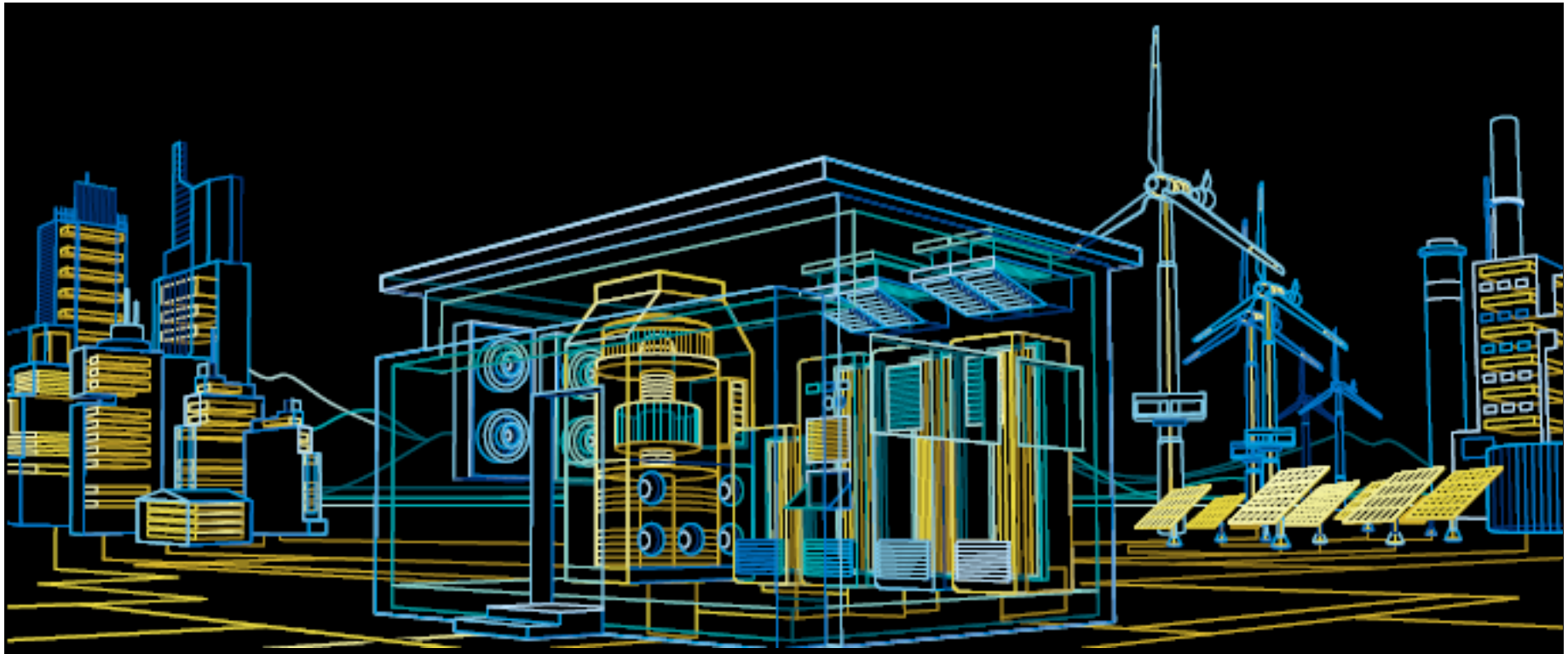


Budi Supomo – ID ABB, 2014

Micro-Grids and renewable energy integration

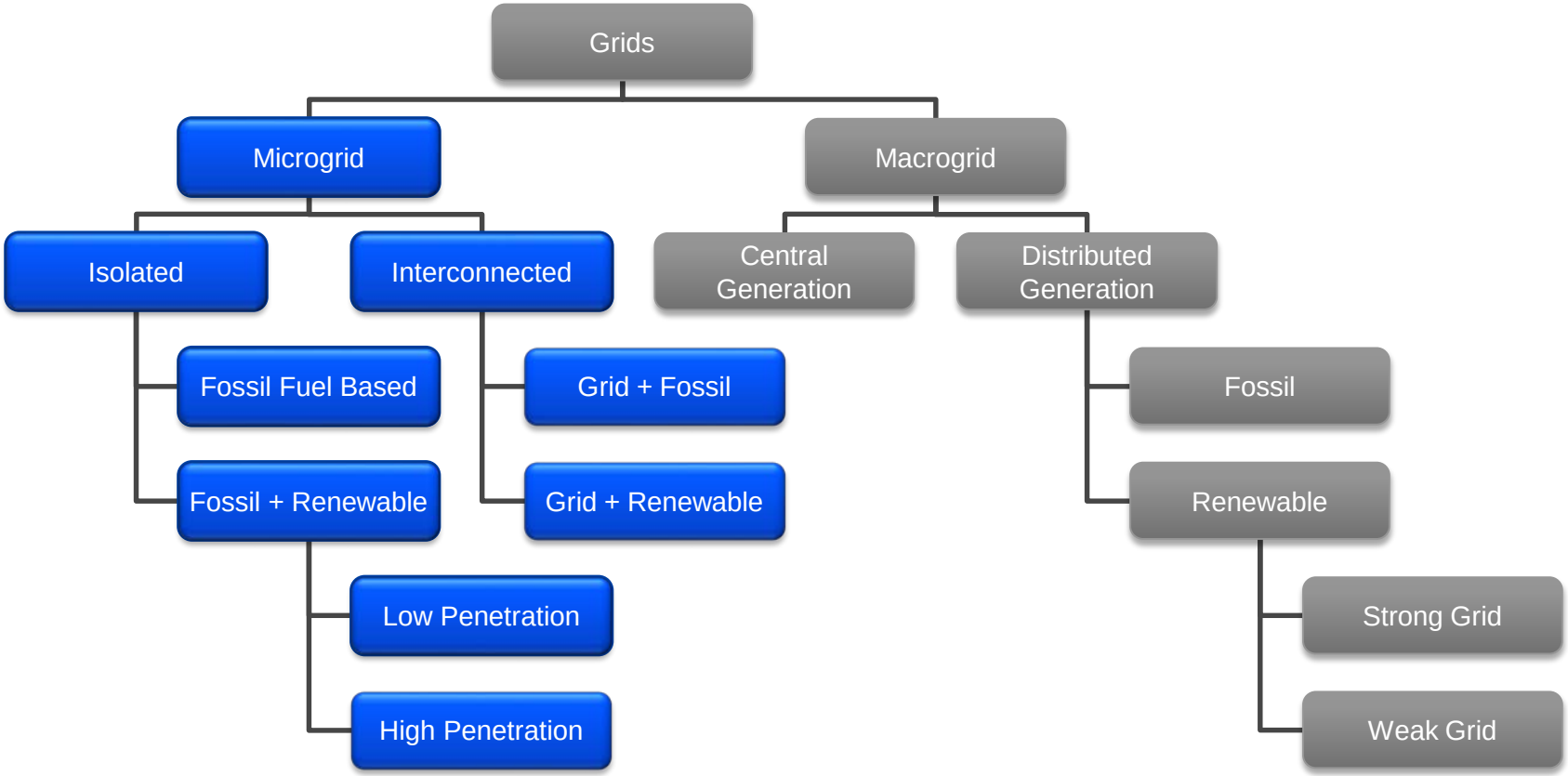
Global energy challenges
Social, economic and environmental

Access to electricity and water
- At an economically viable cost
- For an increasing global population

Climate change and protection
- CO_2 reduction goals
- Sustainable power generation
- Energy efficiency

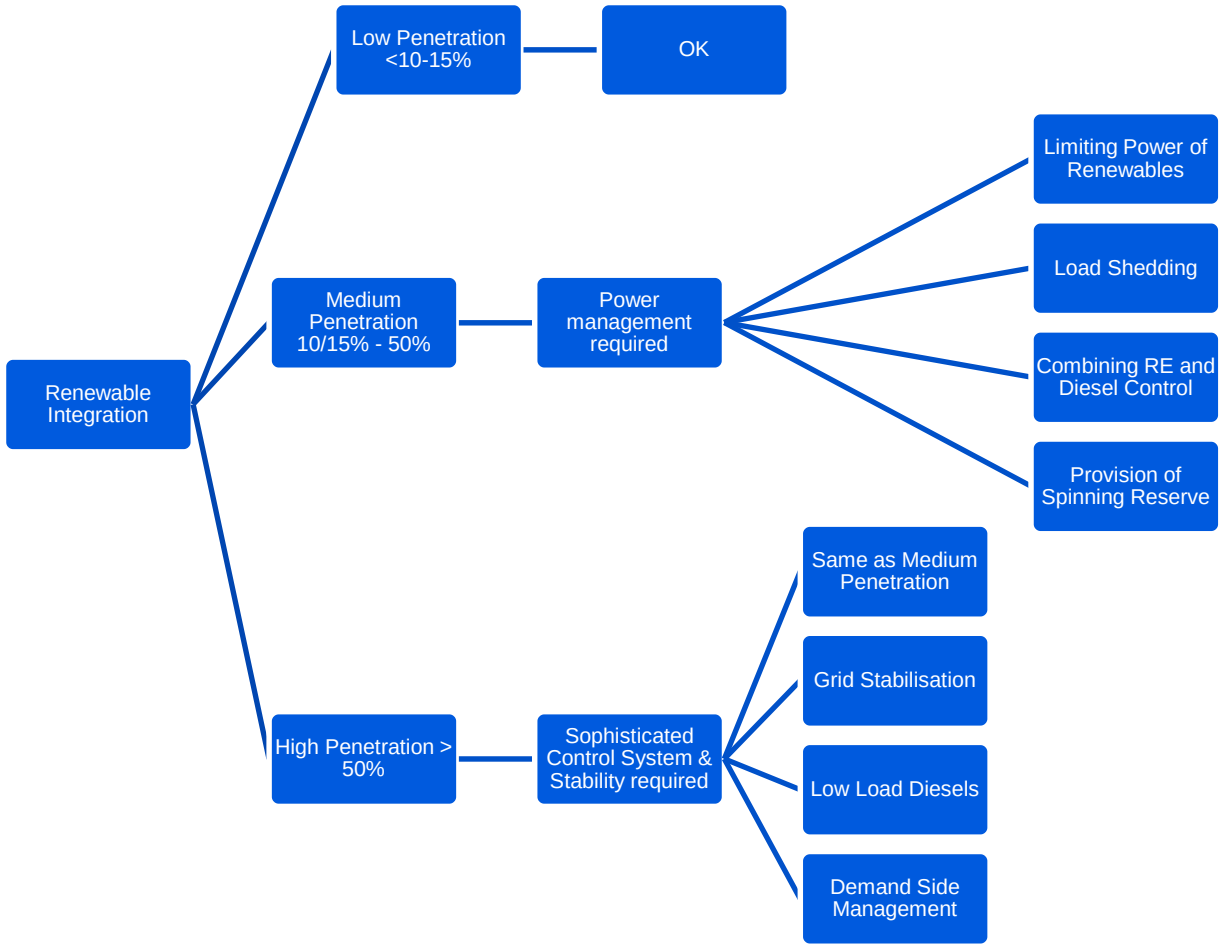
Increased need for significant infrastructure investments to overcome challenges related to
- Centralized solutions
- Decentralized solutions

Micro-Grids
Decentralized, self-sufficient power networks

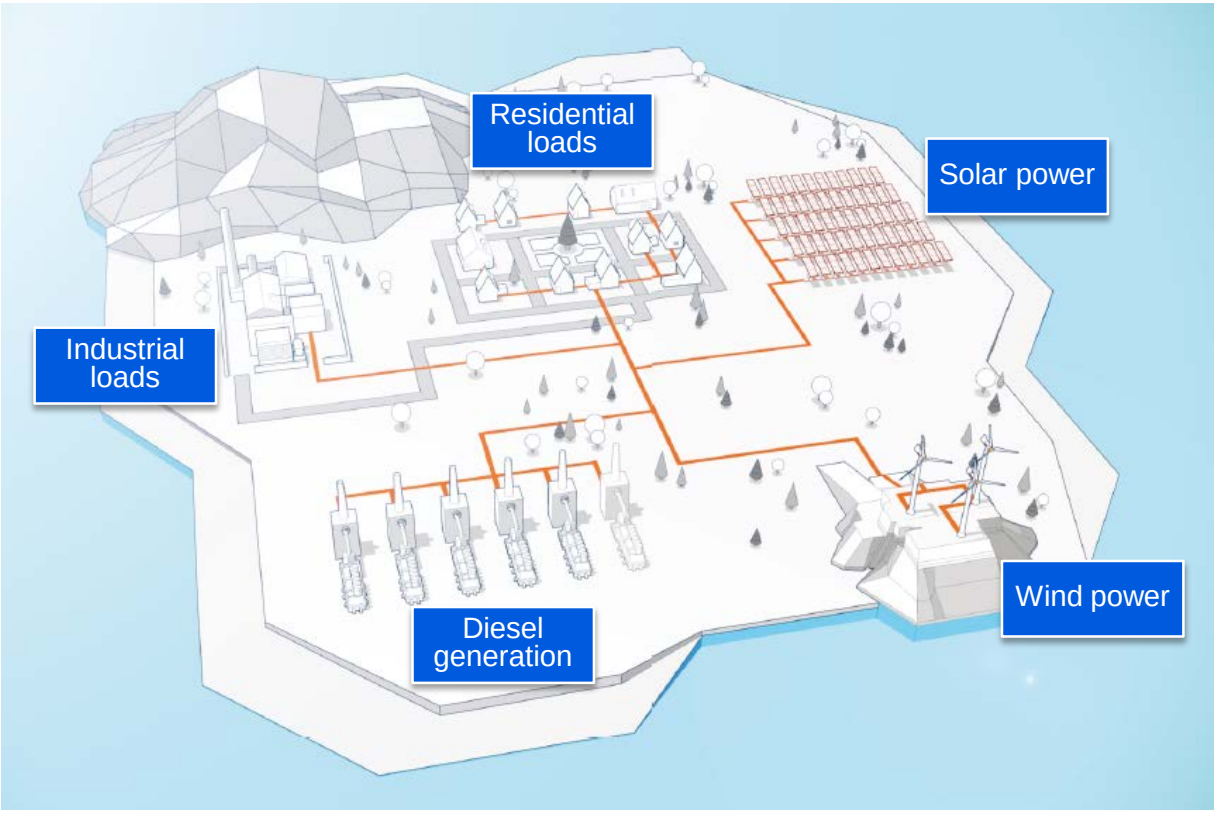


Microgrids are generally located in regions rich in renewable energy resources

Grid stabilization for high penetration systems
Integration Strategies

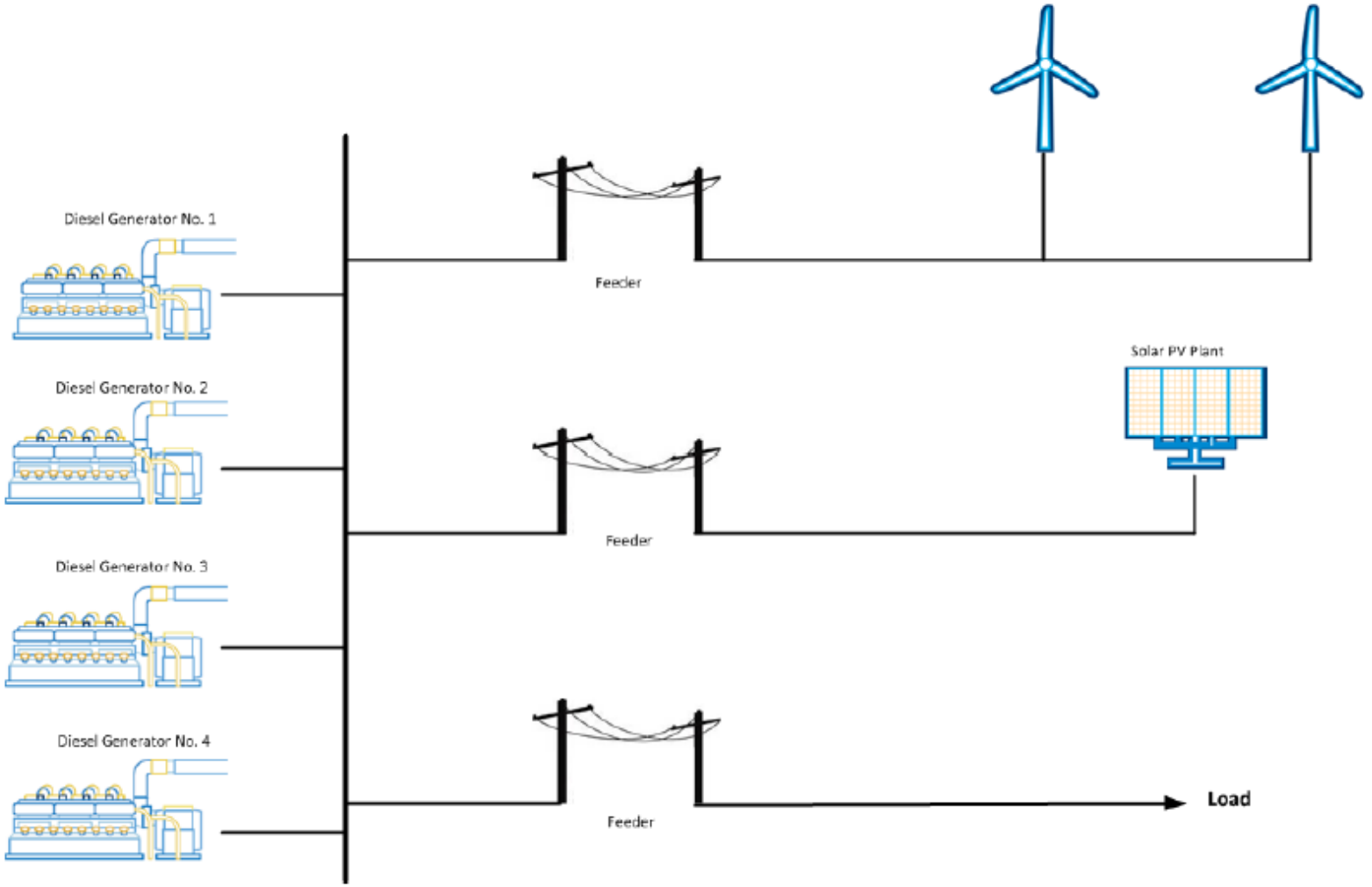


Grids powered by fossil-fuel and renewable energy
Diesel Micro-Grids



Diesel microgrids have the greatest energy cost savings potential

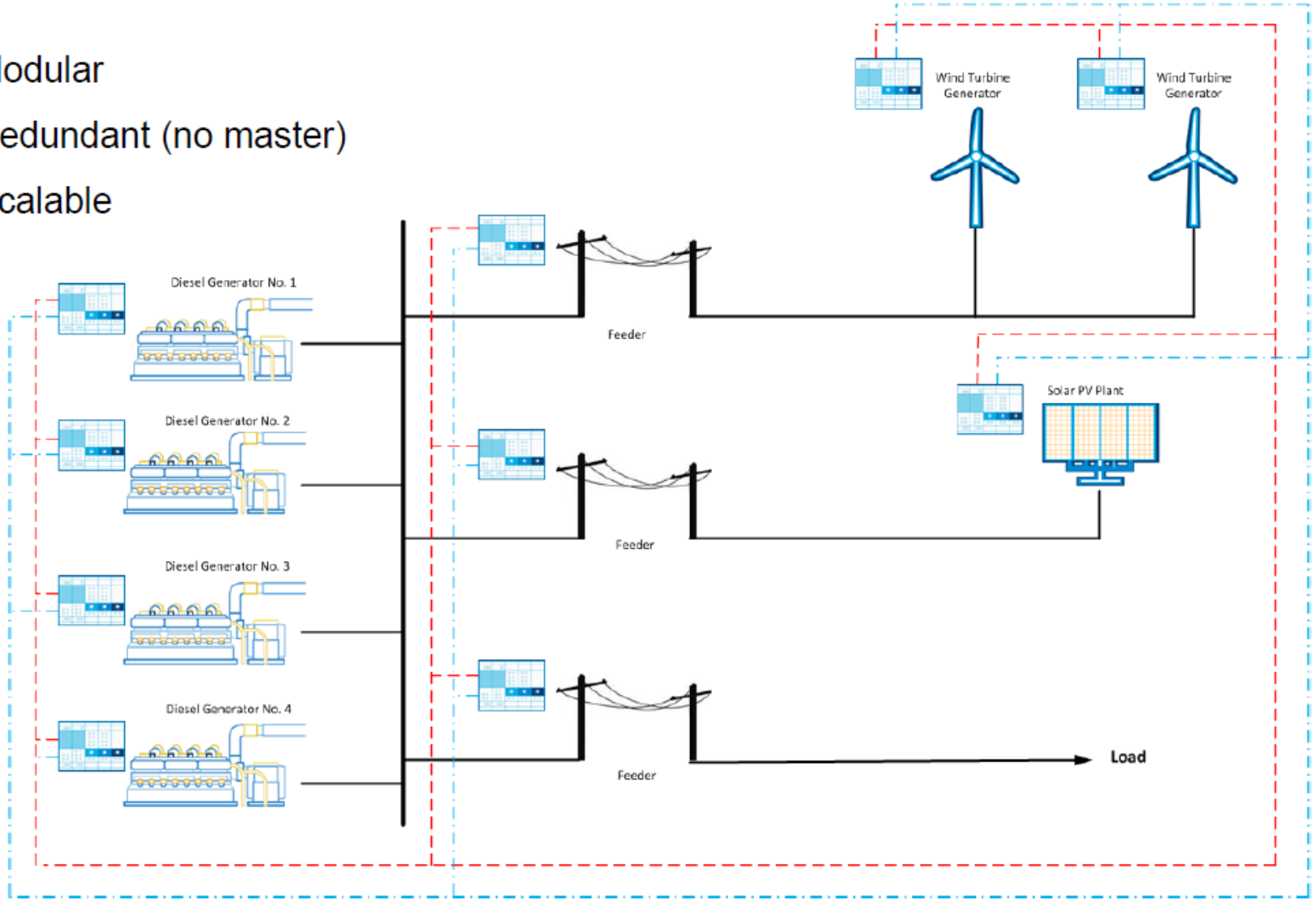
Off Grid Micro-Grid
Typical System Configuration



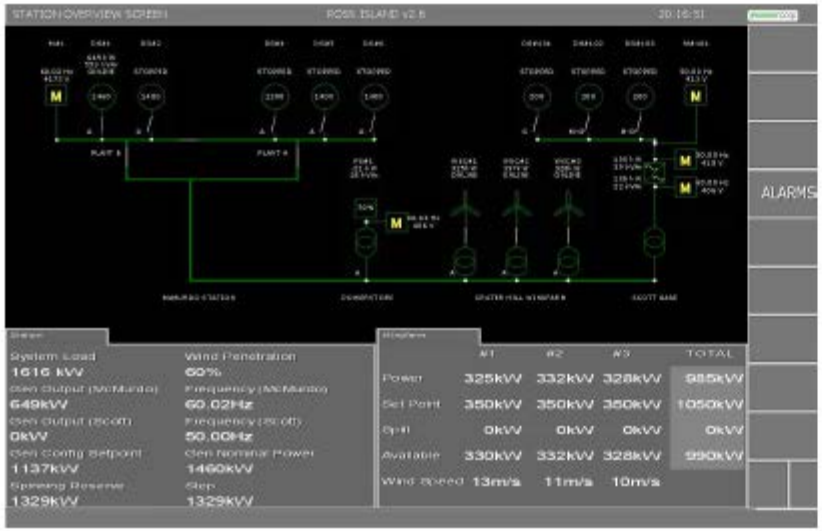
Integration Solution Micro-Grid

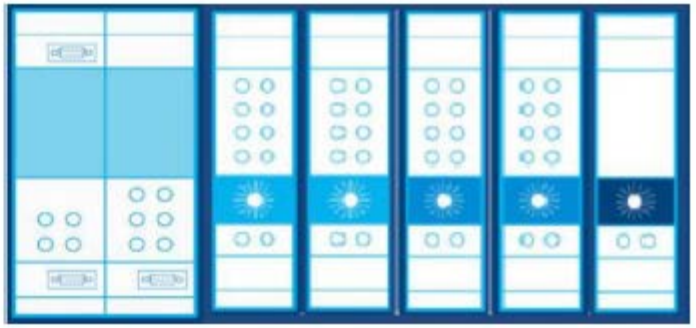
Networked Power Control & Optimization System

- Modular
- Redundant (no master)
- Scalable



Integration Solution Micro-Grid
ABB Solution : RMC 600 System

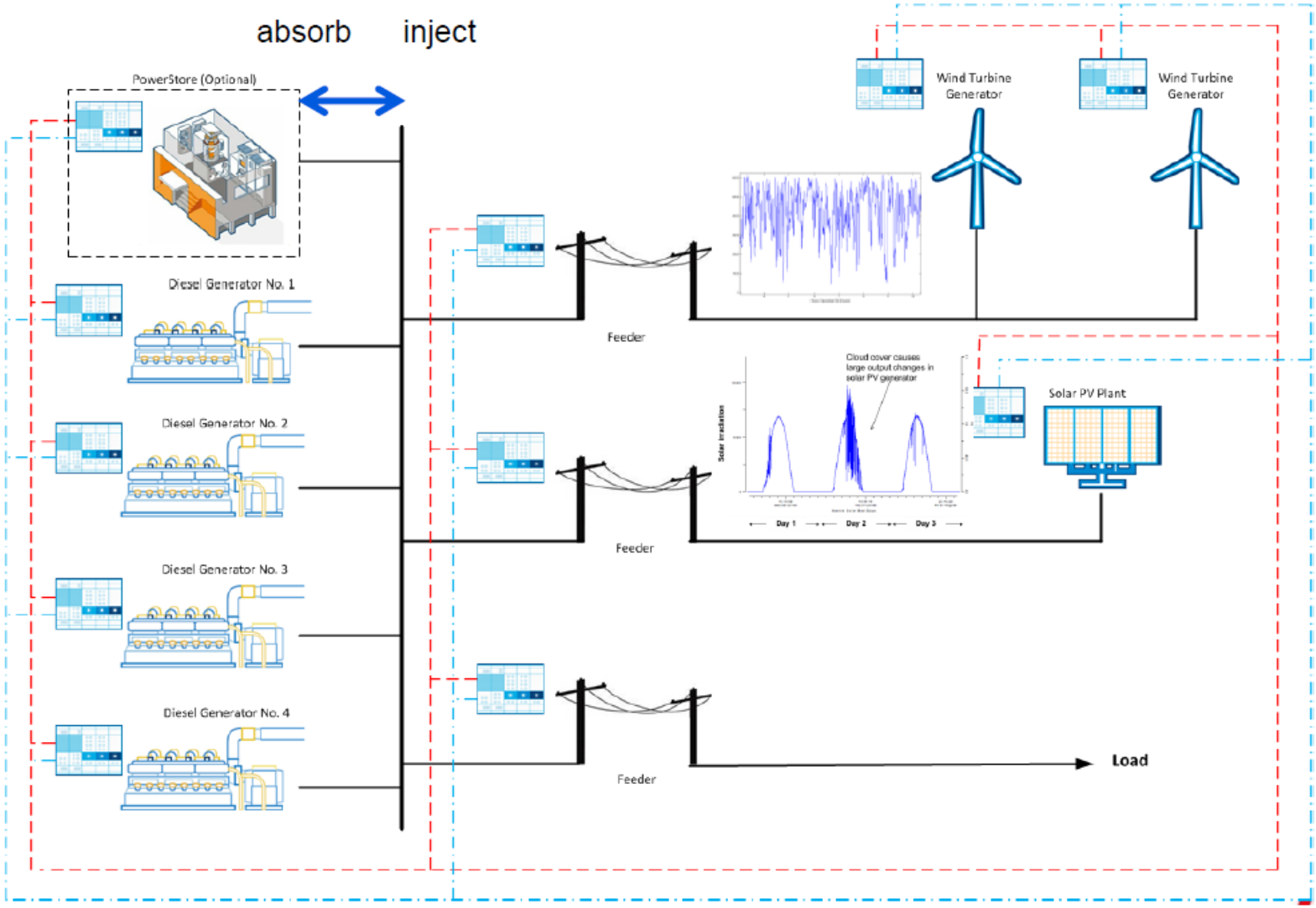




- Retrofit to existing diesel plant
- Integrate generators and loads
- Uses simple non proprietary Interface
- Configuration by Power System Engineers using web pages

Integration Solution Micro-Grid

Grid Stabilizing using Flywheel or Battery



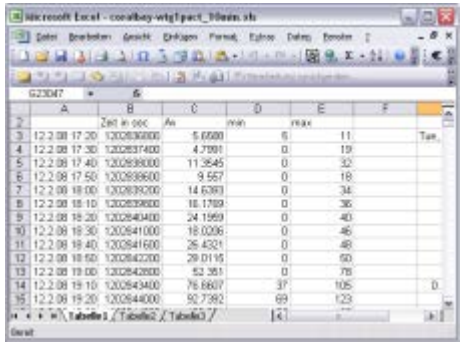
Renewable energy integration challenges
Microgrid technology solutions - typical penetration levels

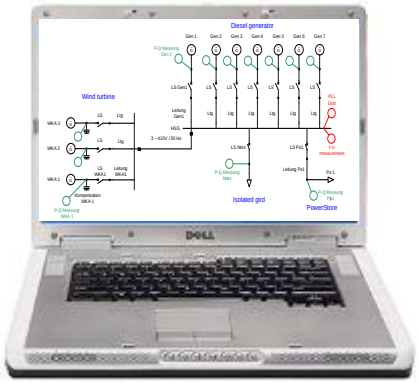
Wind/solar/diesel systems	Annual Average Contribution	Peak Penetration
No integration	7-10%	20%
Automated dispatch	10-15%	22%
Grid stabilizing	40-60%	100%
Automated demand response	60-80%	100%
Energy storage	100%	100%

Microgrid design
Model verification – using real data

Input → Power System Model → Output

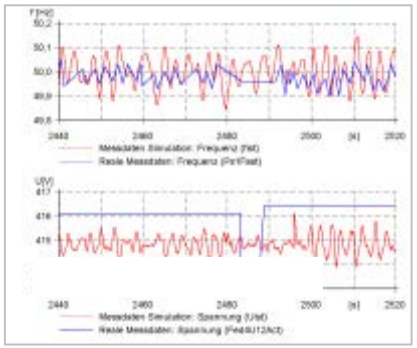
Recorded data from real system



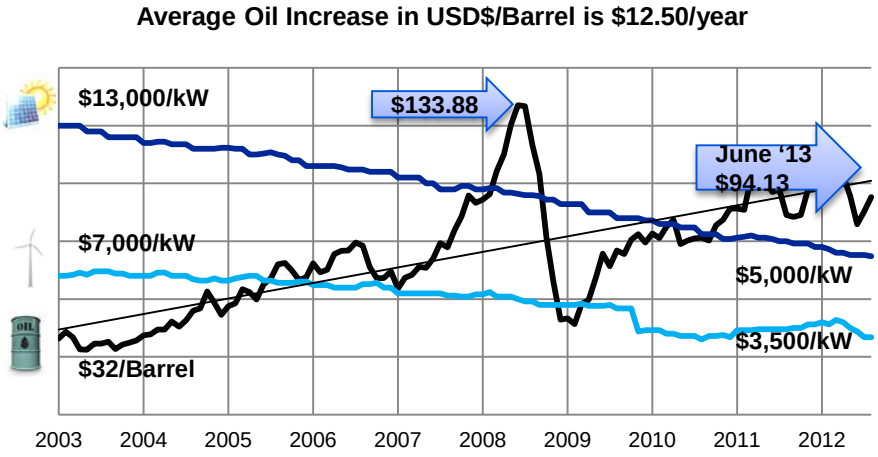


Simulation tool

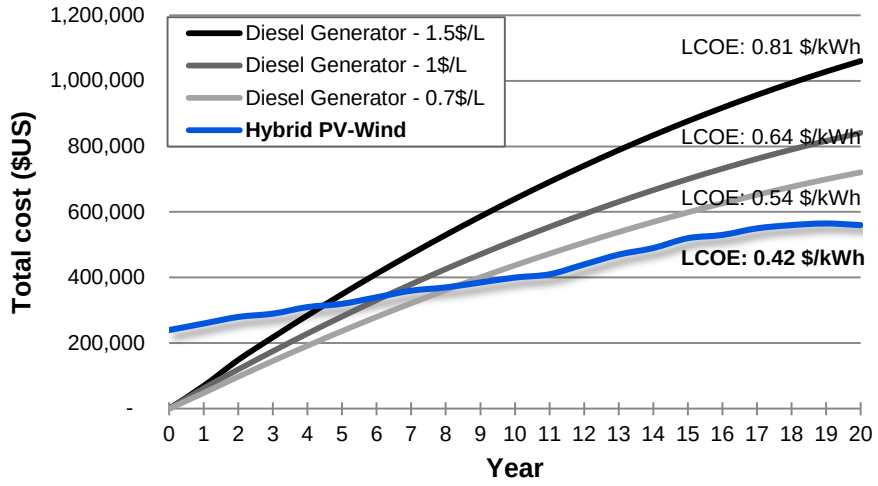
Output of simulation (Voltage, frequency, etc.)



Integrating renewable energy into Micro-Grids
Secure power generation and fuel cost savings



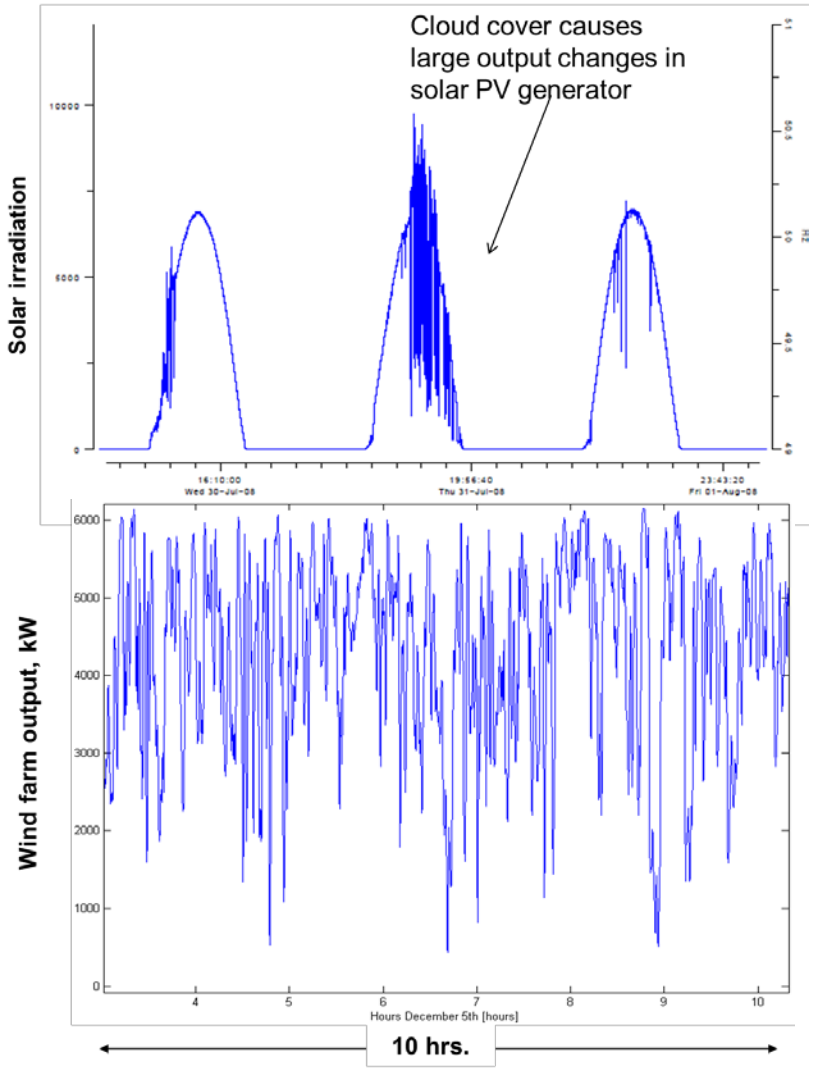
- Diesel fuel cost is volatile and rising over time
- Renewable energy cost is far less volatile and reducing over time
  - Energy source is free



- Renewable energy is economically competitive today
  - Leveled Cost of Electricity (LCOE) lower than diesel fuel generation

Sources: *1) US Energy Information Administration – Independent Statistics and Analysis*
http://www.cleantechinvestor.com/portal/fuel-cells/6422-mining-and-energy.html
2) Alliance for Rural electrification (ARE). Projections made from a case study based in Ecuador with real natural conditions.
http://www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/Position_papers/ARE_TECHNOLOGICAL_PUBLICATION.pdf

Renewable energy integration challenges
Managing power output fluctuations

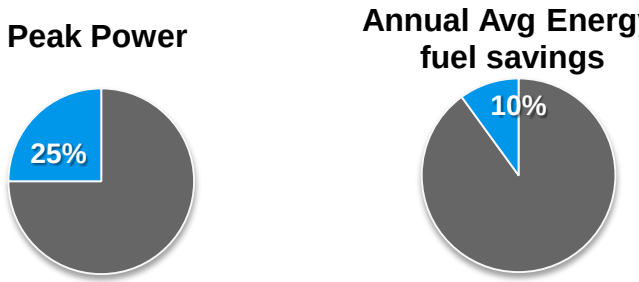


- Inherent volatility of renewable energy can compromise grid stability
- The renewable energy integration solution must address requirements traditionally fulfilled by diesel generation (base load)
  - Frequency and voltage control
  - Sufficient spinning reserve
  - Sufficient active and reactive power supply
  - Peak shaving and load levelling
  - Load sharing between generators
  - Fault current provision
- Renewable energy generation capacity should be sized to maximize ROI and fuel savings

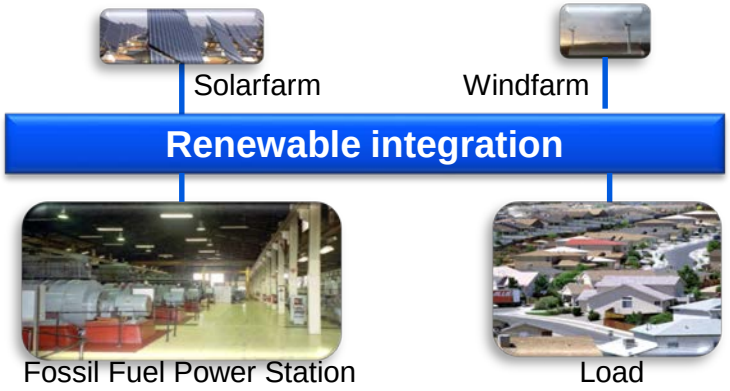
ROI: *Return on investment*

Renewable energy integration
High penetration leads to short payback and higher ROI

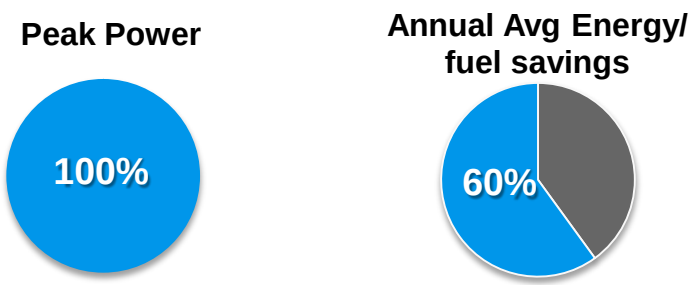
Low renewable energy contribution



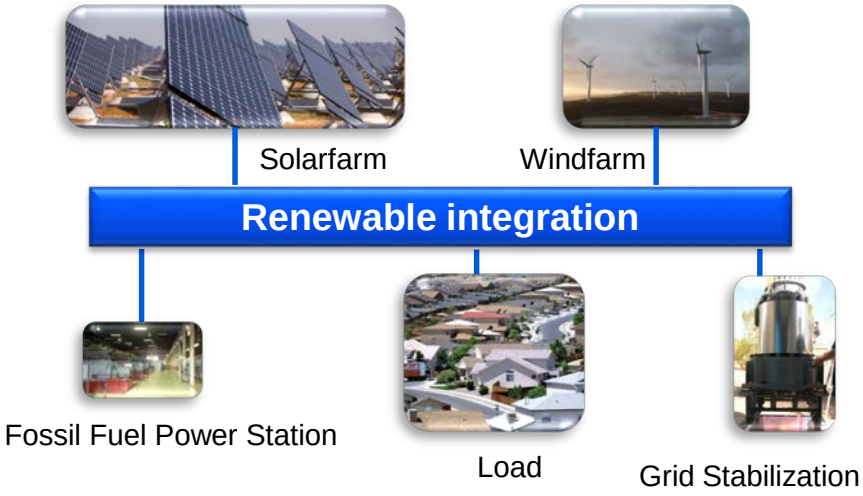
- **Control system:** none/simple
- **Grid frequency:** within operational limits



High renewable energy contribution



- **Control system:** sophisticated
- **Grid frequency:** stable



Renewable energy integration challenges
Summary

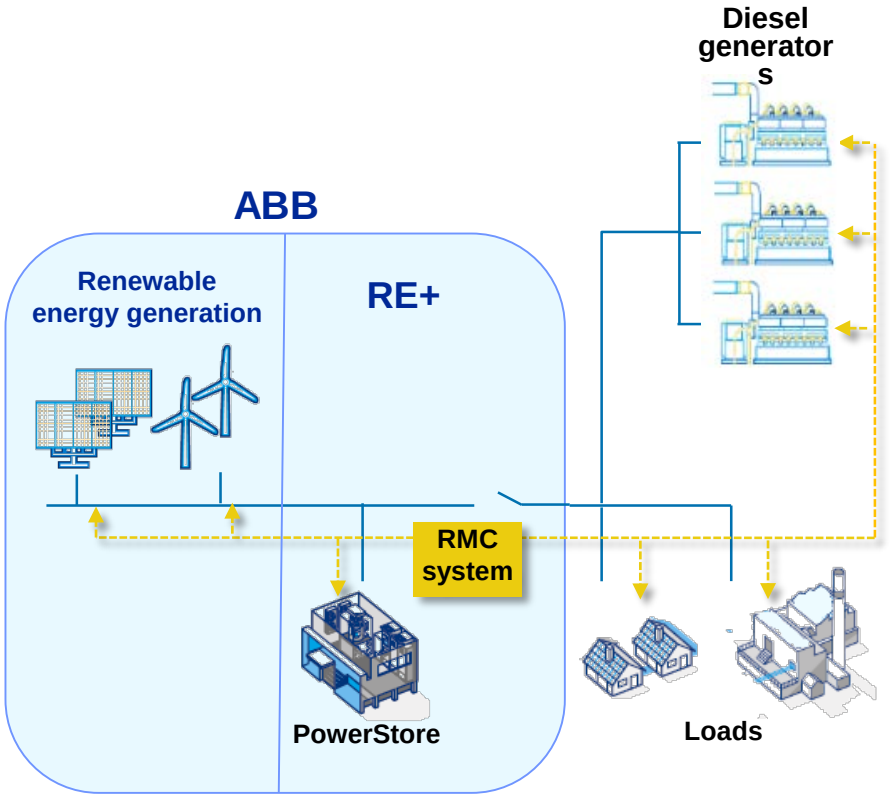
- Renewable energy volatility compromises grid stability
- Integration without intelligent plant control system limits economic benefits
  - Poor integration can damage fossil fuel generators
  - Lack of automatic adjustment of spinning reserve results in higher fuel consumption
  - Renewable generation may have to be curtailed to guarantee grid stability
- Use of intelligent control and grid stabilization enables high penetration systems resulting in shortest payback and highest ROI
  - Up to 100% renewable energy peak penetration and 60% annual energy contribution is typical

ABB solution

ABB RE + and renewable energy generation
Comprehensive solution from a single source

RE + enables high penetration, up to 100%, into diesel microgrids

- **Expertise in engineering and consulting**
  - ✓ 25+ years of microgrid experience and system design optimization
- **Intelligent control and management of all interconnections**
  - ✓ Remote Microgrid Controller (RMC 600)
- **Grid stabilization**
  - ✓ PowerStore™



Additional expertise and capabilities

- **Renewable energy generation**
  - ✓ Solar PV plant/farms turnkey solutions
  - ✓ Wind farm integration

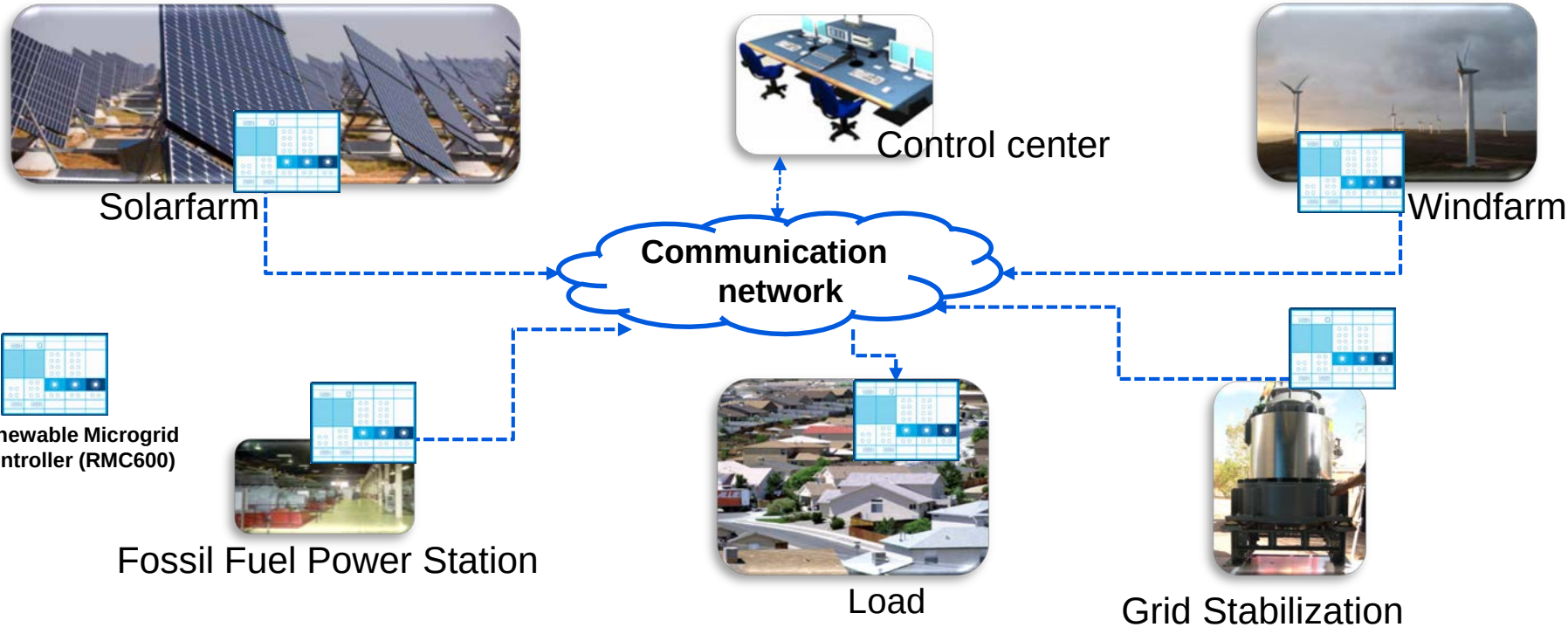
RE+: Renewable Energy +
PV: Photovoltaic

Technologies for Micro-Grids and Distributed Generation

Key Technological Components

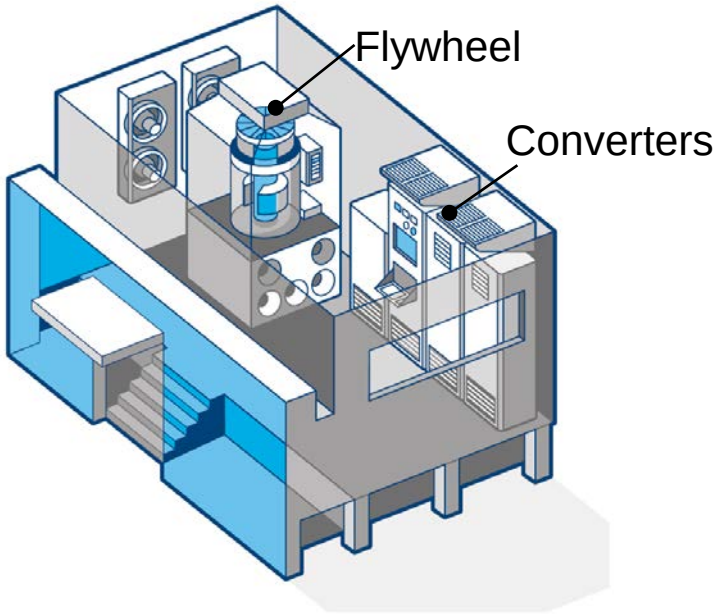
1. Grid Stabilizing Systems
   - Keep the voltage (and frequency) stable even with a high penetration of intermittent renewable energy sources and with sudden load variations
2. Energy Storage Systems
   - To locally increase the match of generation and load, i.e.to consume power predominantly near to where it is generated
3. Distributed Power Flow Control Systems
   - To maximize use of renewable while maintaining the grid stable and providing high quality power and maximizing asset life
4. On/Off-grid Transition Systems

ABB RE+: Renewable microgrid controller, RMC 600
Efficient and reliable power management



- Maximize renewable energy penetration and fuel savings
- Optimum loading and spinning reserve in fossil fuel generators
- Distributed control logic enhances reliability and scalability for future expansions

ABB RE+: PowerStore™ flywheel system
Grid stabilization



- Stabilizes frequency and voltage fluctuations
  - Heavy-duty application: dynamic power injection and absorption in miliseconds
- Maximizes fuel savings through highest possible renewable penetration
- Proven track record
  - 3,000 kW installed and 2,100 kW under commissioning

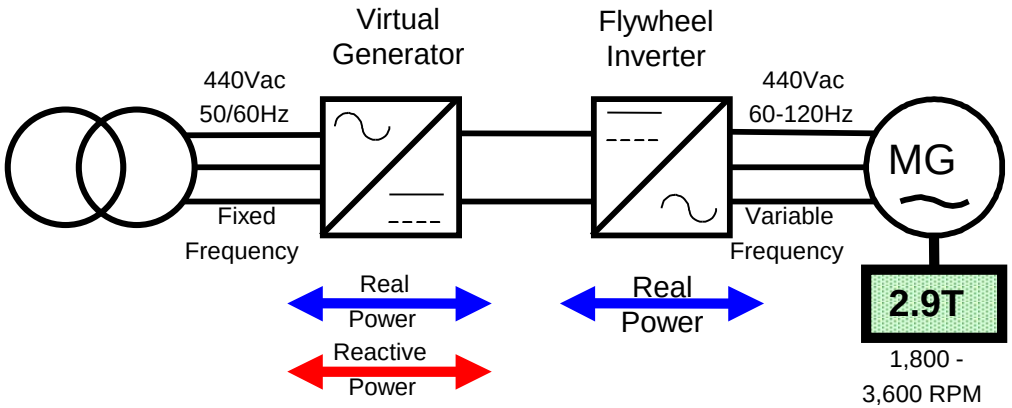
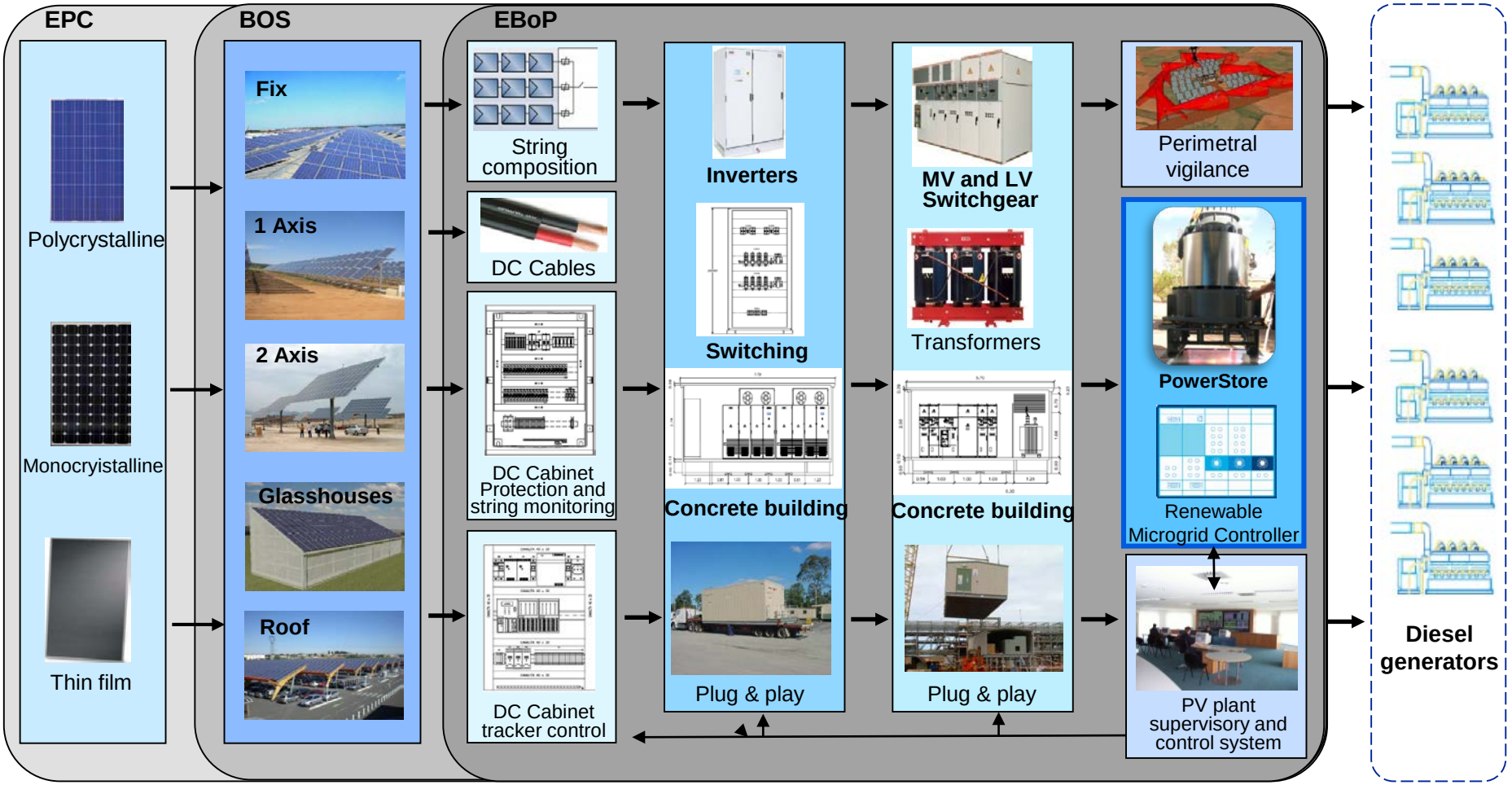


ABB turnkey solar PV solutions

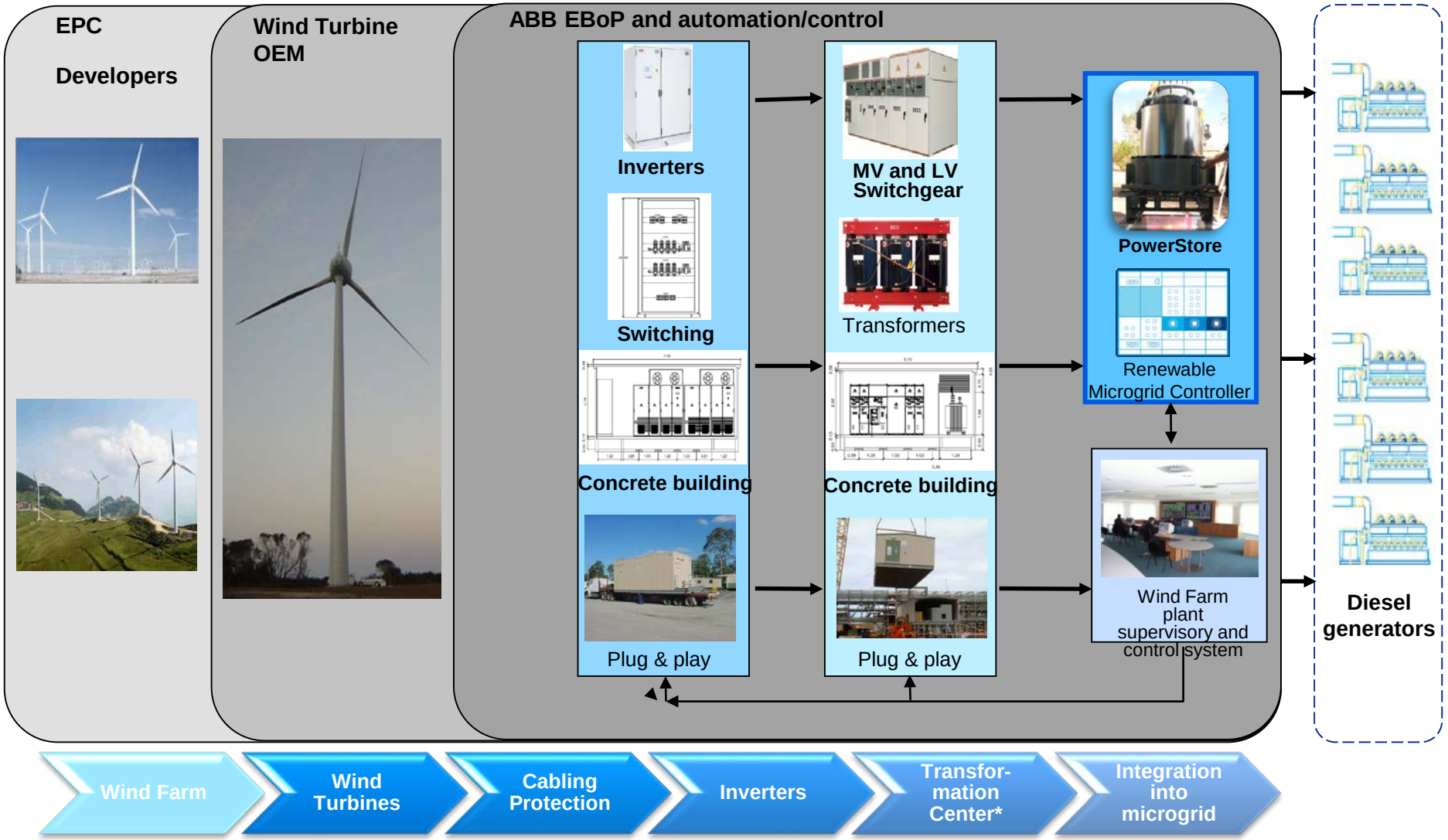


PV Modules → Trackers → DC Cabling Protectors → Inverters → Transfor-mation Center* → Integration into microgrid

EPC: *Engineering, procurement and construction*
BoS: *Balance of system*
EBoP: *Electrical balance of plant*

*Voltage level is stepped up to grid level.

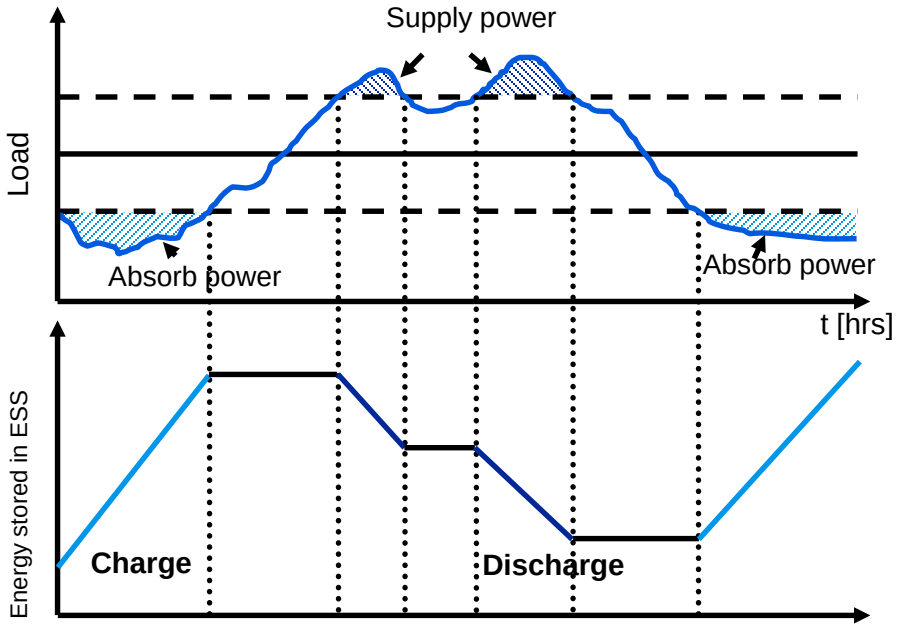
ABB wind integration solutions



EPC: *Engineering, procurement and construction*
EBoP: *Electrical balance of plant*

*Voltage level is stepped up to grid level.

ABB RE+ and battery energy storage
An alternative solution when applicable



Applications: peak demand shaving or load shifting

- Longer stored energy discharge timescale; minutes to hours
- Enable fossil fuel generators to run at stable outputs
- Maximize renewable energy load factor

ABB's comprehensive battery energy storage solutions

- Based on proven power converter technology
- Turnkey and modular solutions suitable for all power levels (~25kW to 70 MW)
- Solutions designed and developed independently of battery technology

ABB RE + and renewable energy generation
Summary

- ABB RE+ solution enables
  - Secure power generation and fuel cost savings
  - Maximum benefits of high ROI and shortest payback time through high renewable energy penetration and grid stabilization
  - Reliable, uninterrupted and high quality power supply to all loads

- ABB renewable energy generation capabilities encompass
  - Turnkey solar PV farms
  - Wind farm integration

References

High penetration reference system
Marble Bar, solar/diesel system, Australia

HORIZON POWER

Australian Government
Department of Climate Change and Energy Efficiency

Government of Western Australia
Office of Energy

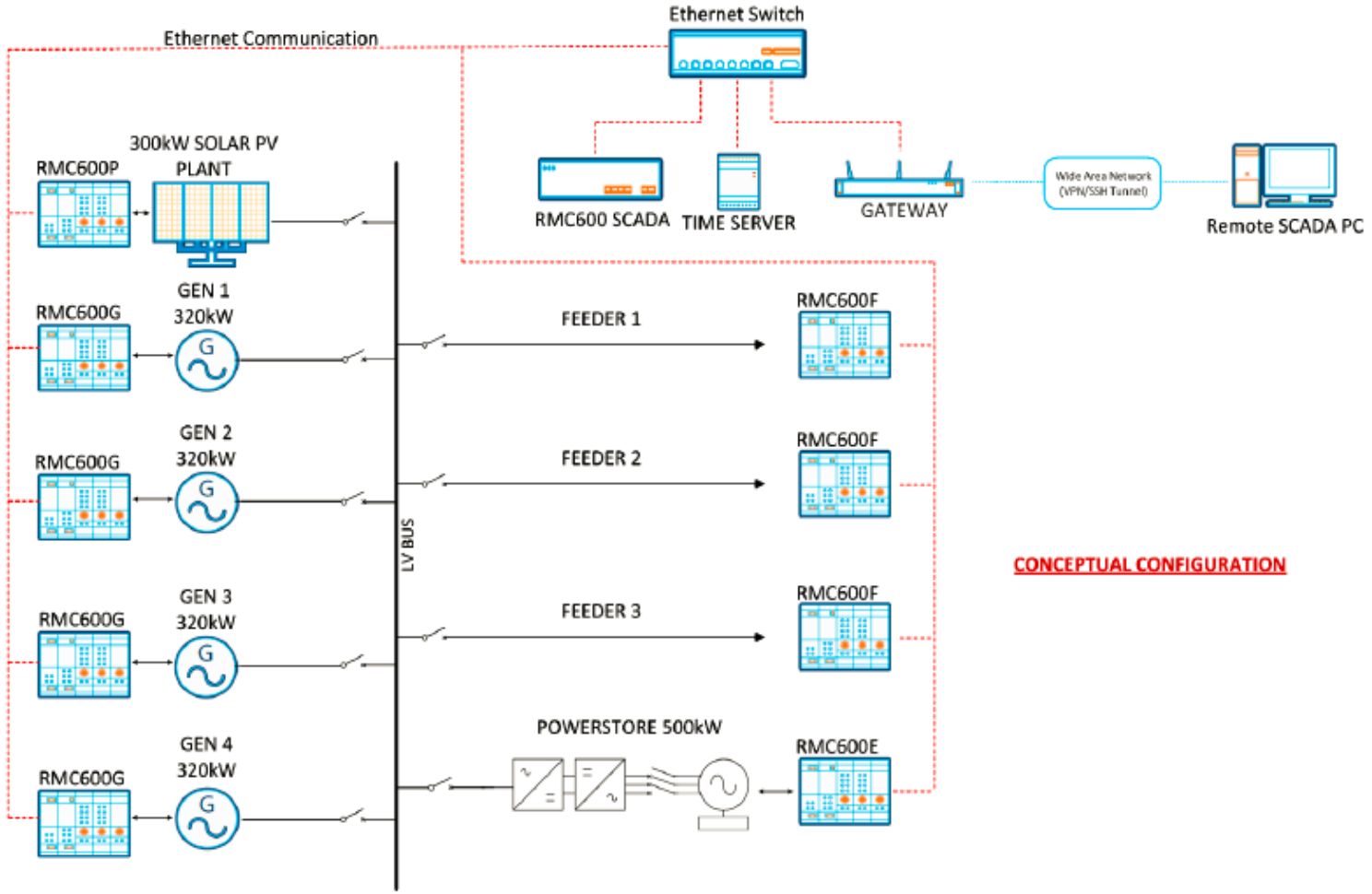
182,000 liters of fuel saved annually
1,100 tonnes CO2 avoided annually
60% of energy supplied from PV plant

Customer
- Horizon Power
- Office of Energy, Government of Western Australia

Key objectives
- Minimize diesel consumption
- Reliable and stable power supply

ABB solution
- Implement a solar microgrid with PowerStore grid-stabilizing technology and microgrid automation

The resulting system has
- Diesel (4 x 320kW)
- PV (1 x 300kW)
- PowerStore grid stabilizing system (1 x 500kW)



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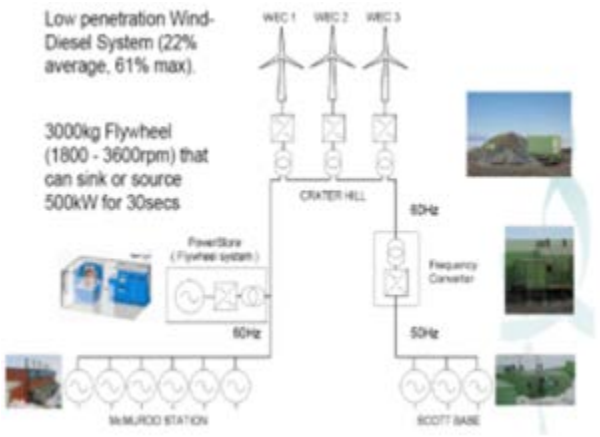
					CLIENT: Internal	
B					FILE NAME: For Internal use	SHEET NO. 1/1
A	MB Layout	WG	06.15.15	BL		
REV	DESCRIPTION	DRN	DATE	CKD	DRAWING NO.: 001	

High penetration reference system
Ross Island, wind/diesel system, Antarctica



463,000 liters of diesel fuel saved annually
2,800 tonnes CO2 avoided annually
Up to 70% wind energy penetration

Customer
- New Zealand's Scott Air Base (50 Hz system)
  America's McMurdo Station (60 Hz system)

Key objectives
- Reduce diesel cost
- Reduce environmental risk of transporting diesel
- Reduce CO2 emissions
- Ensure a reliable, high quality supply

ABB solution
- Implement a wind diesel microgrid with PowerStore grid-stabilization and microgrid automation

The resulting system has:
- 9 x diesel generators
- Wind turbines (3 x 330kW)
- PowerStore grid stabilizing (1 x 500kW)
- Frequency converter to integrate both bases
- Renewable Microgrid control system

Business cases

High Penetration Business cases
Marble Bar – Solar/Diesel

	Low Penetration	High Penetration
Solar PV Array	200kW	500kW
RE+	-	500kW PowerStore + RMC
Capex for PV	$5/W	$3.8/W
PV Capex	1 mio $	1.9 mio $
System Capex	1 mio $	2.85 mio $
Renewable Energy Generated	370 MWh p.a.	925 MWh p.a.
Excess Energy	37 MWh p.a.	147 MWh p.a.
Annual Renewable Energy Contribution	14%	32%
Fuel Savings	**75,000 liter p.a.**	**182,000 liter p.a.**

High Penetration Business cases
Faial Island – Wind/Diesel

	Medium Penetration	High Penetration
Wind Farm	5 x850 kW	7 x 850kW
RE+	RMC	RMC+ 2 x 1MW PowerStore
Capex for Wind Farm	$6,692,110	$9,368,954
System Capex	$6,992,110	$12,068,954
Renewable Energy Generated	15.11 GWh p.a.	21.15 GWh p.a.
Excess Energy	657 MWh p.a.	1,895 MWh p.a.
Annual Renewable Energy Contribution	24%	32%
Fuel Savings	**3,534,000 liter p.a.**	**4,750,000 liter p.a.**

Summary
Micro-Grid challenges

- Allow for sufficient planning time & budget to ensure the integration of renewables
  - Gives you the highest ROI
  - Does not negatively affect your power system
- Being able to control all plant in a system including all renewable generators to
  - Control generation to meet demand
  - Control excess energy and prevent over production and reverse power scenarios
  - Optimize the total system efficiency by maximizing the renewables
- Maintaining grid stability when running high penetration renewable systems by
  - Compensating the frequency and voltage fluctuations

Power and productivity
for a better world™

Grid Stabilization for High Penetration Systems
Storage vs. Stabilization

- Storage
  - Long term application
  - High energy content
  - Typical low duty cycle
- Stabilization
  - Fast charge/discharge
  - Low energy content
  - High duty cycle

ABB RE+

Grid Stabilizing PowerStore™ Flywheel System

- The flywheel is a robust, mechanical device using simple technology such as a synchronous motor/generator
- It is failsafe, utilizing it‘s own energy to supply the lifting magnets

Flywheel Performance Data

Net. energy content	18 MWs
Max Input/output power	1650 kW
Speed range	1800 to 3600 rpm
Total weight	6000 kg
Rotor weight	2900 kg
Idling losses	10 kW
Greasing frequency	5 years
Bearing service life	8 years

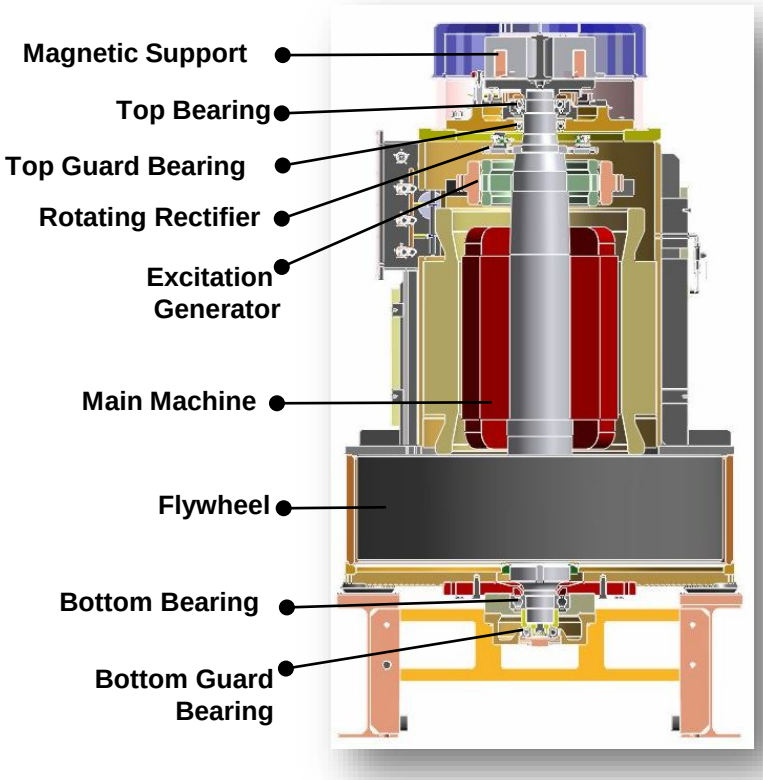
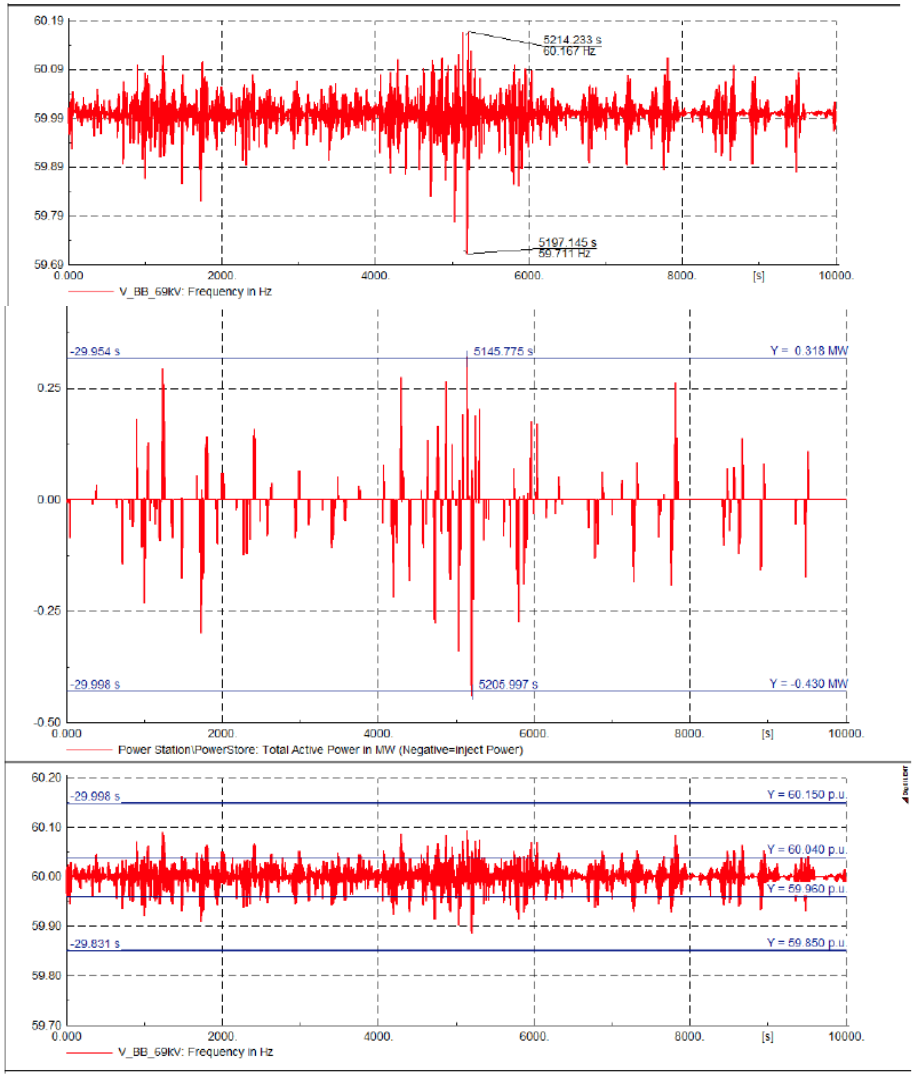


ABB RE+ Solution
Grid Stabilizing PowerStore Flywheel System

Features

- Scalable & Modular
- High duty cycle
- Grid Stabilising
- Frequency Control
- Voltage Control
- Grid forming in 100% RE scenario
- Unbalance load supply
- Spinning reserve
- Active & reactive power supply
- Fault ride through



Power electronic conversion
ABB energy storage converter portfolio

Typical grid connection levels

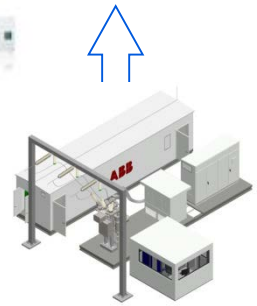
LV range
~25kW – 300kW rating

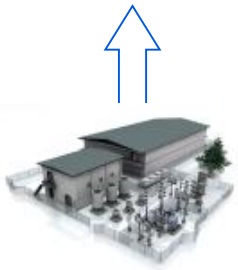
LV - MV range
~200kW – 30MW rating

MV - HV range
~10MW – 70MW rating

MV - HV range
≥30MW rating

Optimized converters



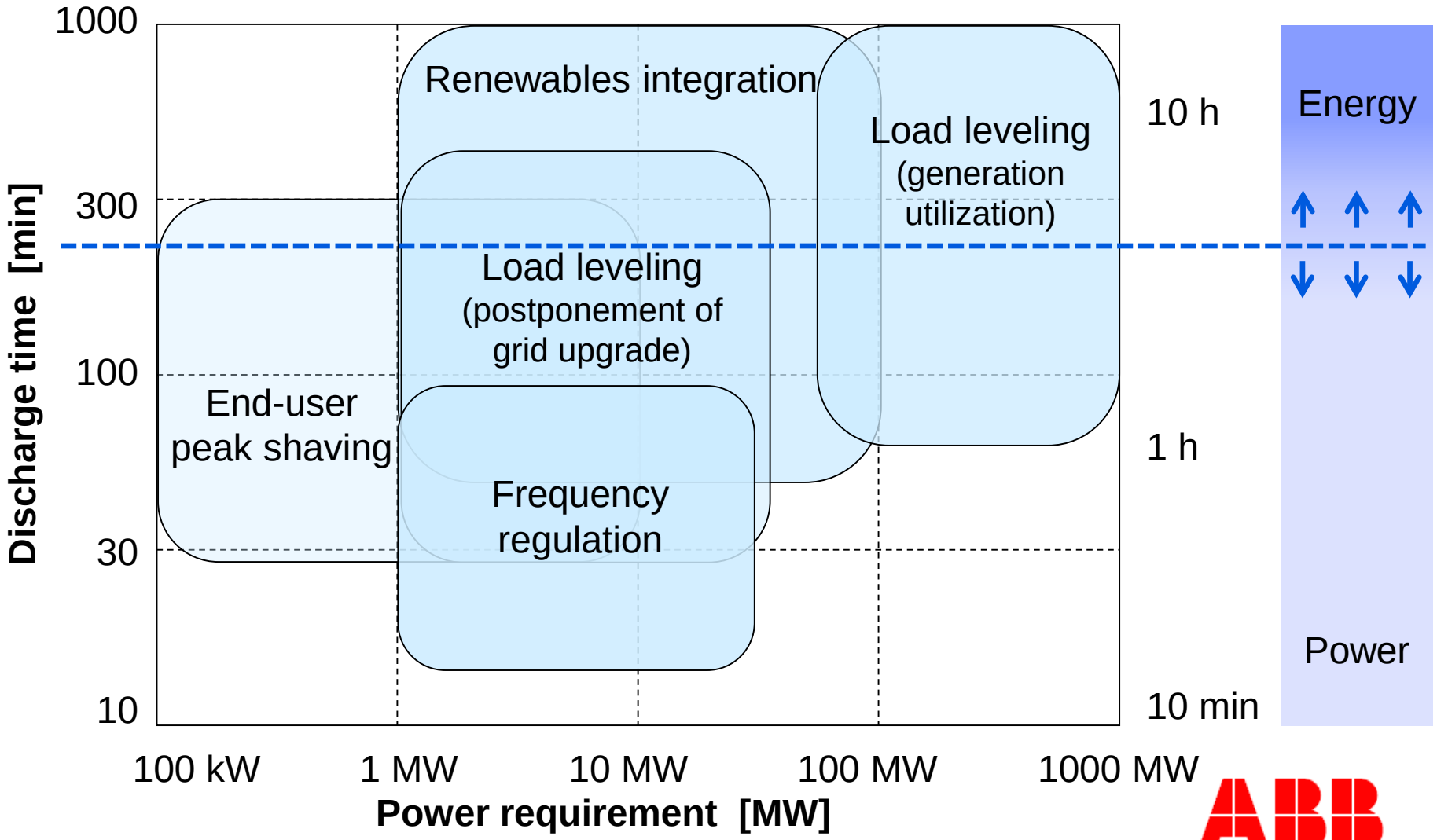


ESI PCS 100 DynaPeaQ PCS 8000

Batteries, flywheels, super-capacitors

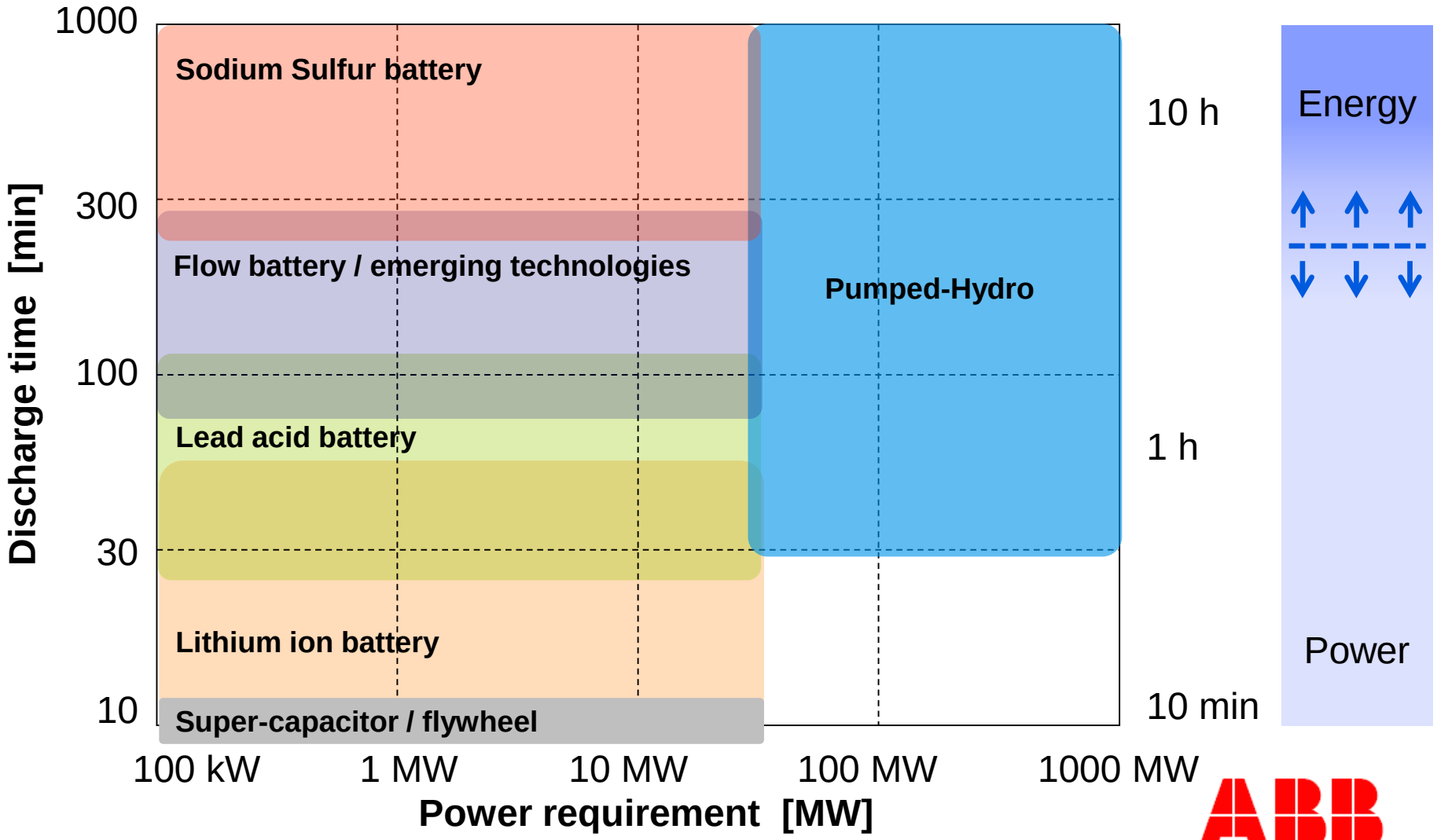
Pumped hydro

ESS applications fall into 2 categories
Segmentation between long and short discharge time



ESS = Energy Storage System

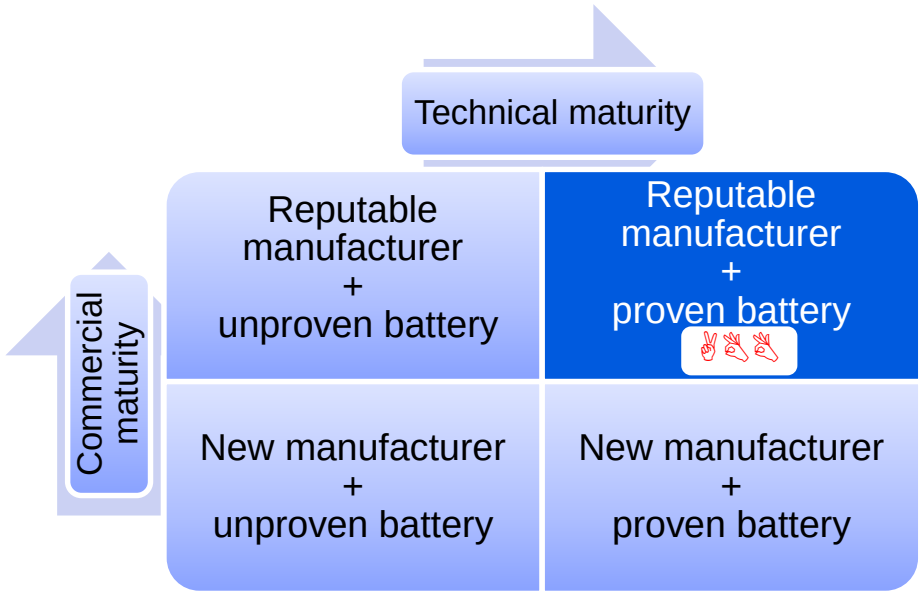
Right technology for right application
Segmentation on ‘power’ and ‘energy’ technologies



How ABB selects the right battery manufacturer
Evaluate both technical and commercial maturity

Specific to batteries

- Right performance
- Right total cost
- Support with in-house testing
- … as ‘due diligence’
- … to stay at the cutting edge of battery technology



All ABB suppliers

- Supplier Code of Conduct
- Process Audit
- Supplier Qualification
- Supplier Risk Management

An ABB battery module testing facility