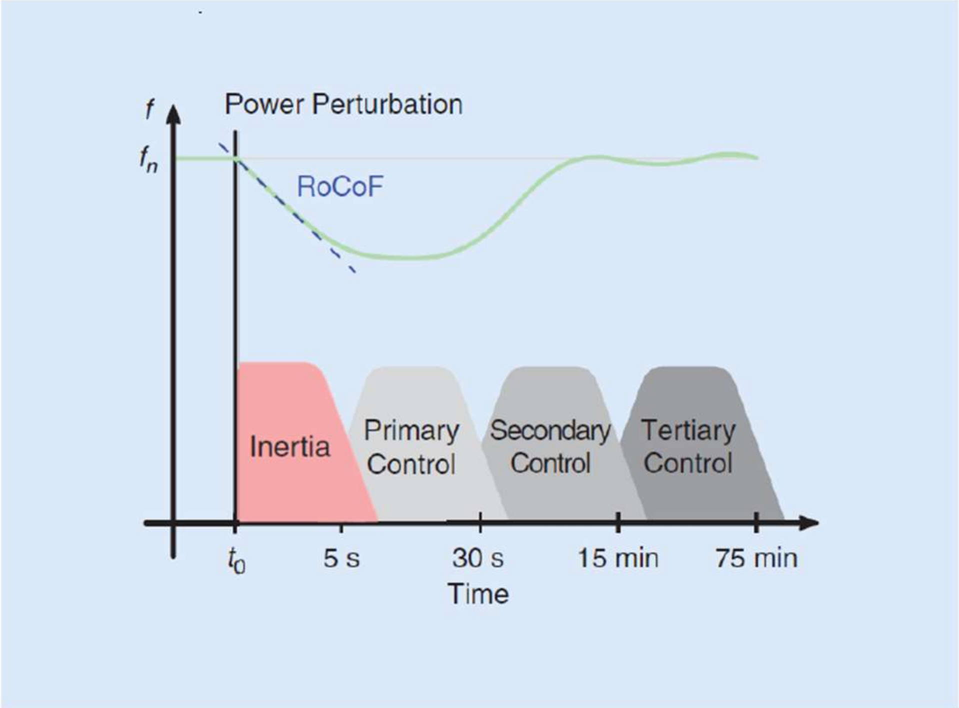
Fast Frequency Response (FFR)

Fast frequency response is not inertia, but an important service

FFR and inertia are technically different services:

- FFR is a response in 2 seconds or less but does not have a single definition globally
- FFR isn't an inherent response
- FFR requires measurement, detection, processing, filtering and activation – inertia does not
- FFR is an important service to compensate for less inertia in the power system but is does not replace inertia
- FFR can falsely trigger or fail to trigger when attempting to measure frequency and RoCoF very quickly after a major power system fault
- FFR can be provided by grid following and grid forming inverters; inertia only by grid forming inverters

Inertia and FFR in the context of frequency support:



RoCoF = Rate of change of frequency

E. Unamuno, J. Paniagua, J.A. Barrena "Unified Virtual Inertia for ac and dc Microgrids. And the role of interlinking converters.", IEEE Electrification Magazine, December 2019
AEMO: (Fast Frequency Response in the NEM Working Paper, Future Power System Program, 2017) (Inertia requirements methodology)

Virtual Inertia is driven by same physics as synchronous inertia

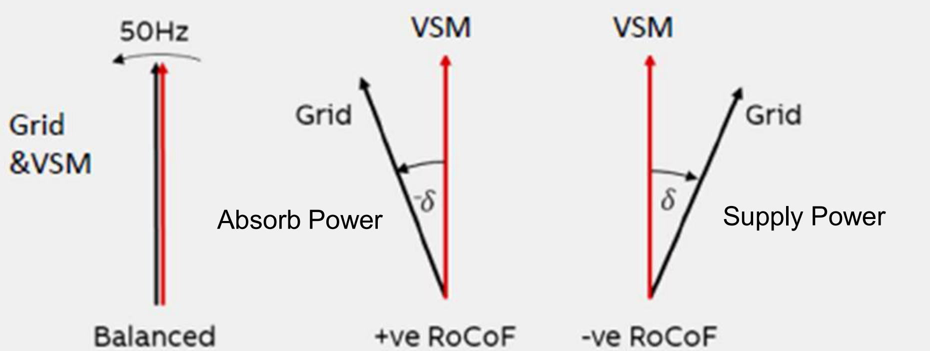
Response equivalent but tunable

Power transfer equation:

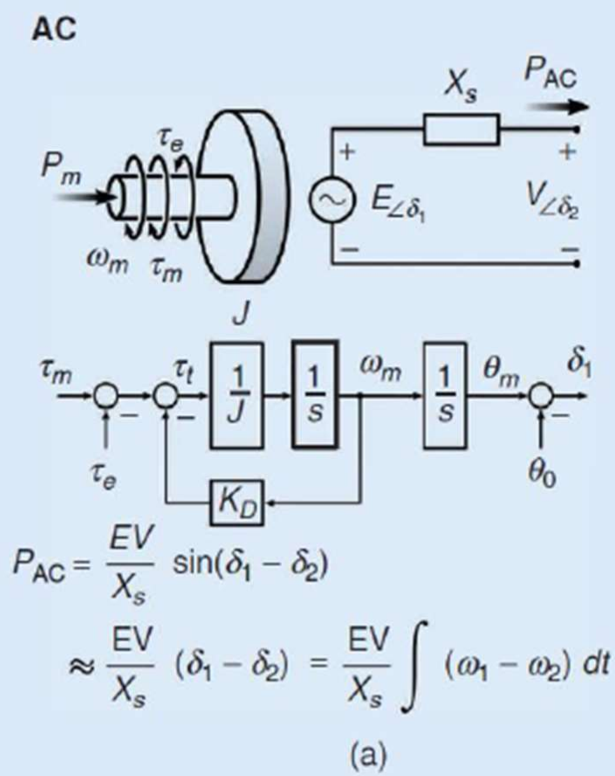
$$P = \frac{V_s V_r}{X} sin\Delta\delta \;\propto\; \Delta\delta$$

where:

- Vs is the sending end voltage (BESS internal voltage)
- Vr is the receiving end voltage (Grid voltage at coupling terminals)
- X is the coupling impedance
- $\Delta\delta$ is the phase angle between the two voltage sources (internal BESS voltage and voltage at the coupling terminals)



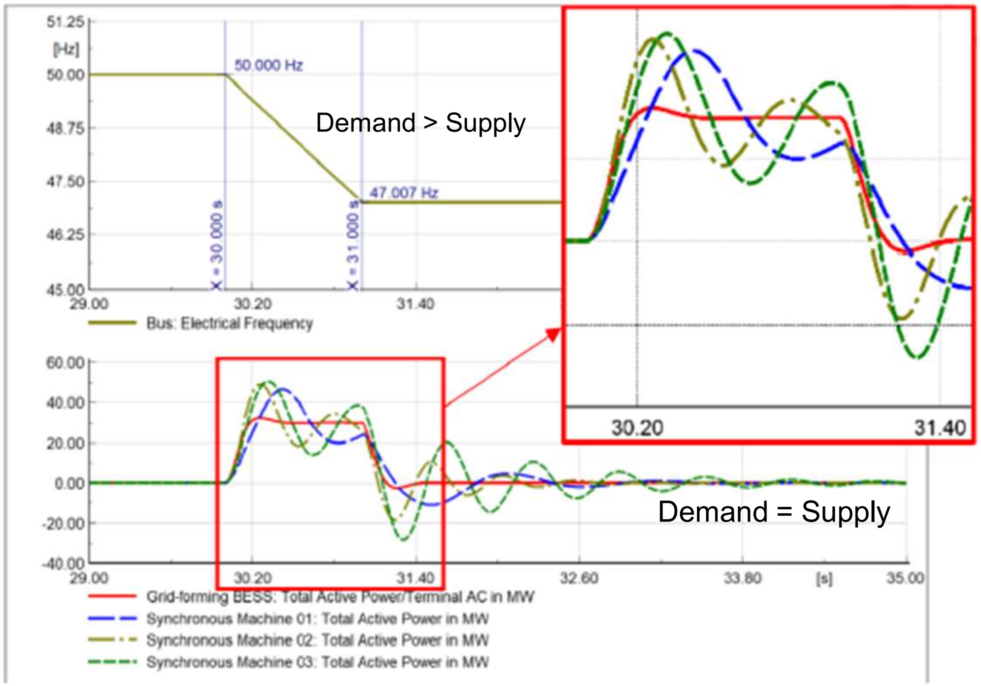
Dynamic model of Synchronous machine:



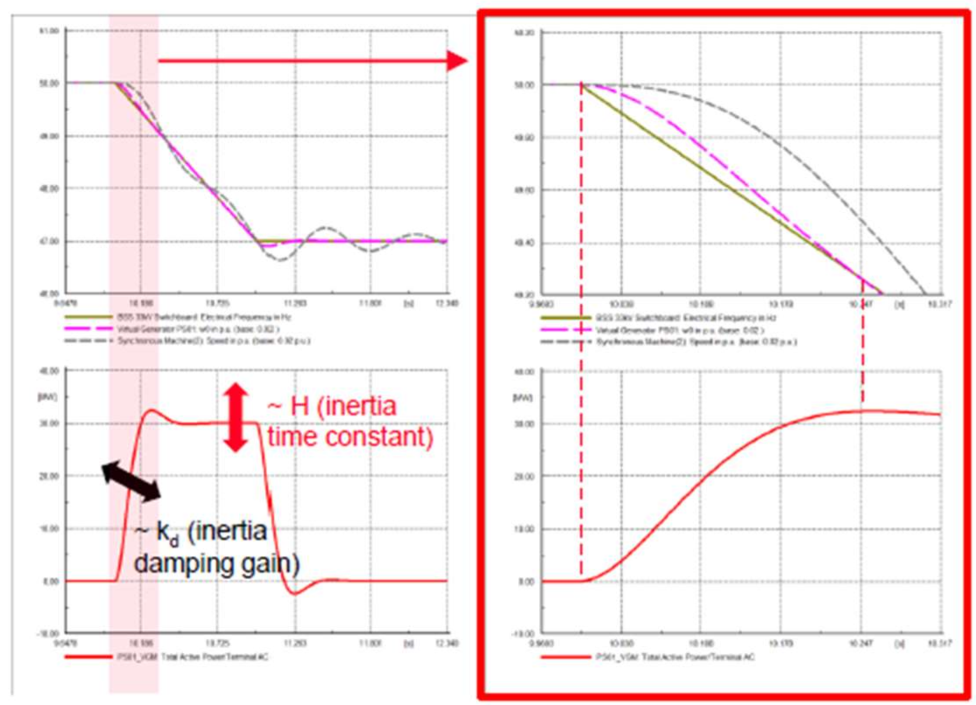
E. Unamuno, J. Paniagua, J.A. Barrena “Unified Virtual Inertia for ac and dc Microgrids. And the role of interlinking converters.”, IEEE Electrification Magazine, December 2019

Virtual Inertia – Tunable inertia

RoCoF response of VSM vs Synchronous Machines:



The difference between the internal speed & grid frequency drives response:



RoCoF = Rate of Change of Frequency; VSM = Virtual Synchronous Machine

Source : Hitachi Energy

Real World Results

ESCRI Dalrymple – World’s first large scale utility connected Grid Forming BESS

Unplanned islanding without the wind farm

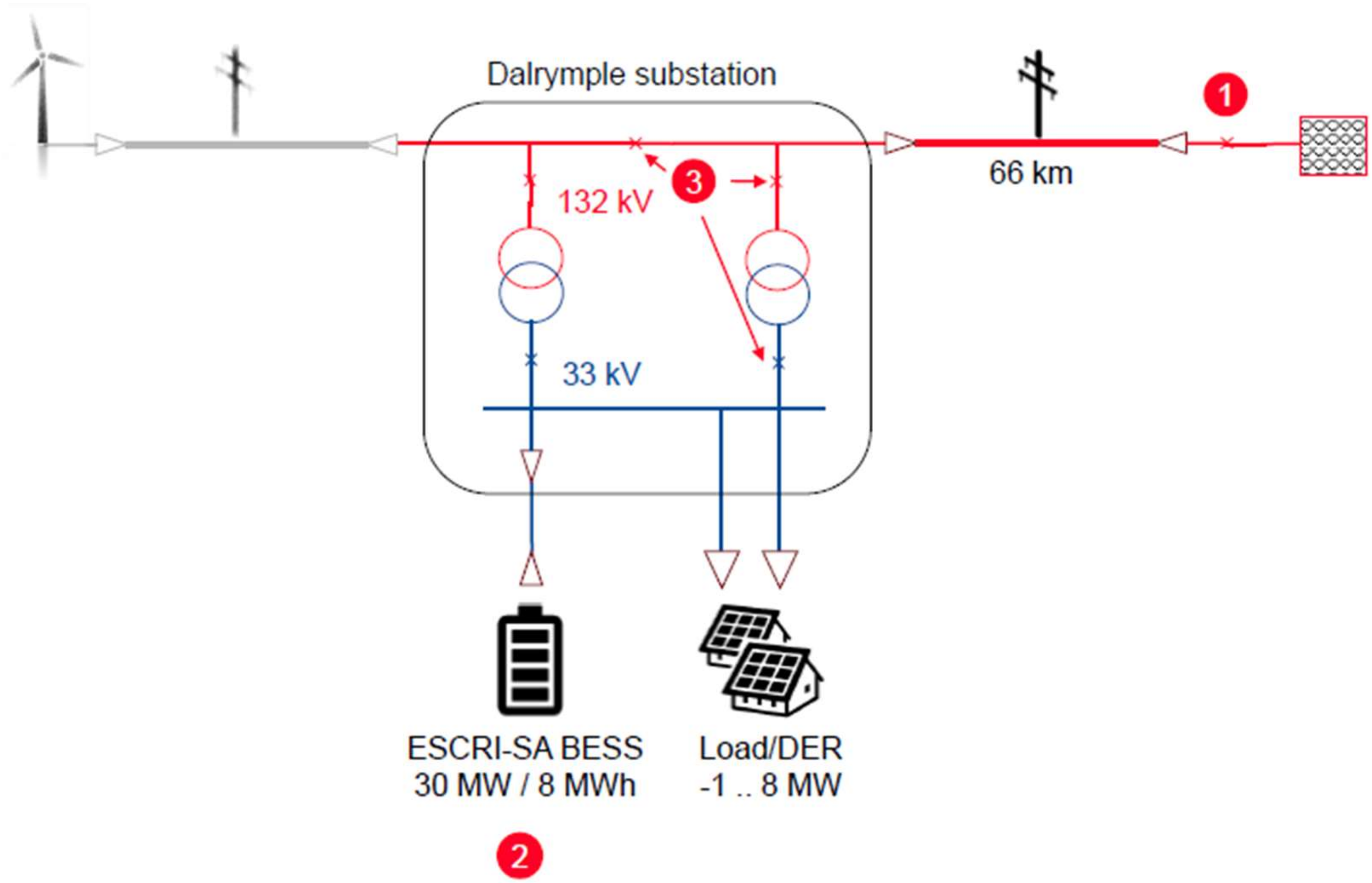
Sequence of events

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
2. BESS becomes the only grid forming source in the now islanded microgrid and instantaneously supplies the area
3. Some 80 msec later the protection system at Darlymple disconnects the upstream line



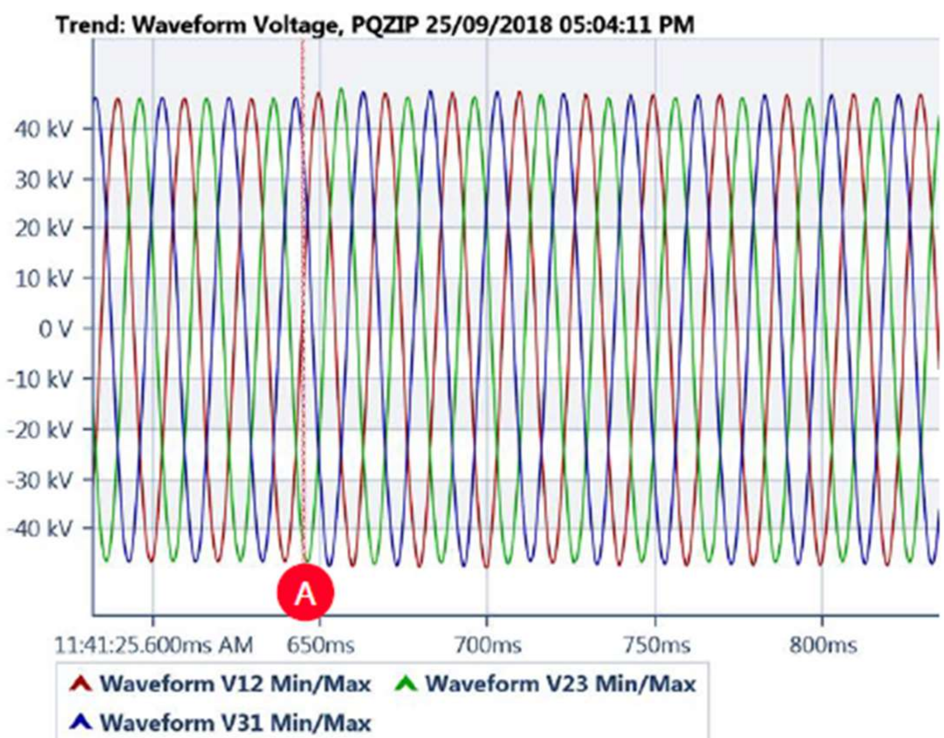
NEM = National Electricity Market

Source : Hitachi Energy

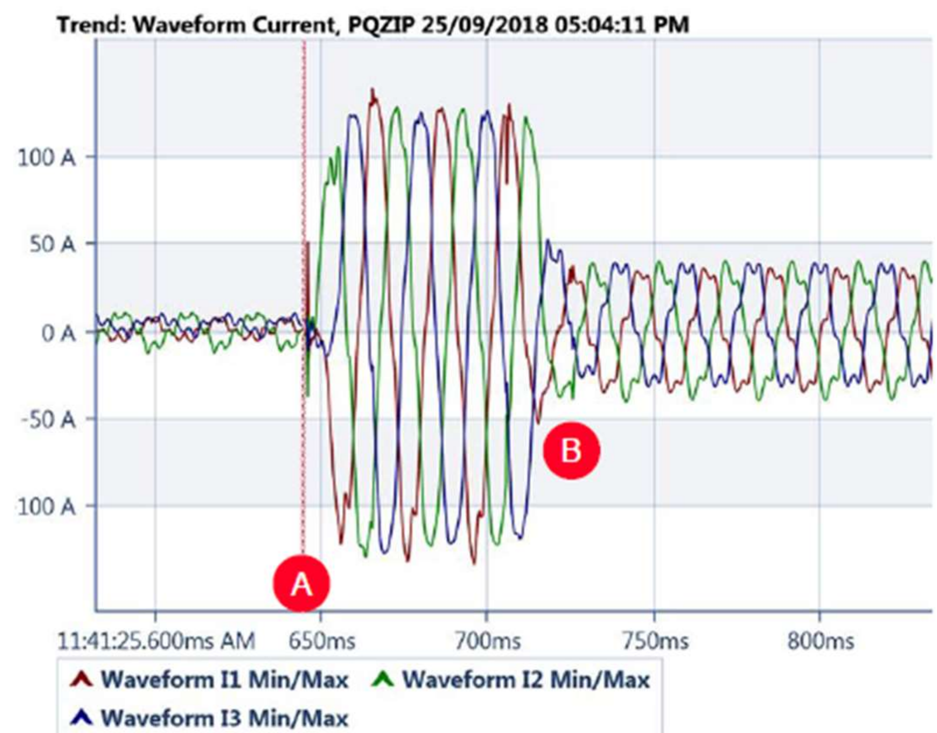
Unplanned islanding without the wind farm

The islanding instant – BESS voltage and current waveforms

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



B Upstream line is disconnected



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

Source : Hitachi Energy

Unplanned islanding with the wind farm

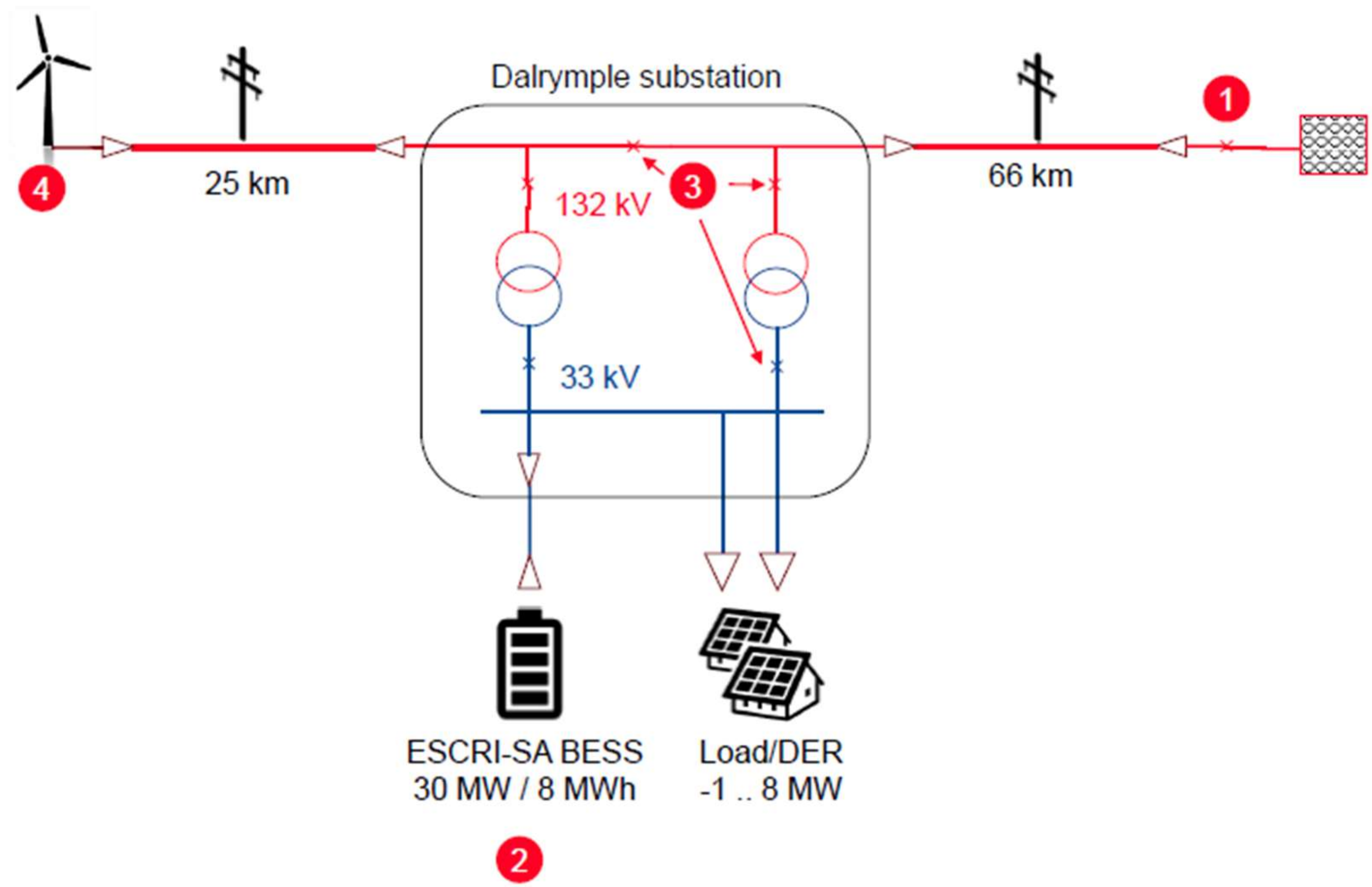
Sequence of events

Pre-event conditions

- Wind farm output ~ 80 MW
- BESS running unloaded on the NEM
- Local load ~ 4 MW
- All breakers closed

Event

1. 132 kV breaker at the upstream substation opens
2. BESS becomes the only grid forming source in the now islanded microgrid and instantaneously supplies the area
3. Some 80 msec later the protection system at Dalrymple substation disconnects the upstream line
4. At about the same time protection at the wind farm trips 4 out of 5 collector groups (~80% of capacity)



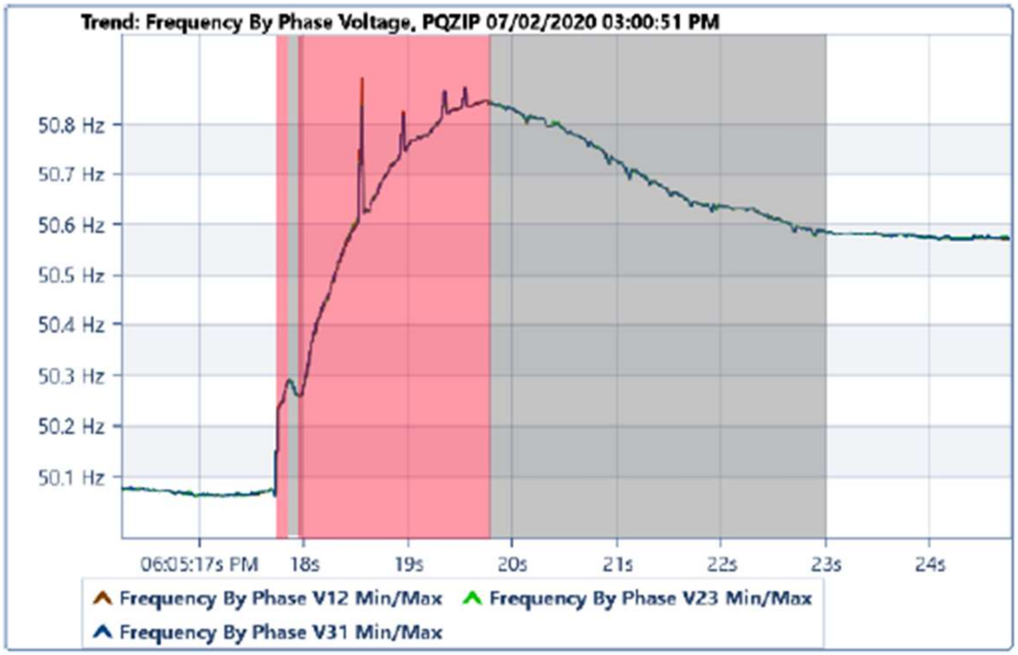
NEM = National Electricity Market

Source : Hitachi Energy

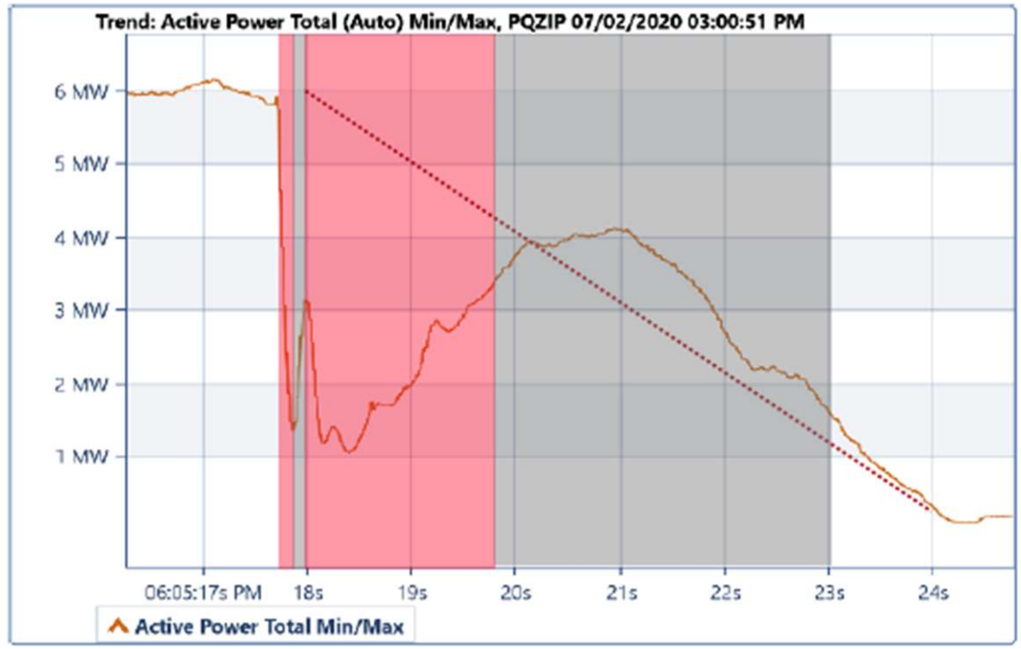
South Australia Islanding Event: Inertia Response

Grid forming inverter responds to frequency change in the network – 8-second view

RoCoF event in South Australia over 8s (red positive RoCoF, grey negative RoCoF)



Active Power response over 8s – Inertial response initially to grid frequency (left) prior to FCAS setpoint (red dotted line) on secondary controller driving 6 second FCAS market response as per bid 6MW bid



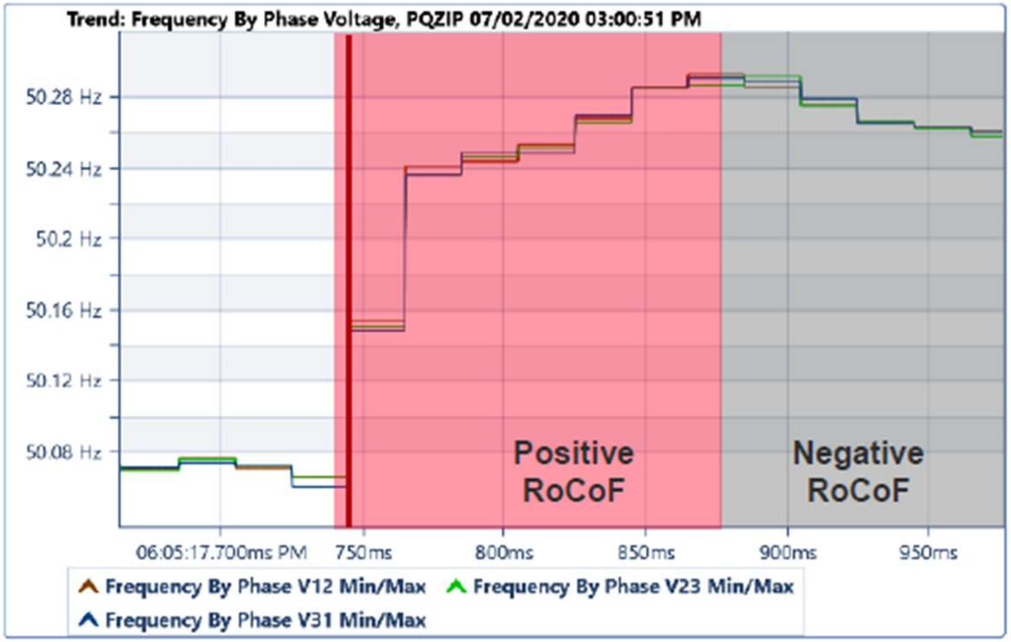
RoCoF = Rate of change of frequency

Source : Hitachi Energy

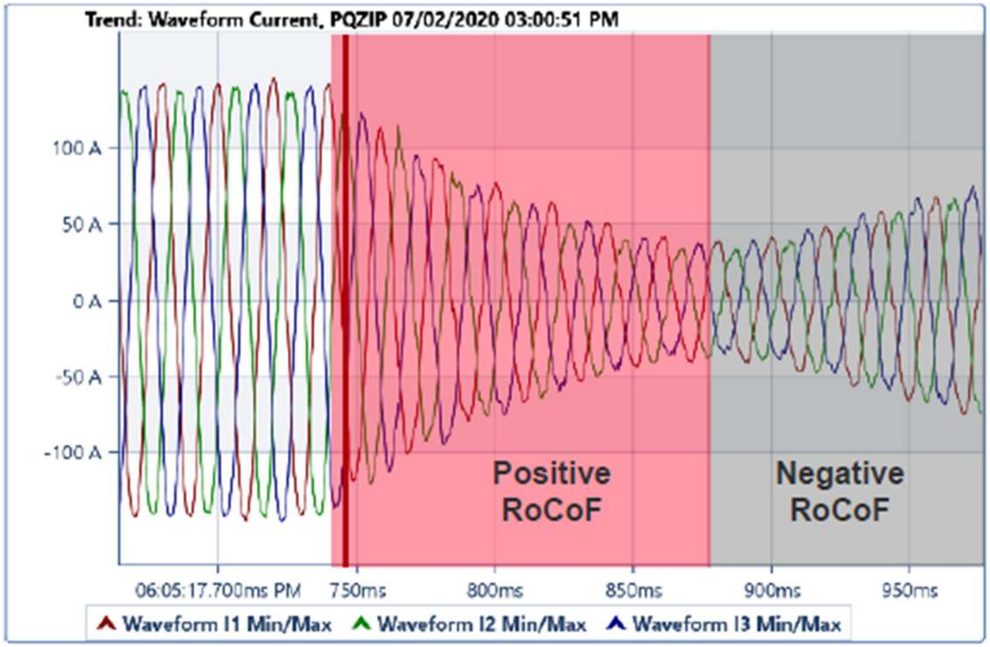
South Australia Islanding Event: Inertia Response

Grid forming inverter responds to frequency change in the network – 8-second view

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 with its purely inertial response in this timeframe



RoCoF = Rate of change of frequency

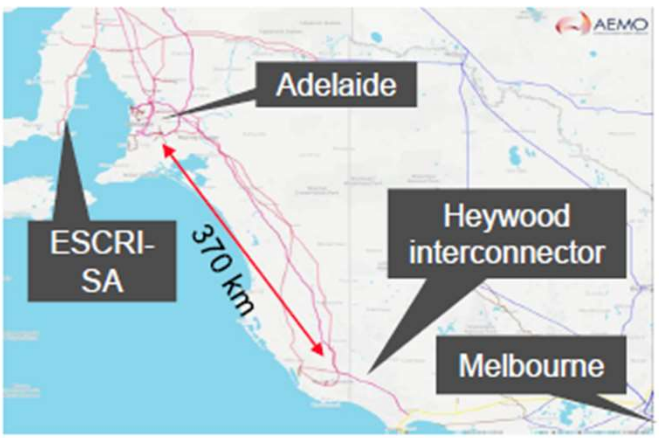
Source : Hitachi Energy

South Australia Islanding Event: Inertia Response

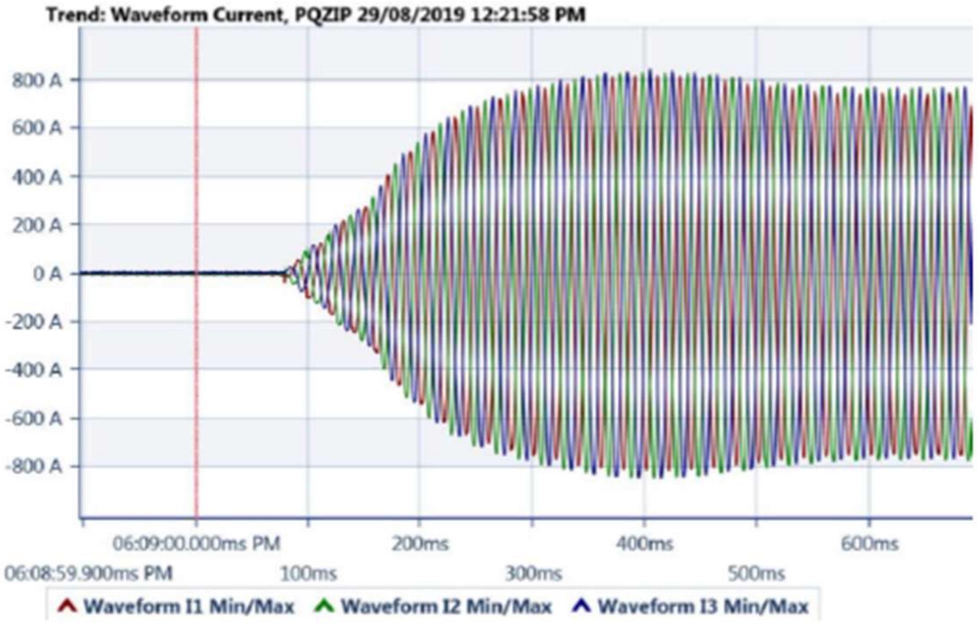
Grid forming inverter responds to frequency change in the network – 8-second view

System Integrity Protection Scheme (SIPS):

- Designed to prevent SA system separation from the NEM
- Acts to pre-empt a large RoCoF event
- Based on measurements taken along the Heywood interconnector
- Takes over measurement/detection for Fast Frequency Response
- Triggers grid-scale BESS to inject power and, if required, sheds load to restore balance between supply and demand
- Requires the BESS to inject full power in 250 msec



BESS grid-parallel fast response: 30 MW in 250 msec



SA = South Australia
Source: ElectraNet

Source : Hitachi Energy

Supporting Renewable Interconnections

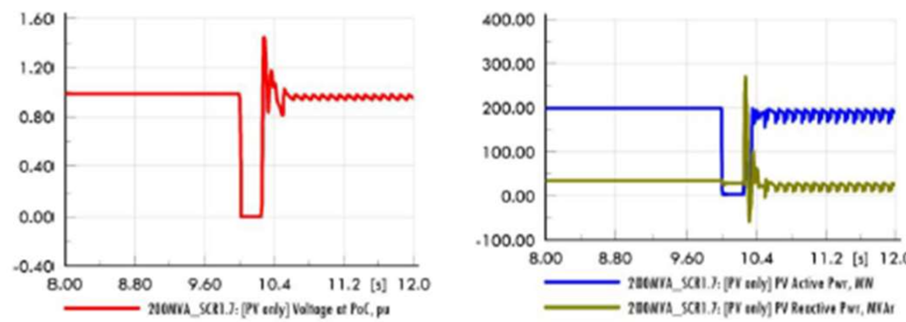
Connecting and operating higher levels of renewable energy

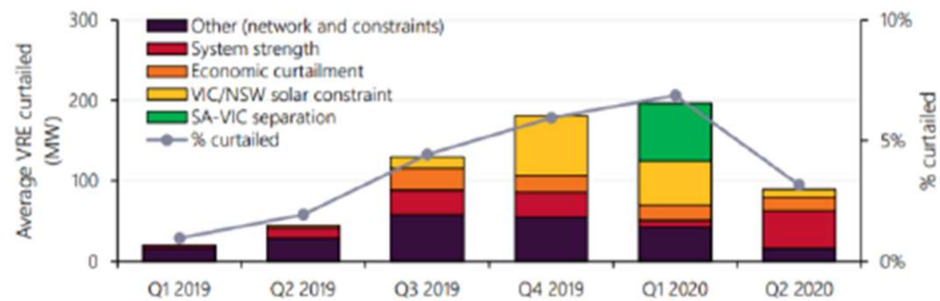
Renewable Interconnection Support

Low system strength

- Low system strength presents significant challenges to connecting and operating renewables
- The viability of renewable energy projects can be jeopardised due to the time and cost implications of "remediation measures"
- Current "remediation measures" include synchronous condensers
- Synchronous condensers are a very good technical solution but unfortunately their services can't be monetized at present
- Grid Forming BESS offers the same technical services but also opens up access to revenue streams

Lack of system strength prevents interconnection and increases renewable curtailment





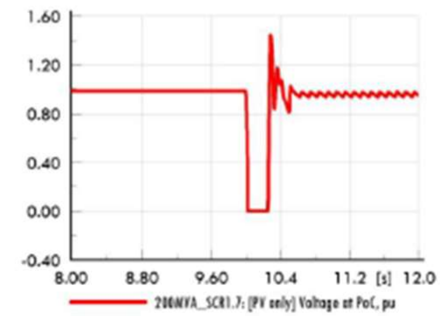
Verified PSCAD model from ESCRI Dalrymple demonstrates technical merits for system strength

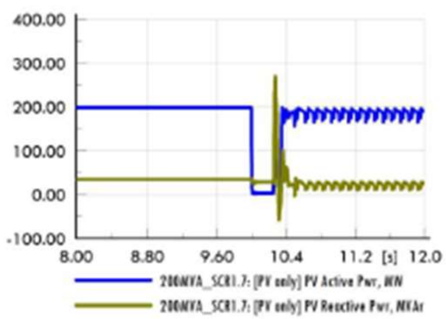
Source: https://aemo.com.au/-/media/files/major-publications/qed/2020/qed-q2-2020.pdf?la=en&hash=D1A82334D16E915FCB1B628640A05223

Renewable Interconnection Support – Modelling in PSCAD

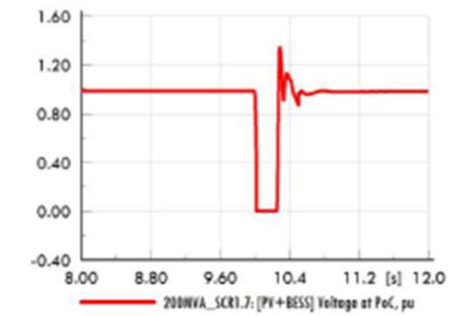
SCR = 1.7

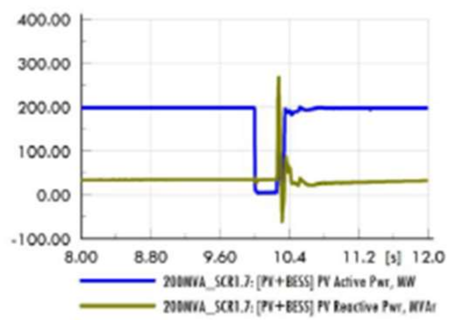
200 MVA PV Plant



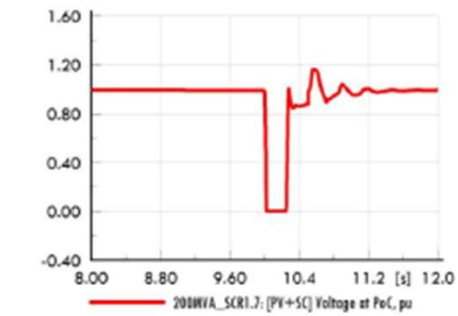


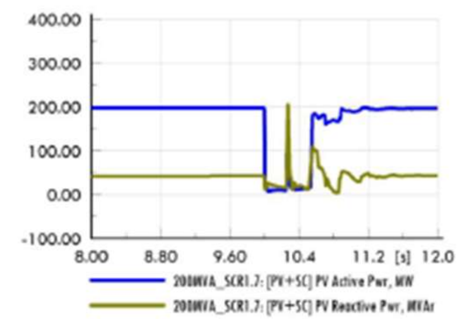
200 MVA PV + 30 MVA PowerStore™





200 MVA PV + 32 MVA Sync Con





SCR = Short Circuit Ratio

Post Fault instability resolved by PowerStore™ or Synchronous Condenser

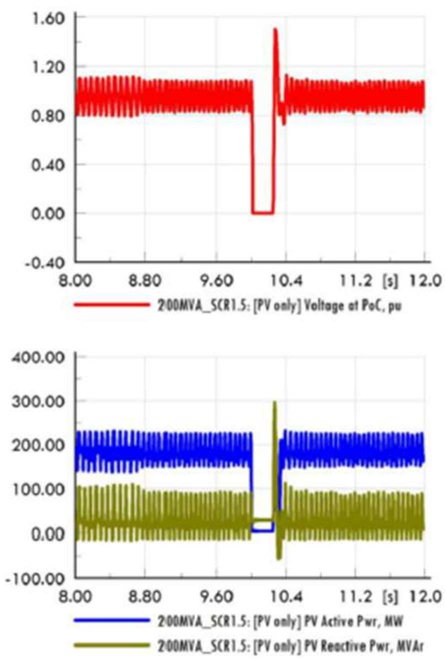
Source : Hitachi Energy

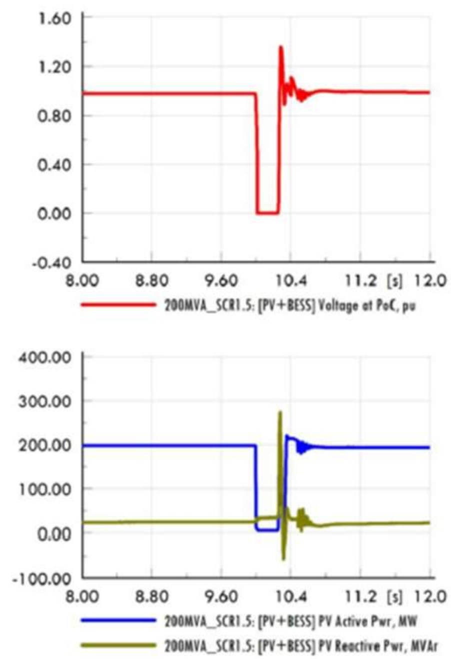
Renewable Interconnection Support – Modelling in PSCAD

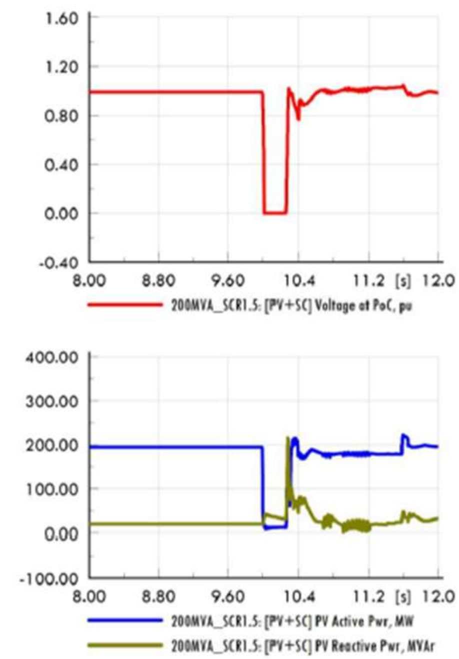
IEEE PES Power & Energy Society® | IEEE

SCR = 1.5

200 MVA PV Plant	200 MVA PV + 30 MVA PowerStore™	200 MVA PV + 32 MVA Sync Con







SCR = Short Circuit Ratio

Steady-State and Post Fault instability resolved by PowerStore™ or Synchronous Condenser

Source : Hitachi Energy

Economics & Commercial Models

Connecting renewables in an economically sustainable way

VSM - A New Technology Class

How do these solutions fit together?

Grid Stability

Service	Analogue Technology	Digital Technology
Reactive Power	SVC	STATCOM
Real Power	Synchronous Condenser*	VSM*

* Both Synchronous Condensers and VSM can do reactive compensation as a secondary service

	Synchronous Condenser	VSM
Fault Current	~6 times rating	2-3 times rating
Inertia (MWs/MVA)	Fixed 1-10 sec (with flywheel)	Configurable 0 to >32 sec

System strength is about more than fault current. It is a combination of fault current, inertia and reducing the impedance to a voltage source and requires modelling to compare synchronous machine and VSM sizing.

You can't just compare fault current contribution

SVC = Static Var Compensator; VSM = Virtual Synchronous Machine 44

Source : Hitachi Energy

What solution is appropriate?

Depending on your place in the market, regulation and application, there are a range or technologies

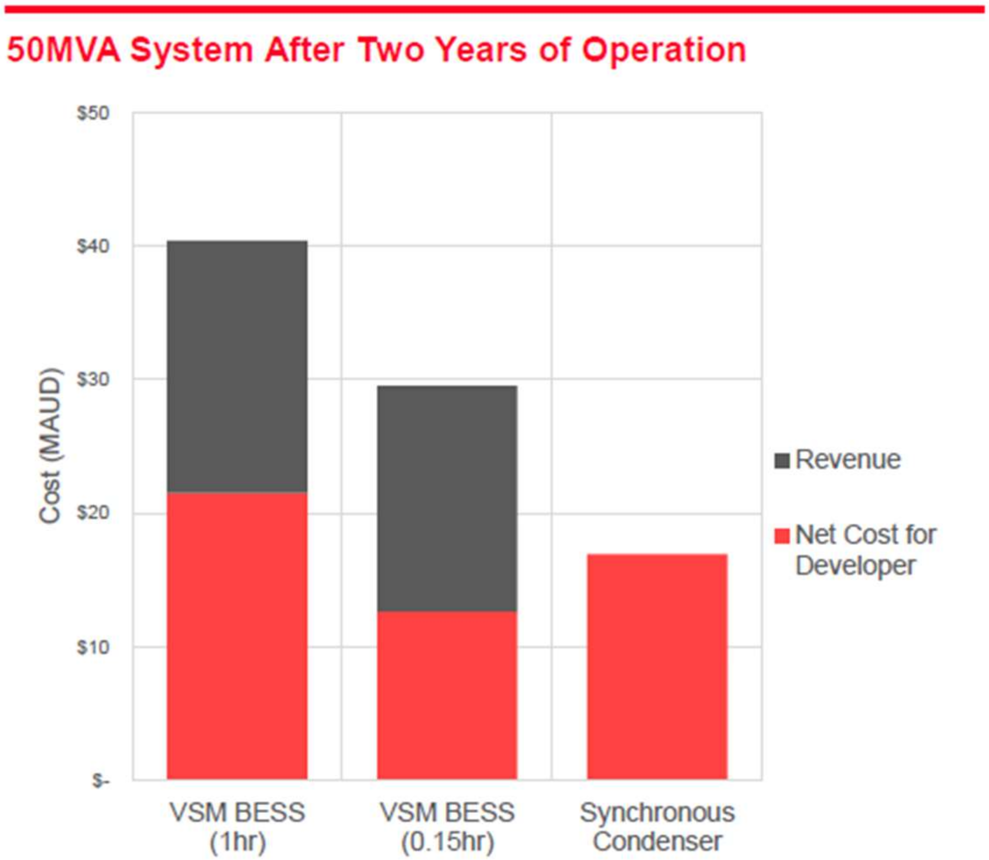
Market Services Focus ⟷ Regulated Services Focus

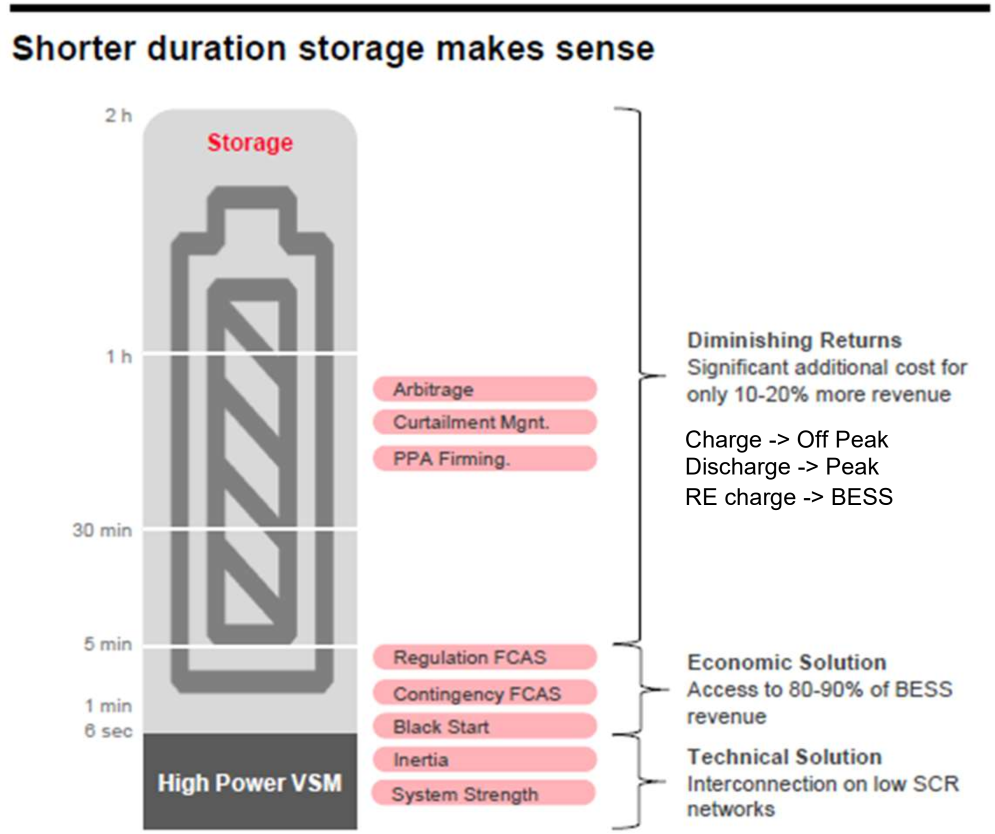
30MVA System

	Grid Following BESS	Grid Forming BESS (VSM)	Synchronous Condenser
Duration	**1 Hour**	**20 min**	**A few seconds**
Market Rev. 2019	AUD 6M	AUD 5M	-
Regulated return	-	AUD 1.3M	< 10%
Low SCR Support	No	Yes	Yes
Payback	~ 6 yrs	~ 5 yrs	> 10 yrs
	Developer Owned	Hybrid Ownership Developers + Utilities	Utility Owned

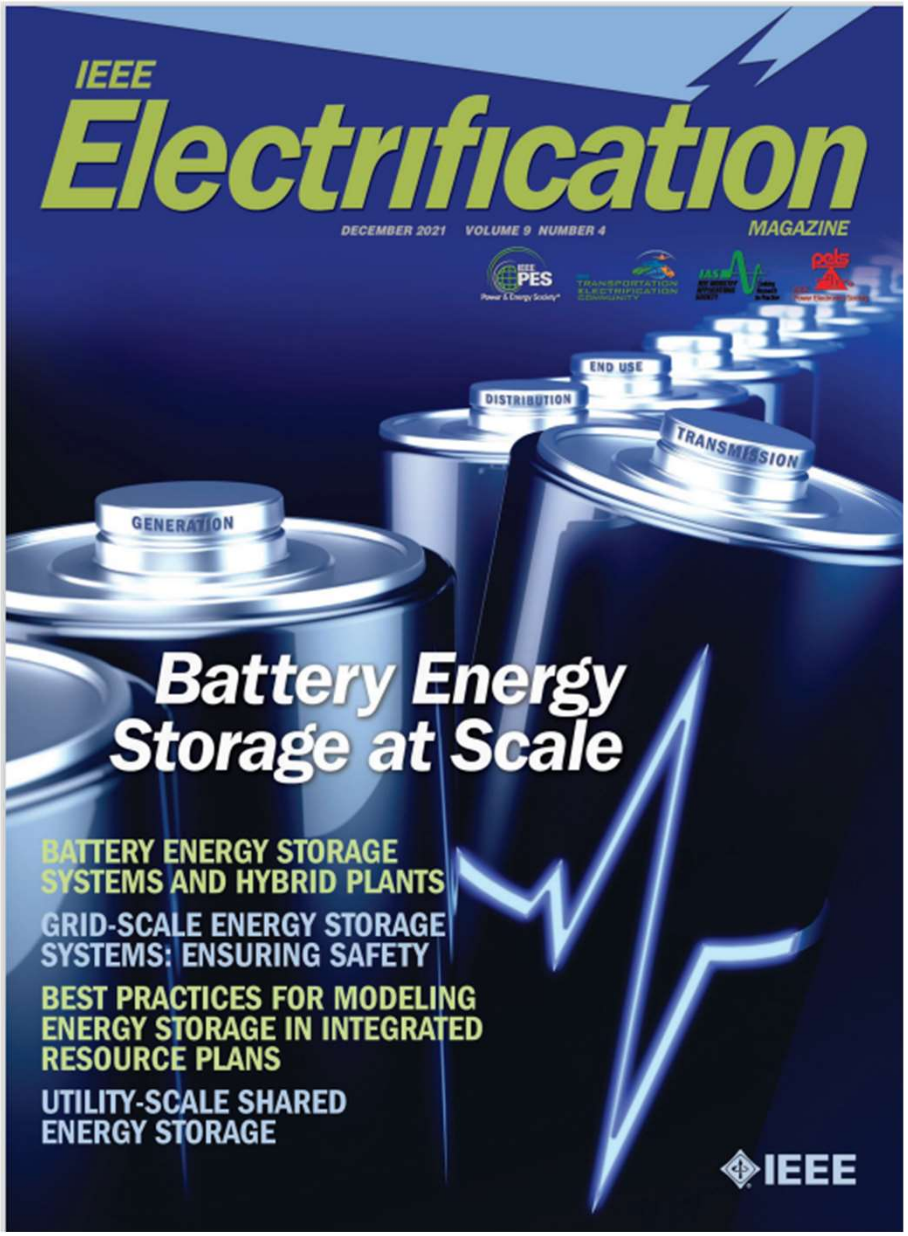
Source: ARENA project costs for Dalrymple 30MVA/8MWh and Ballarat 30MVA/30MWh BESS. Revenue based on Dalrymple and AEMO quarterly energy dynamics Q2 2020
https://aemo.com.au/-/media/files/major-publications/qed/2020/qed-q2-2020.pdf?la=en&hash=D1A82334D16E915FCB1B628640A05223

Commercial solutions to low SCR interconnections





SCR = Short circuit ratio, FCAS = Frequency control ancillary service, VSM = Virtual Synchronous Machine
Net cost equals installed cost plus OPEX minus revenue. Pricing based on 2020 market data.
Source:https://aemo.com.au/-/media/files/major-publications/qed/2020/qed-q2-2020.pdf?la=en&hash=D1A82334D16E915FCB1B628640A05223



The Future of Electricity Storage:

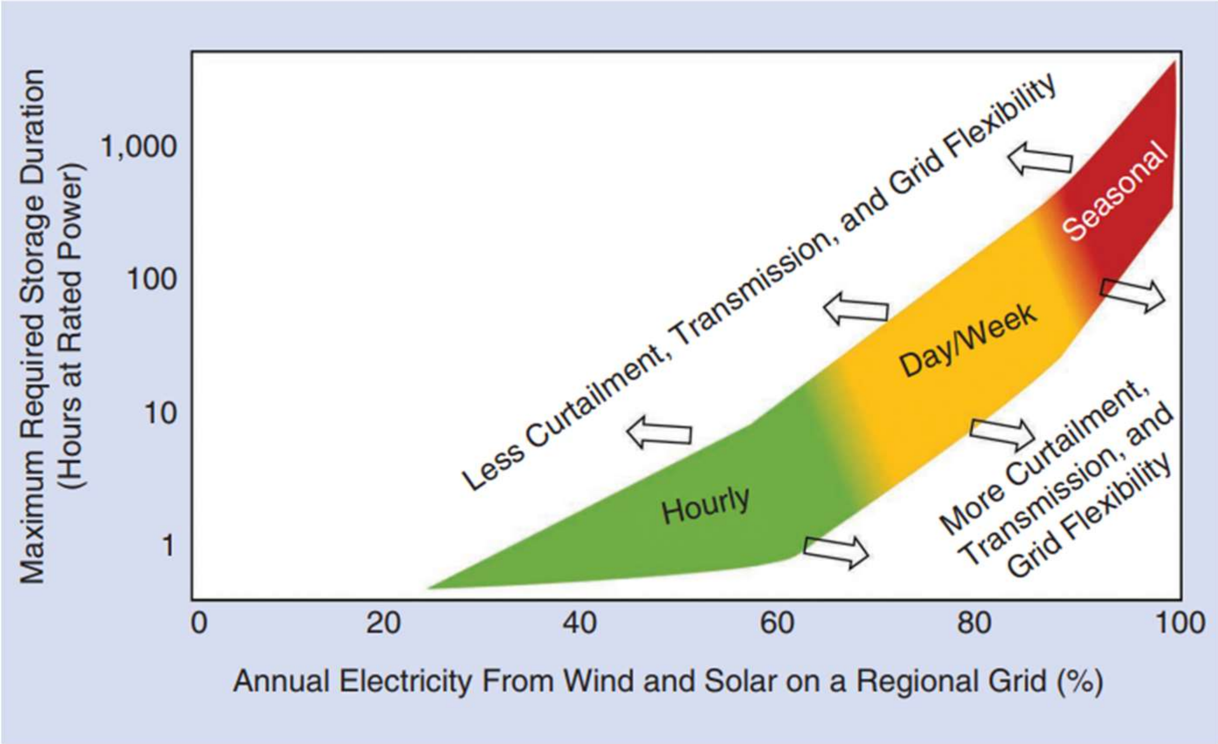
From Hours to Days

LDES (Long-Duration Electricity Storage) Technology

LDES (long-duration electricity storage) technology focused on >12 h of the duration of battery energy storage.

These are a number of additional applications

- **Resilience** market could be met by an LDES technology
- **Secure** self-generation for off-grid individuals
- **Managing** transmission and distribution congestion.



A semiquantitative overview of the maximum duration of electricity storage needed to ensure demand is met at all times versus the fraction of annual energy from variable generators, such as wind and solar (Albertus 2020)

The annual from renewable electricity on a regional grid

Source : IEEE Electrification Magazine / December 2021

The World's Largest Standalone Lithium-ion BESS

The MOSS350 project at Moss Landing represents an expansion project for Vistra Energy's Moss Landing Energy Storage Facility.

The world's largest standalone lithium-ion BESS (400MW/1,600MWh).

Source: Vistra Corp.

Reference Cases

Utilities (1/3)

ElectraNet Pty Ltd

Transmission company which operates 5,591 km of high-voltage grid in South Australia

Installed in a complex and large-scale energy network in South Australia, this grid edge solution strengthens the power grid and improves reliability services, including fast-acting power response to better balance the overall network.

GVEA

Powering through the extreme environment of Alaska for more than 18 years

GVEA BESS has reduced outages in the Fairbanks area by over 60%. The power conversion system enables the BESS to power the city of Fairbanks for seven minutes and provides frequency regulation even for the larger Railbelt transmission.

EKZ

A pioneering 1 MW BESS project the largest of its kind in Switzerland and the first in Europe.

By improving power quality and grid stabilization, the system helps to preserve 250 kWh of energy – the equivalent consumed by a four-person household in 40 days.

Southern Cal Edison

Tehachapi Project was the largest Li-ion BESS operating at the Monolith Substation in North America and one of the largest in the world

Assess the capability and effectiveness of storage to support 13 operational applications and Sufficient to power between 1,600 and 2,400 homes for four hours

Source : Hitachi Energy

Utilities (2/3)

Kaua'i Island Utility

To help Hawaii reach its ambitious renewable energy targets by providing grid services such as capacity firming and frequency regulation

BESS value stacking co-located with solar PV, utilizing existing grid connection, thus increasing project value, revenue streams and grid stability

Ray Power

To provide fast response frequency regulations and avoid continuous adjustments on the turbine valve of PuZhou 300 MW coal fired power plant in Shanxi province, China.

Reduce the adjustment frequency of valve in turbine DEH and the probability of failure, Extend the service life of the generator and Increase earnings of plant on frequency modulation function

Shin Chitose Solar

To comply with local grid codes to reduce power fluctuation and improve renewable integration

Enabling Shin Chitose Solar plant to adhere to the stringent grid code requirements of a ramp rate of ±1%/minute of local utility, Ensuring reliable integration of renewables into the main power grid and Helping Shin Chitose plant to generate power to 11,000 local households

Snohomish County PUD

A state-of-the-art microgrid with solar PV, generator and battery storage with electric vehicle-to-grid (V2G) integration

The Arlington Microgrid demonstrates all the things a microgrid can do to support an electrified future—from grid stabilization to V2G integration to ancillary services to operation on 100% renewable power.

Source : Hitachi Energy

Utilities (3/3)

ELES d.o.o.

Project with local TSO to test different applications in urban area to prevent power outages during grid failure

The system ensures the quality electricity through voltage dips, mitigation measures, and provides frequency control to electricity transmission system operator

Sembcorp and NTU

A flagship research project between Sembcorp and Nanyang Technological University (NTU)

To develop a Virtual Power Plant (VPP) by deploying a BESS connected and powered by the grid and/or PV to provide ancillary services to Singapore Power Grid

PEA Betong

The microgrid gives a new way to address the problems in Betong district

Overcome recent grid reliability challenges, as outages in the area have increased due to terrorist activities, damaged equipment, unplanned maintenance or weather events. Improve the reliability and quality of power in coverage area and Reduce levels of greenhouse gas and CO2

TVO

One of the largest BESS in Europe and by far the largest BESS in the Nordic region

Enables the 1.6 GW Powerplant to operate at 100% output power in combination with several Demand Response Assets (BESS, Gas Turbines, Industrial plants) will support the grid in case an of unexpected power dropout from the plant and Reserve Market participation.

Source : Hitachi Energy

Island Utilities

Porto Santo

Electricidade de Madeira sought to increase meet the enhanced electricity demand during summers with a high inflow of tourists

Increase the contribution of renewables in the energy mix from 15 to 30 percent

Stabilize the power system to address frequency and voltage fluctuations

Grand Bahama

The grid modernization at the Grand Bahama Power Company (GBPC)

Address the frequency and voltage fluctuations due to the power requirements of the harbor operations and enable the Island's electricity system to integrate additional renewable energy sources

Jamaica Public Service

A game changer for the renewable energy market in Jamaica

The 24.5MW PowerStore ensures grid stability and supports Jamaica's Vision 2030 Renewable Energy Goal. It is the largest hybrid flywheel/battery energy storage system in the world

WEB Aruba N.V

This microgrid solution allows the integration of a complex energy mix and maximizes the use of renewable energy

Enabling WEB Aruba to meet the peak demand (134 MW) of the island. The embedded software, automation and control technologies also facilitate 24-hour forecasts and enable a more resilient grid for the island

Source : Hitachi Energy

Industrial facilities

Woodside Energy Ltd.

Largest operator of oil and gas production in Australia

Developed to support on offshore platform, this solution greatly reduces dependency on diesel, lowering gas consumption by 2000 tons/year, while also lowering CO_2 emissions by 5%.

Alinta Energy

One of the largest microgrid installations in the world, Alinta's Roll Hill remote mine needed a reliable and stable power supply to reduce interruptions and ensure worker safety

Increased energy efficiency, Ensure continuous operations of Roll Hill mining, BESS provides spinning reserve as replacement for gas turbine operation

ITM Banpu Group

Indo Tambangraya Megah (ITM)'s Bontang Mine in Indonesia

dramatically reduced fuel consumption & CO_2 emissions. It maximizes renewable penetration, driving both energy efficiency & sustainable growth, with improved reliability

Rio Tinto

The largest off-grid energy storage system at Tom Price in Australia will provide virtual spinning reserve

To switch expensive and highly polluting gas generation off

CO_2 reduction, reduced fuel and running costs and enhanced power system stability and reliability

Source : Hitachi Energy

Dalrymple: Utilities

Customers of ElectraNet often experienced reliability issues due to lightening strikes. The utility reduced outages from 11 hours down to 30 minutes in the first two years of operation.

The solution improved network reliability, minimizing renewable curtailment, and brought in new revenue to achieve payback within two years.

Web Story / Business Case

Blog / In the media

ElectraNet

About the project

- **Project name:** ESCRI-SA Dalrymple BESS
- **Location:** Australia
- **Customer:** ElectraNet
- **Completion date:** 2018

Solution

- Wind (91 MW)
- Distributed rooftop solar (3+ MWp)

- PowerStore Battery (30 MW / 8 MWh)
- e-mesh Control System

Customer benefits

- Improve the overall reliability of power supply in the region
- Deliver enough power to run around 400 homes for 24 hours without the input from renewable generators
- Uninterrupted power supply during transmission line outage

Source : Hitachi Energy

Woodside: Industrial facilities

The Woodside platform is located 135 km offshore in highly rugged conditions. An advanced grid edge solution was implemented to meet the complex needs of remote management, operations and service.

This solution reduces dependency on diesel, lowering gas consumption by 2000 tons/year and CO2 emissions by 5%.

Press release / In the media

Video / Infographic / Fact Sheet

Woodside

About the project

- **Project name:** Goodwyn A
- **Location:** Northwest Australia
- **Customer:** Woodside Energy
- **Completion date:** 2017

Solution

- Gas Turbines (5 x 3.5 MW)
- PowerStore Battery (2.8 MW / 1.43 MWh)
- e-mesh Control System
- Remote monitoring

Customer benefits

- Providing ‘spinning reserve’ to aid short term backup
- Minimize the dependency on diesel generator
- Reduce fuel gas consumption by 2000 tons per year and CO_2 emissions by 5%

Source : Hitachi Energy

Skagerak Arena: Commercial facilities

A first-of-its-kind project, Skagerak Energilab includes solar-powered grid edge solution. The system not only powers floodlights in the stadium, but also provides the neighborhood with locally produced electricity.

Together this solution sets Skagerak up for new opportunities like Vehicle to Grid (V2G) integration.

Press release

About the project

- **Project name:** Skagerak Arena
- **Location:** Skien, Norway
- **Customer:** Skagerak Energi
- **Completion date:** 2019

Solution

- Solar PV (800 kWp)
- PowerStore Battery (800kW / 1MWh)
- e-mesh Control System
- e-mesh EMS energy management system

Customer benefits

- Optimal integration of renewables and energy management with advanced grid automation
- Optimal use of renewable (PV) assets even when sun light is low
- Reduced energy import and peak load cost
- Availability of locally produced electricity to the surrounding neighborhoods

Source : Hitachi Energy

Robben Island: Remote Communities

Robben Island, a UNESCO World Heritage Site and former prison that receives up to 2,000 visitors a day, is drastically reducing their diesel consumption by deploying microgrid solution.

The island now operates on solar power for at least nine months out of the year. Due to treacherous currents, it is safely operated remotely.

Web story / Video

Infographic / Fact Sheet

About the project

- **Project name:** Robben Island
- **Location:** South Africa
- **Customer:** Department of Tourism, South Africa
- **Completion date:** 2017

Solution

- Solar PV (667 kWp)
- Diesel (1 x 500 kW)
- PowerStore Battery (500 kW / 837 kWh)
- e-mesh Control System

Customer benefits

- Lower fuel costs and carbon emissions by 75 %
- Enabling the island to run on solar power for at least 9 months of the year
- Remote monitoring of the entire system from Cape Town
- Remote set-up eliminates the need to maintain a workforce on the island

Source : Hitachi Energy

Saha Industrial Park: Industrial park

Hitachi ABB Power Grids' battery energy storage system (BESS) is a critical part of Impact Solar Group's plans to develop the largest private microgrid in Thailand, creating a more sustainable and resilient industrial park.

The model balances generation from various distributed energy sources, builds in redundancy for future data center demand, and lays the foundation for a peer-to-peer digital energy exchange platform among the industrial park's customers.

Press release / In the media

IMPACT SOLAR

About the project

- **Project name:** Saha Industrial Park
- **Location:** Sri Racha, Thailand
- **Customer:** Impact Solar Limited
- **Completion date:** Estimated 2021

Solution

- Rooftop & Floating Solar PV (14MWp)
- Gas Turbines (200 MW)

- PowerStore Battery (500 kW / 680 kWh)
- e-mesh Control System

Customer benefits

- Maximized performance the integration of renewables and energy management with advanced grid automation
- Optimal use of renewable (PV) assets
- Energy Shifting (Charge during Off-peak and Discharge during On-peak)
- Power Quality support

Source : Hitachi Energy

PEA Betong: Utilities

The Betong district is a valley surrounded by mountains on the Malaysian border. With the power lines passing through forested areas, tree damage often causes interruption and outages, as well as challenges in power quality. It is difficult for PEA to identify the interruption causes and takes a long time to recover the system. The microgrid gives a new way to address the problems.

Press release

About the project

- **Project name:** Betong
- **Location:** Betong, Yala province, Thailand
- **Customer:** Provincial Electricity Authority (PEA)
- **Completion date:** Estimated 2022

Customer benefits

- Overcome recent grid reliability challenges, as outages in the area have increased 20-fold due to terrorist activities, damaged equipment, unplanned maintenance or weather events.
- Improve the reliability and quality of power in the Betong coverage area
- Reduce peak demand and power losses in the distribution line
- Reduce levels of greenhouse gas (GHG) and carbon dioxide (CO_2)

Solution

- Utility Grid-connected
- Diesel Generators (7 x 1 MW)
- VSPPs (7.5 MW)
- Solar PV (150 kWp)

- PowerStore Battery (4 MW / 6 MWh)
- e-mesh Control System
- e-mesh SCADA
- Distribution management System (DMS600)

Source : Hitachi Energy

Porto Santo: Island utility

Bloomberg

Business

World's First Smart Fossil-free Island Deploys Hitachi ABB Power

August 25, 2020 9:39 AM

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World's First Smart Fossil-free Island Deploys Hitachi ABB Power Grids' Solution

ZURICH, SWITZERLAND, Aug 25, 2020 - (JCN Newswire) - Hitachi ABB Power Grids has teamed up with Groupe Renault to give EV batteries a new lease of life and support the integration of renewable energy into the grid, as part of the 'Sustainable Porto Santo' initiative.

Porto Santo, a Portuguese island in the Madeira archipelago, is home to about 6,000 people. The Portuguese government aims to make Porto Santo the first smart, fossil- free island in the world and launched the "Sustainable Porto Santo" initiative. A fundamental part of this initiative is to increase the production of renewable energy. The challenge, however, is the unpredictable and intermittent nature of solar and wind energy.

Groupe Renault, Europe's largest electric vehicle (EV) maker, has provided the island with a sustainable energy transition platform comprising of a full ecosystem of EV solutions based on Vehicle-to-Grid technologies, and an aggregation platform to manage the flexibility provided by EVs and their batteries. When EV batteries reach the end of their useful first lives, they are either disposed, recycled or reused. At the end of their service life in electric vehicles, however, batteries may still retain 70-80 percent of their

Grid Edge Solution enables the island of Porto Santo to achieve clean energy goals

Source : Hitachi Energy

Porto Santo: Island utility

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About the project

- **Project name:** Porto Santo
- **Location:** Porto Santo Island – Madeira, Portugal
- **Customer:** Empresa de Electricidade da Madeira (EEM)
- **Completion date**: 2019

Customer benefits

- Increase the contribution of renewables in the energy mix from 15 to 30 percent
- Stabilize the power system to address frequency and voltage fluctuations
- Reliable power supply, supported by renewable energy
- Meet the enhanced electricity demand during summers with a high inflow of tourists

Solution

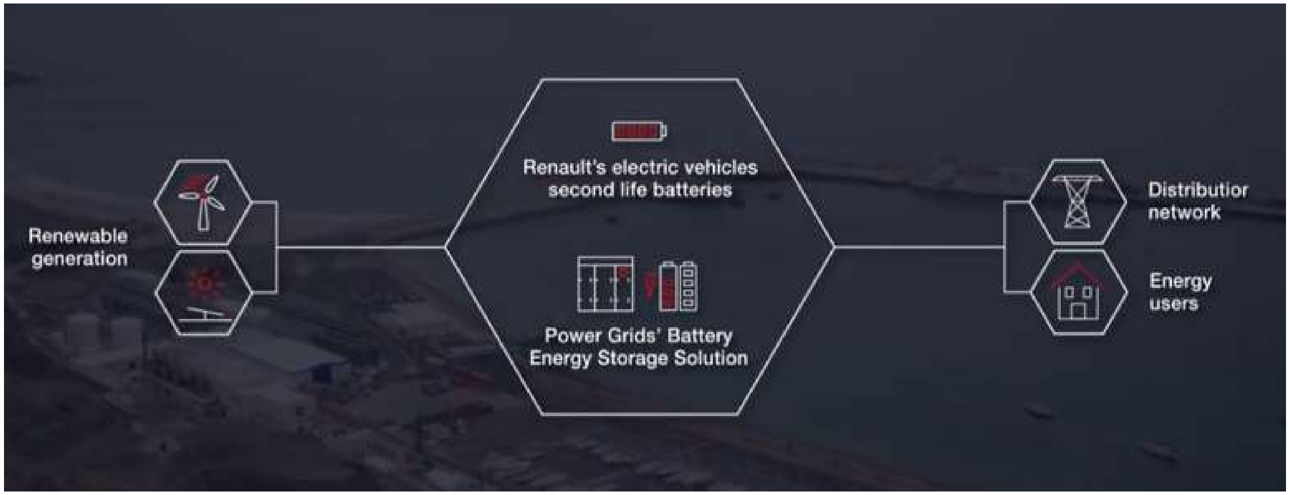
- PowerStore Battery (4 MW/3 MWh)
- e-mesh Control System
- Solar PV (2.25 MW_p)
- Wind (1.5 MW)
- Diesel (4 x 4 MW)
- Network Manager ADMS

Source : Hitachi Energy

Porto Santo: Island utility

Renault's electric vehicles second life batteries

100 % RE



V2G

Second life batteries

Grid Edge Solution enables the island of Porto Santo to achieve clean energy goals

Source : Hitachi Energy

Porto Santo: Island utility

Renault's EV storage experiment projects Portugal's Porto Santo towards zero-carbon status

February 2018 :

- 20-vehicles test on the island of Porto Santo
- 40 charge points around the island
- Using two-way Vehicle-to-Grid (V2G) charging technology, the vehicles recharge when plugged in with cheap, abundant electricity but at times of peak demand, the EVs release electricity back into the grid.

Grid Edge Solution enables the island of Porto Santo to achieve clean energy goals

Source : Hitachi Energy

Snohomish PUD Microgrid: utility

A state-of-the-art microgrid with solar PV, generator and battery storage with electric vehicle-to-grid (V2G) integration

The Arlington Microgrid demonstrates all the things a microgrid can do to support an electrified future – from grid stabilization to V2G integration on 100% renewable power

SNOHOMISH COUNTY PUD PUBLIC UTILITY DISTRICT NO. 1

About the project

- **Project name:** Snohomish PUD Microgrid
- **Location:** Seattle City, USA
- **Customer:** Snohomish PUD Microgrid
- **Completion date**: 2033

Customer benefits

- Community solar photovoltaic array so members can invest in solar generation
- An advanced grid-forming battery energy storage system (BESS) for reliability
- Distributed control and automation technologies to enhance and simplify operations
- An integrated V2G product for the electric vehicle fleet

Solution

- 500-kW solar array with smart inverters
- 1,000 kW/1,400 kWh lithium-ion battery storage system
- Several vehicle-to-grid charging stations for use with the PUD's electric fleet vehicles
- Solar tree

Source : Hitachi Energy

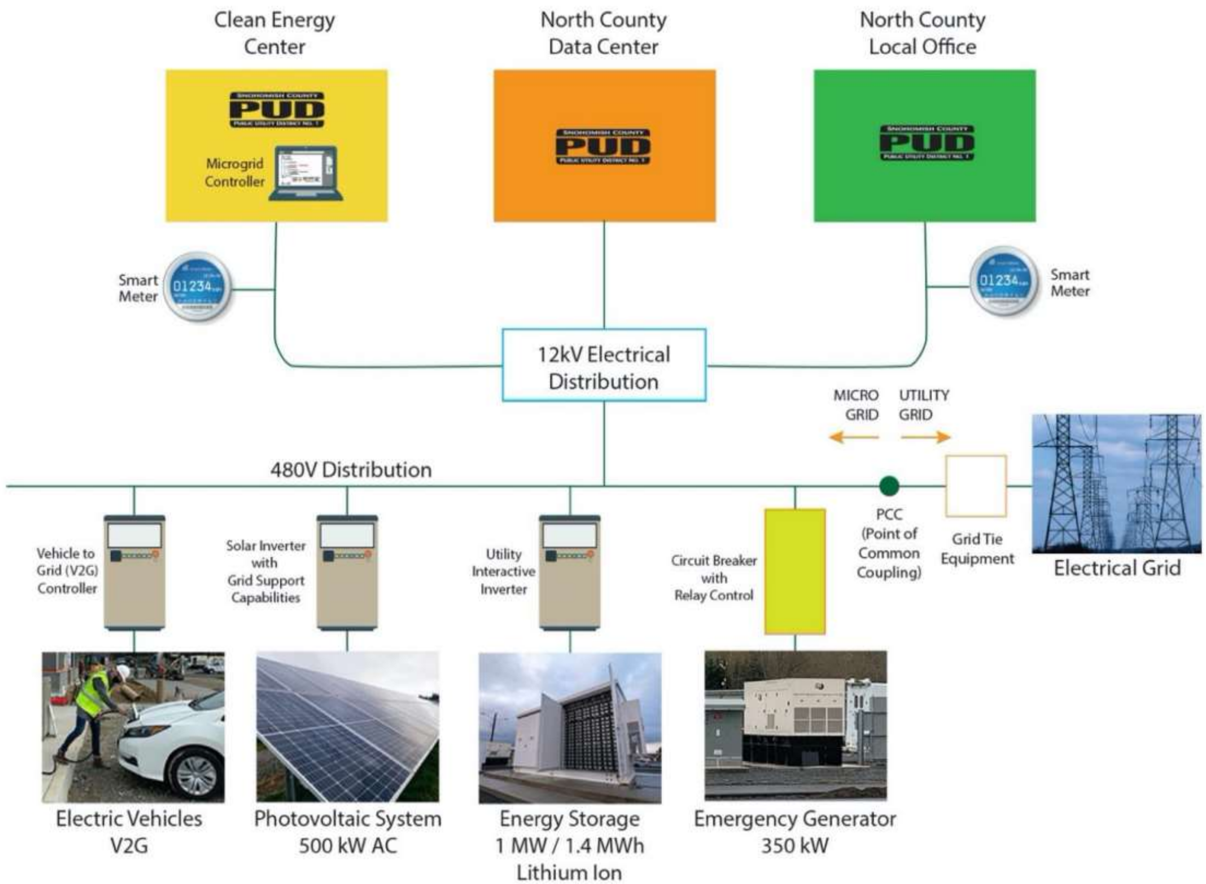
Snohomish PUD Microgrid: utility

Community Solar

- Largest community solar array in the state of Washington
- 500+ PUD customers reserved 100% of the available solar units in under a month
- Granted 10% of the units to two community service providers to benefit low-income households
- Program will produce energy and production credits for customers for 20 years

Arlington Microgrid Contributors	
Snohomish County PUD	Owner
WA Dept of Commerce	Financial Partner – CEF2 Grant
University of Washington	Contract – Modeling, Data Analysis & Reports
Burns & McDonnell	Contract – Owner's Engineer
Mitsubishi Electric	Contract – V2G - Equipment and Support
A&R Solar	Contract – Solar Array Construction
Hitachi - ABB Power Grids	Contract – Battery and Microgrid Controls Supply
PUD Substation Crews	Battery & Controls Install

SnoPUD microgrid is a glimpse into a V2G future
by John Glassmire, Senior Advisor, Hitachi Energy



Source : https://www.power-grid.com/renewable-energy/snopud-microgrid-is-a-glimpse-into-a-v2g-future/

Snohomish PUD Microgrid: utility

New technology and approach to electrical service, offering improved reliability and renewable energy integration

SnoPUD microgrid is a glimpse into a V2G future by John Glassmire, Senior Advisor, Hitachi Energy

1,000 kW/1,400 kWh lithium-ion battery storage system

Source : https://www.power-grid.com/renewable-energy/snopud-microgrid-is-a-glimpse-into-a-v2g-future/

Snohomish PUD Microgrid: utility

Uninterruptible power supply with the benefits of a back-up generator that gets its fuel from renewables

- Demonstrates multiple uses of energy storage
- Provides utilities, municipalities and organizations a plan and design to study for future microgrid projects
- Increases reliability in case of an emergency
- The Community Solar array "One of the largest in the state" will provide the largest amount of solar energy generation in the PUD's service area

SnoPUD microgrid is a glimpse into a V2G future
by John Glassmire, Senior Advisor, Hitachi Energy

Source : https://www.power-grid.com/renewable-energy/snopud-microgrid-is-a-glimpse-into-a-v2g-future/

Snohomish PUD Microgrid: utility

PEA Executives visited SnoPUD microgrid

Source : Hitachi Energy

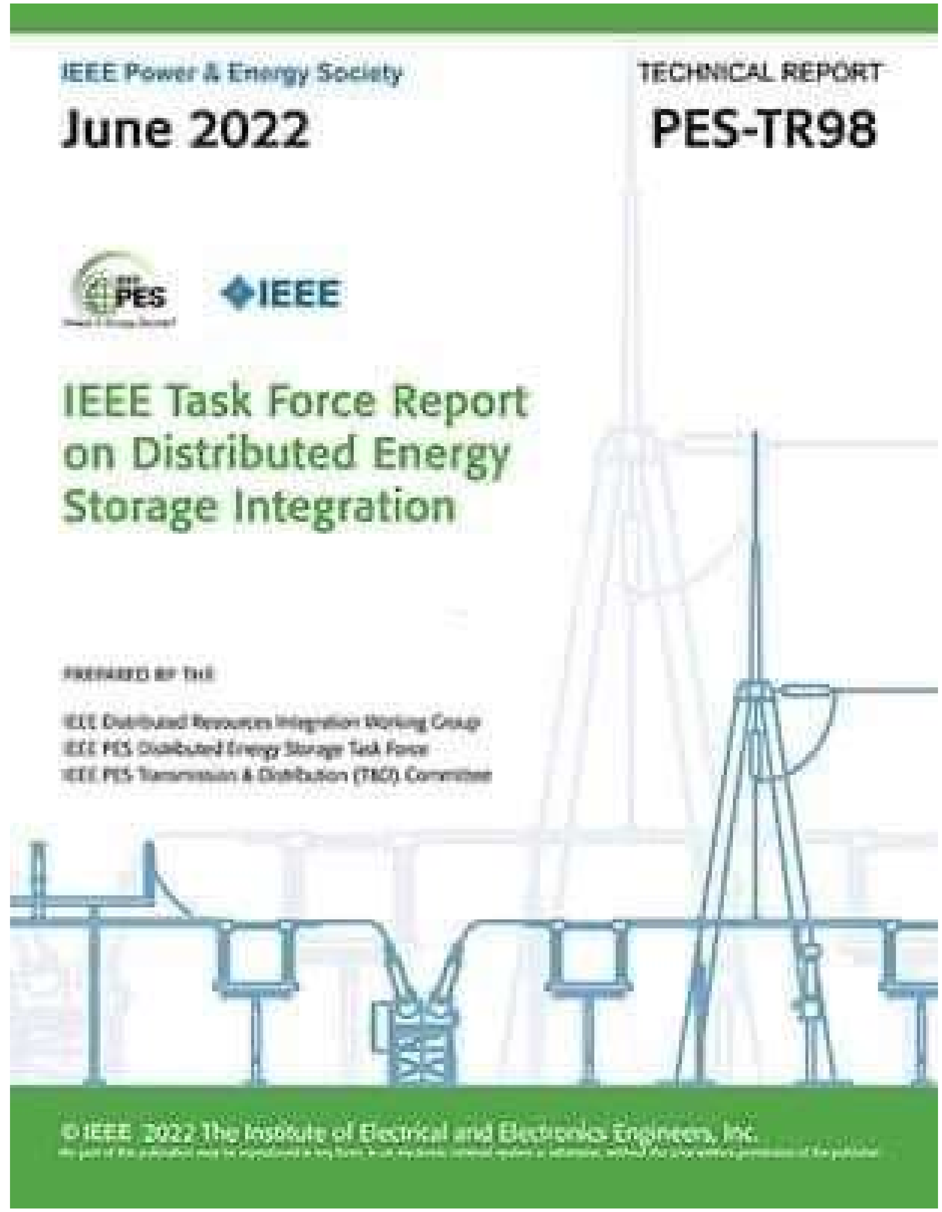
Read more here: https://lnkd.in/gU49e8bY

SnoPUD microgrid is a glimpse into a V2G future
by John Glassmire, Senior Advisor, Hitachi Energy

Source : https://www.power-grid.com/renewable-energy/snopud-microgrid-is-a-glimpse-into-a-v2g-future/

Q&A

Upcoming Event



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