6.1. Plenary Session 5

September, 27th. 2024

6.1.1 Energy Storage: an alternative to increase reliability in power systems and facilities

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Special thanks to Francisco Blánquez

Sustainability ⟷ Reliability

Electric Grid ⟷ Research Facility

Energy storage

Benefits that Energy Storage can provide to a research facility

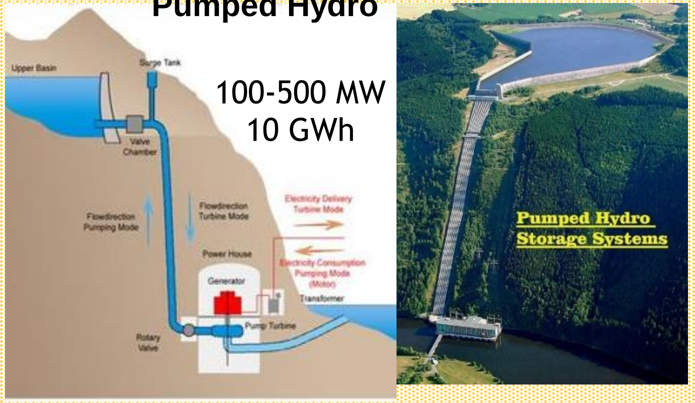
- Backup to provide continuous power supply during grid outages
- Isolation and immunity against external interferences
- Reduction in the required electric infrastructure
- Energy cost savings – peak power shaving
- Protection of sensitive equipment
- Integration of renewable energy for power supply
- Improve the power quality and grid stability (voltage regulation and harmonic distortion filtering)
- Provide additional grid services when the energy is not used

However, when designing the application, we need to keep in mind the technical limitations of each technology!

Energy Storage Technologies

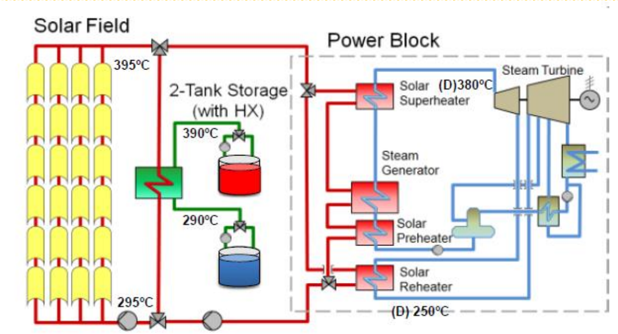
Pumped Hydro

100-500 MW
10 GWh



Thermal Storage

50-300 MW
0.1- 6 GWh

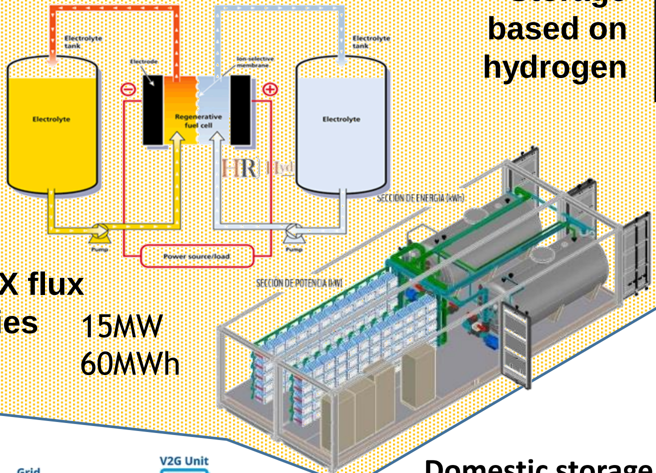


Storage based on hydrogen

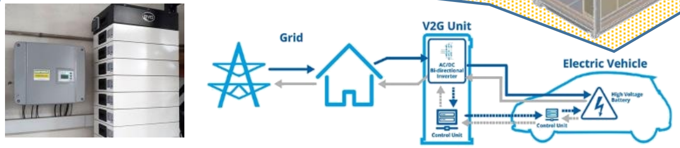
Compressed air energy storage (CAES)

REDOX flux batteries

15MW
60MWh



Liquid Air Energy Storage (LAES)



Domestic storage and electric vehicles

Flywheels

100-1000 kW
10-100 kWh

Supercapacitors

100 kW
1 kWh

Lithium batteries

1MW/1MWh

SMES

1 MW, 1 kWh

Classification of the Energy Storage Technologies

High-energy Storage

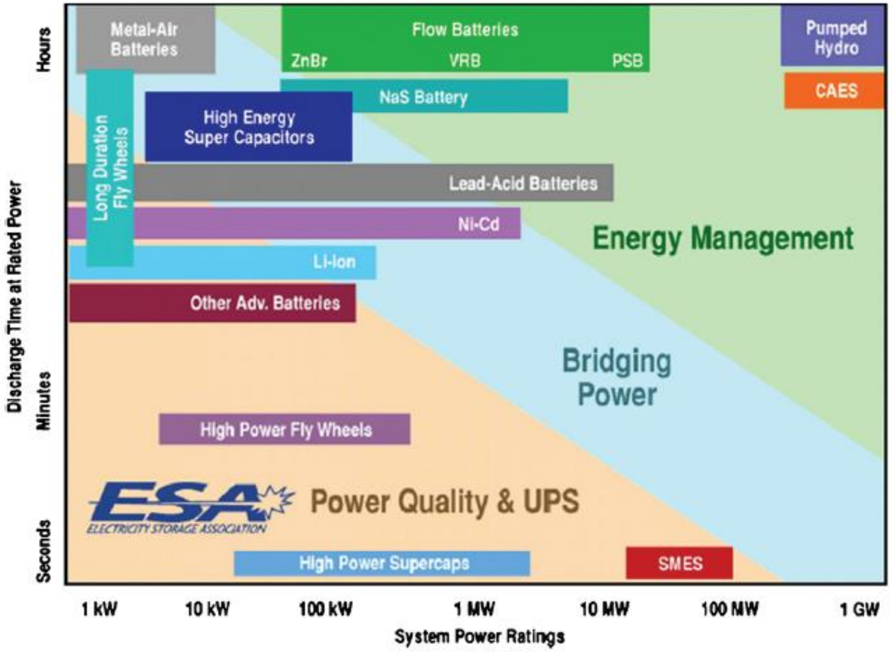
Characteristics: Long term, Energy >>> Power

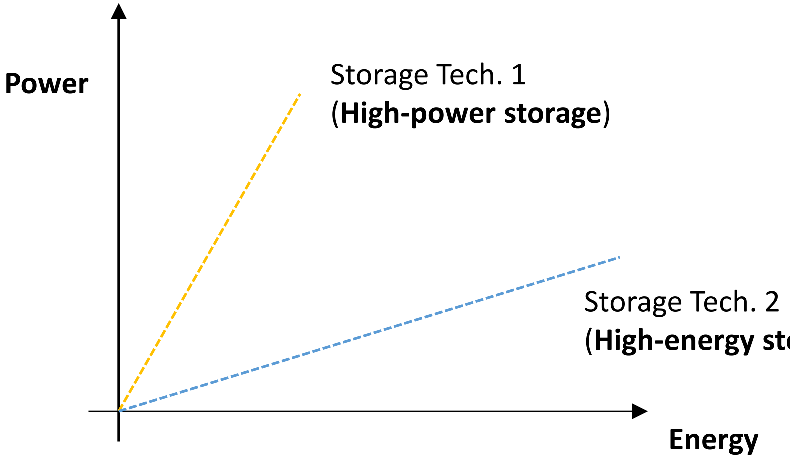
(Pumped hydro, CAES, LAES, Thermal Storage, Hydrogen, Redox flux batteries, gravitational, …)

High-power Storage

Characteristics: Short term, Power >>> Energy.

(Lithium batteries, supercapacitors, flywheels, Superconducting Magnet Energy Storage - SMES)

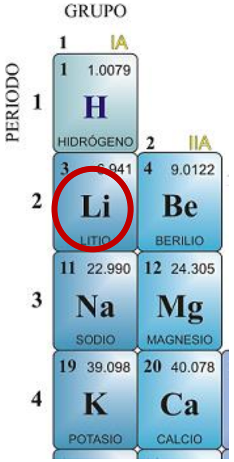




Approaches to face reliability challenges in research facilities: Energy storage technologies

The possibility of using Lithium-ion Batteries as energy storage system

- Lithium batteries is the most extended energy storage technology due to the electric vehicle deployment.
- High energy density but low power density
- The main problem is a very limited number of cycles. Rapid aging, losing their capacity (5,000 cycles)



Lithium Titanate Oxide (LTO) Batteries

- **Higher numer of cycles** (7,000 – 30,000).
  - Operating during 20 years with 1500 cycles/year
- **Higher termal stability** (-30ºC- 50ºC) - > **improve safety**.
- **Fast charging** capability and **higher efficiency.**

- **Lower energy density**.
- **Higher cost** per kWh.

Approaches to face reliability challenges in research facilities: Energy storage technologies

The possibility of using Capacitors and Supercapacitors as energy storage system

Ioxus (USA)
3150F, 2.85 V

3200F,
2.85 V
(Estonia)

Supercapacitor manufacturers provide very **similar** power, energy and power/energy ratios.

Eaton (UK)
3000F, 2.7V

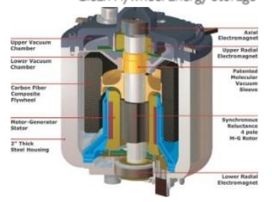
LS (China)
3000F, 2.8 V

Maxwell (USA)
3000F, 2.85V

Approaches to face reliability challenges in research facilities: Energy storage technologies

The possibility of using Flywheels as energy storage system

POWERTHRU Clean Flywheel Energy Storage



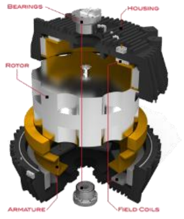
190 kW, 0.63 kWh
(USA)

250 kW
0.9 kWh
(USA)

Beacon POWER

100 kW, 50 kWh
(USA)

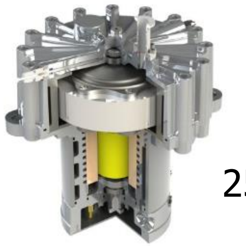
ACTIVEPOWER



VYCON

500 kW, 0.83 kWh
(USA)

Flywheel manufacturers provide very **different** power, energy and power/energy ratios.



Gyrotricity DURABLE ENERGY STORAGE

25 kW, 0.069 kWh
(UK)

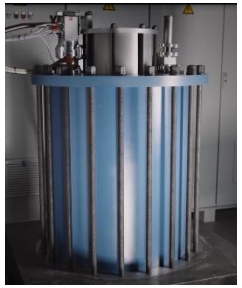
TERA LOOP

250 kW, 5.5 kWh
(Finland)

PILLER Power Systems

1600 kW
4 kWh
(Germany)

ADAPTIVE Balancing Power



700 kW, 12 kWh
(Germany)

KineticTraction Systems

700 kW, 12 kWh
(Germany)

STORNETIC The Energy Storage Company

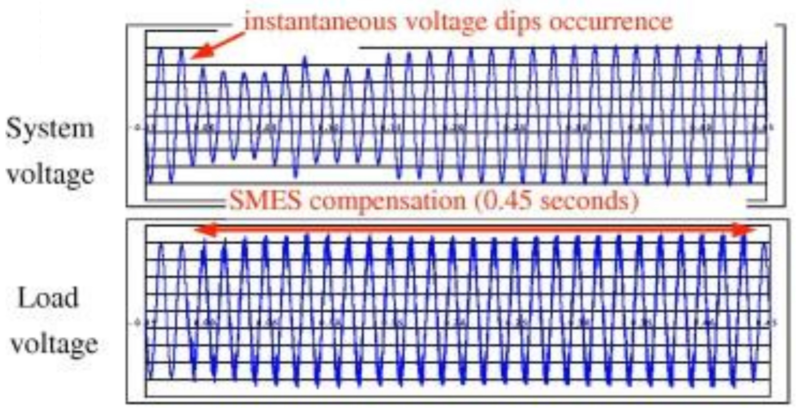
80 kW, 3.6 kWh
(Germany)

Approaches to face reliability challenges in research facilities: Energy storage technologies

The possibility of using of Superconducting Magnet Energy Storage (SMES) in research facilities

Kameyama SMES to **compensate voltage dips** in a plasma research facility.

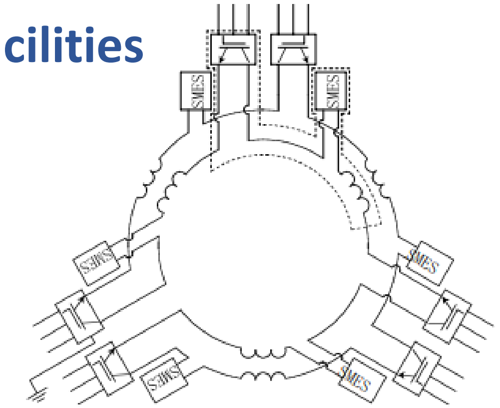
(Few seconds)



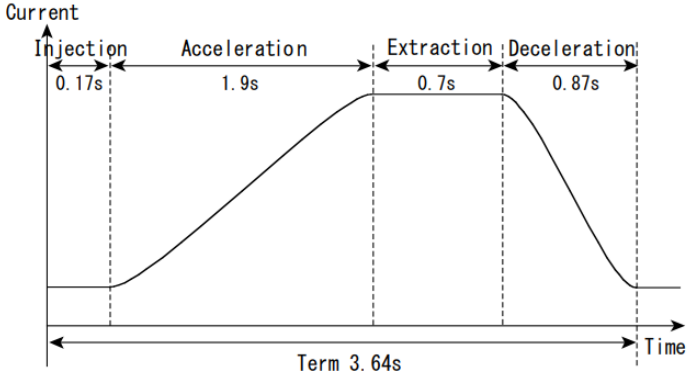
SMES: 10 MVA 10 MJ, 6.6kV, 1400A

Source: S. Nagaya et al. 2012. The state of the art of the development of SMES for bridging instantaneous voltage dips in Japan

An example of pulsed load (200 to 3,000A in 2 secs)



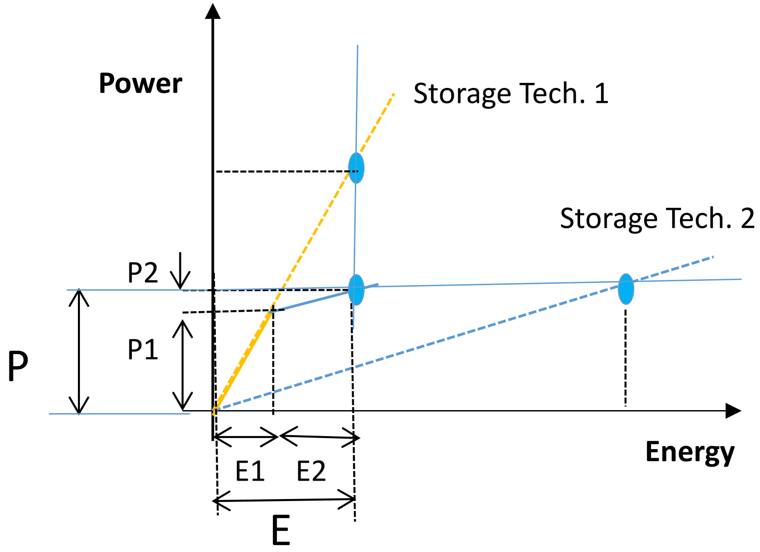
SMES in power supply of bending magnet.



***Source:** COMPENSATION OF LOAD FLUCTUATION OF POWER SUPPLY SYSTEM FOR LARGE ACCELERATOR USING SMES . H. Sato et al.*

Approaches to face reliability challenges in research facilities: Energy storage technologies

Selection of Storage Tecnologies



$$P_{total} = N'_{T1} \cdot P_{cell\_T1} + N'_{T2} \cdot P_{cel\_T2} + \Delta P$$

$$E_{total} = N'_{T1} \cdot E_{cell\_T1} + N'_{T2} \cdot E_{cell\_T2} + \Delta E$$

The possibility of using Hybrid Energy Storage (HESS)

Used tipically to:

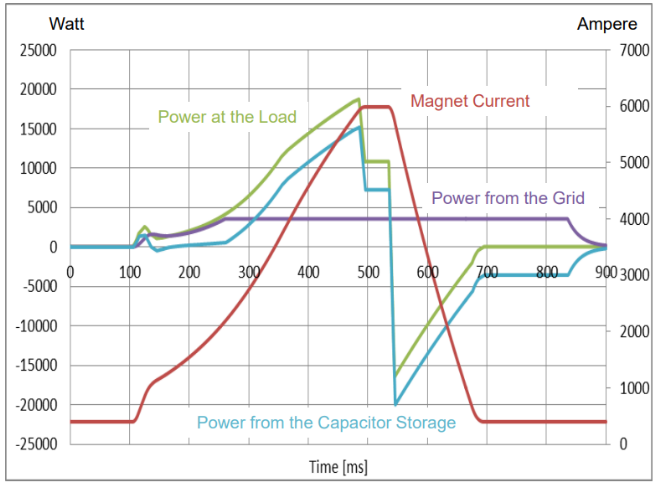
- Increase the life-cycle in the case of batteries or even some other plants, reducing wear and tear.
- Provide a more accurate solution to the system
- Provide additional flexibility services
- Increase the KPIs in some facilities

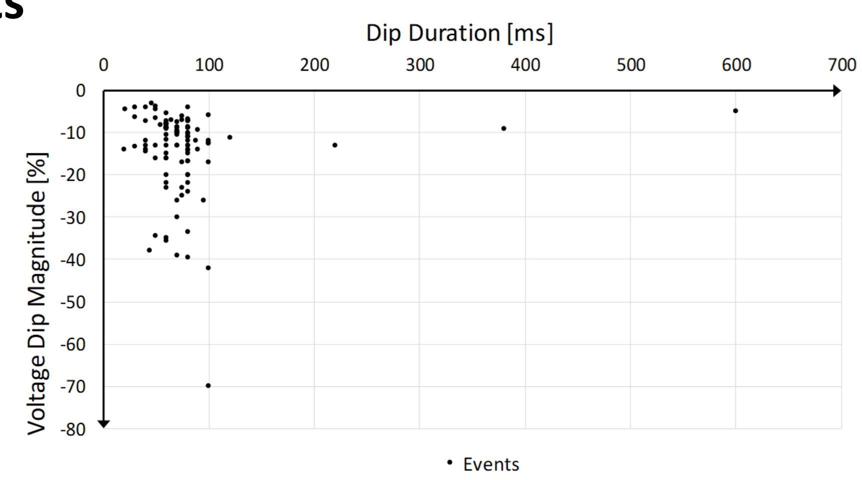
SCs, FW and SMES are good candidates for HESS.

8.8MW/7.12 MWh Lithium battery combined with 6 flywheels (3MW total) providing a total of 9MW for frequency support. Almelo (The Netherlands)

Technical challenges detected in research facilities related to power supply

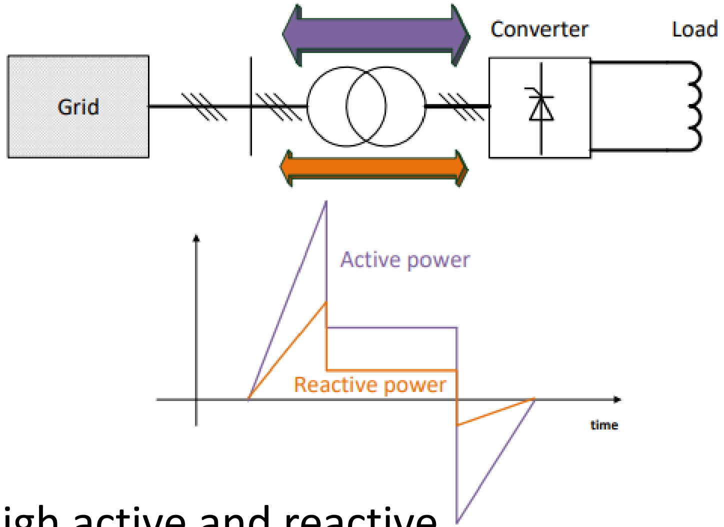
1. Network **stability** during **high pulsed or cycling loads**
2. **Immunity** against **fast transients and voltage dips**
3. Reduction or elimination of the effects of **active power transients**
4. Reduction or elimination of the effects of **reactive power transients**
5. **Powering infrastructure optimization**





Source: Back-to-Back HVDC Modular Multilevel Converter for Transient Voltage Dip Mitigation in Passive Networks. T. Hoehn et al. 2019. CERN.

Technical challenges detected in research facilities related to power supply

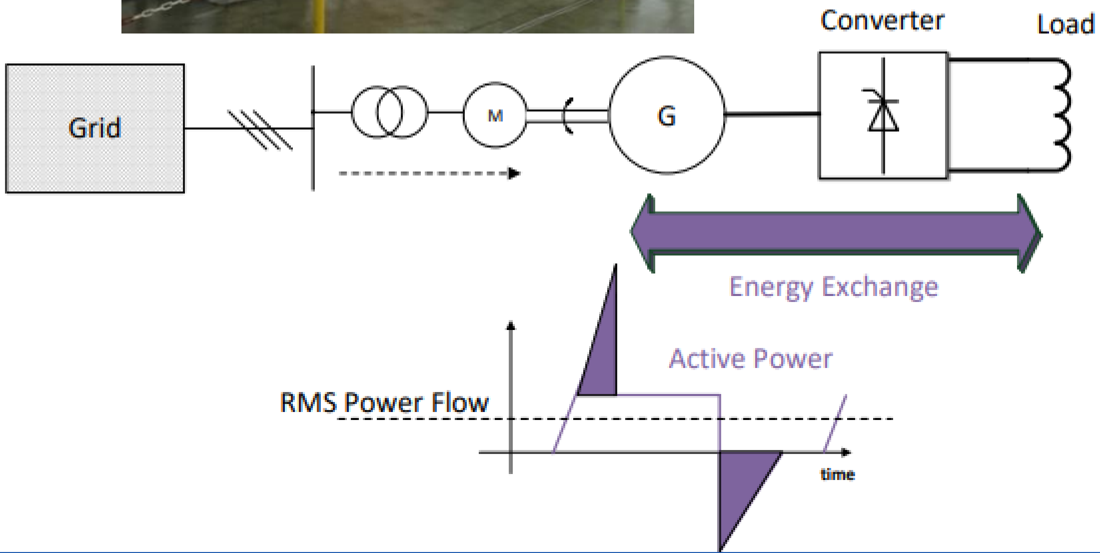


High active and reactive power consumption from the electric grid.

Solution based on adding inertia with electric machines.

The connection of the load through a huge inertia gives the possibility to provide pulsed power supplies without compromising grid stability.

95 MW Inertia

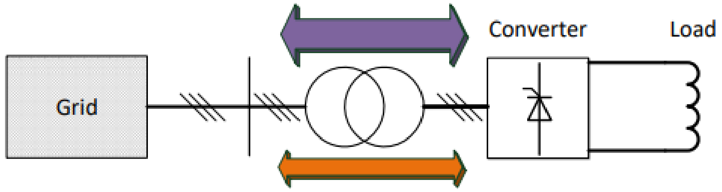


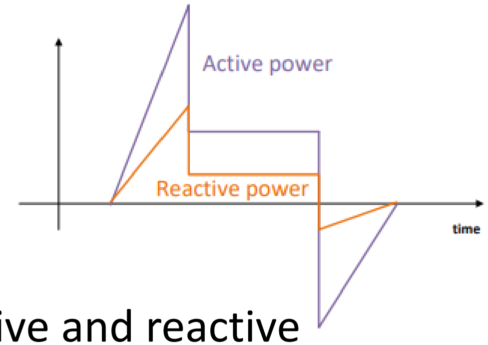
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

7th Workshop Energy for Sustainable Science at Research Infrastructures. September 25th to 27th - Madrid, Spain

Technical challenges detected in research facilities related to power supply

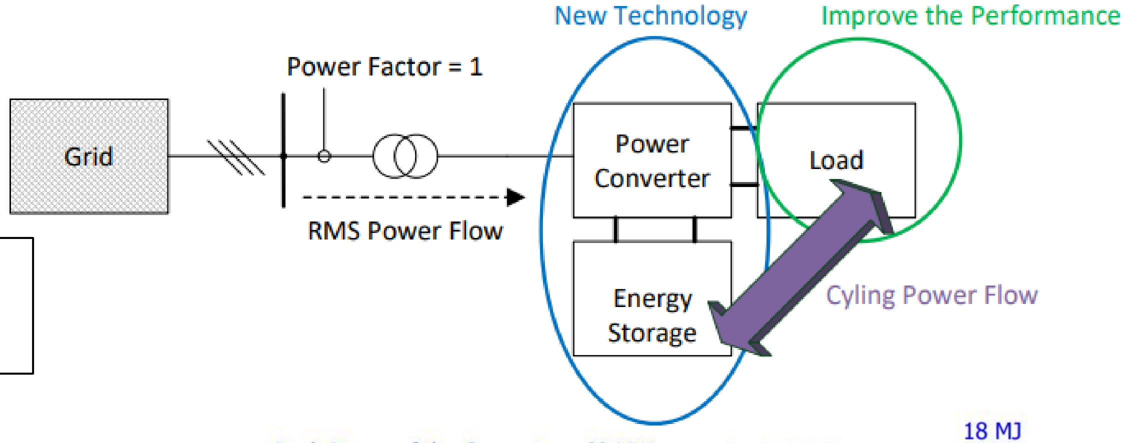


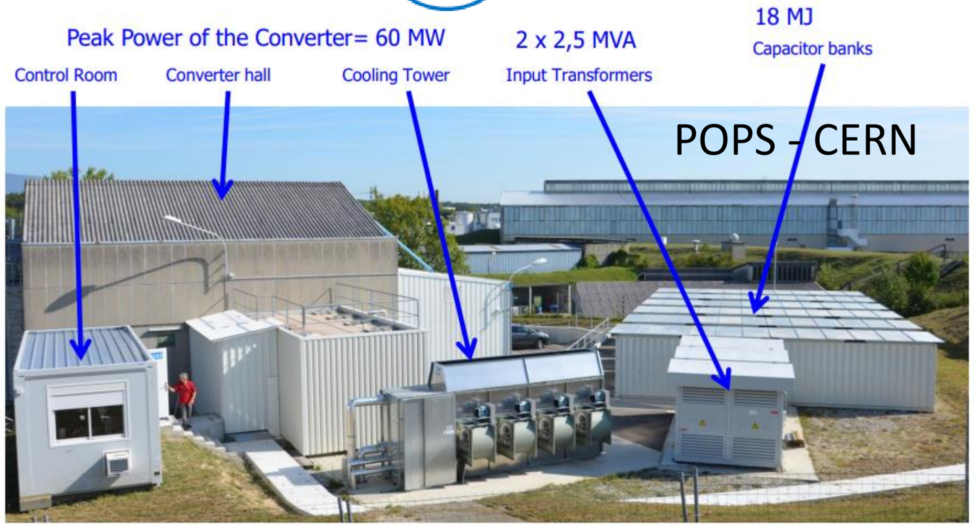


High active and reactive power consumption from the electric grid.

Solution based on energy storage using capacitors.

The technical design of these DC caps required an active cooperation with the manufacturers.
(technical limitation of the technology)

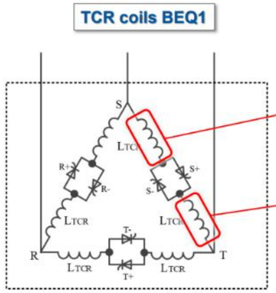




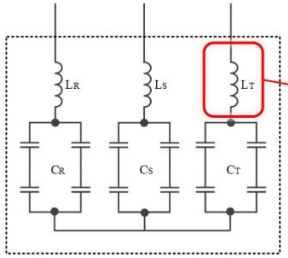
CERN

Technical challenges detected in research facilities related to power supply

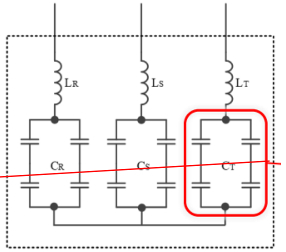
Reduce reactive consumption and harmonic distortion: Static Var Compensators (SVC)



TCR: Thyristor-Controlled Reactor

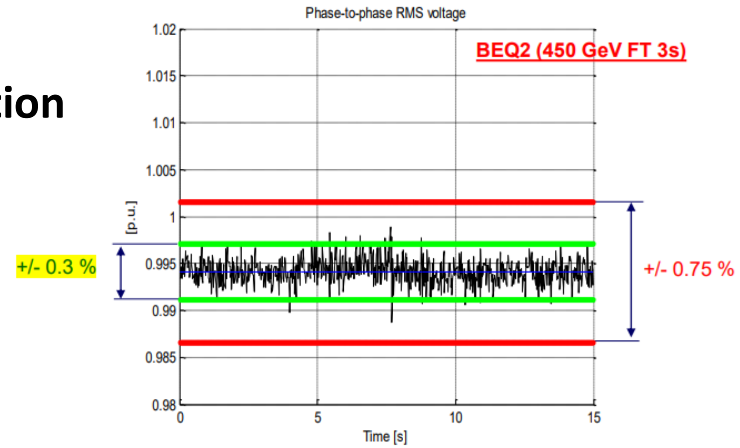


Harmonic Filters

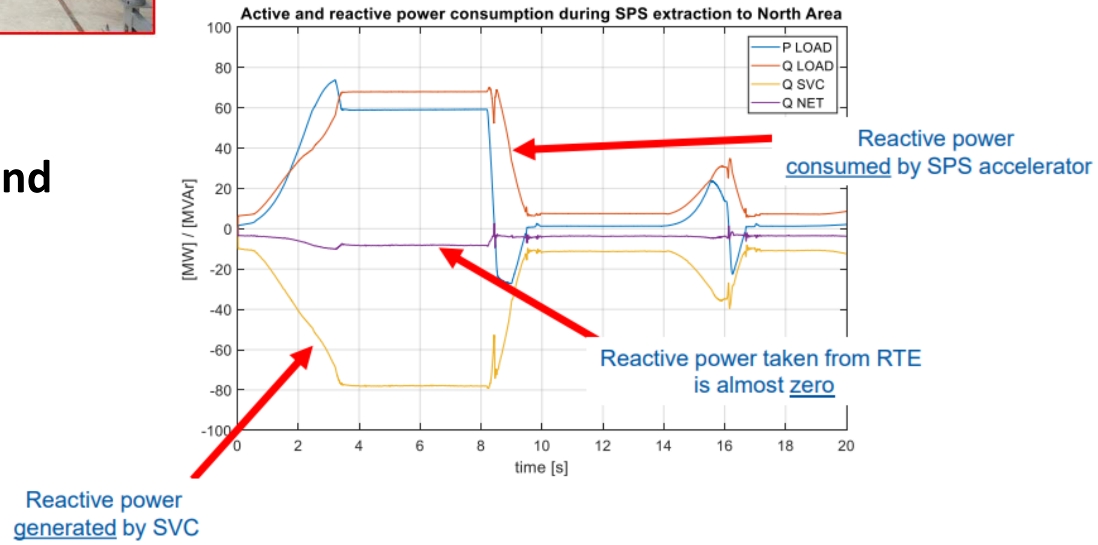


Harmonic Filters

Voltage stabilization



Reactive power compensation and response time

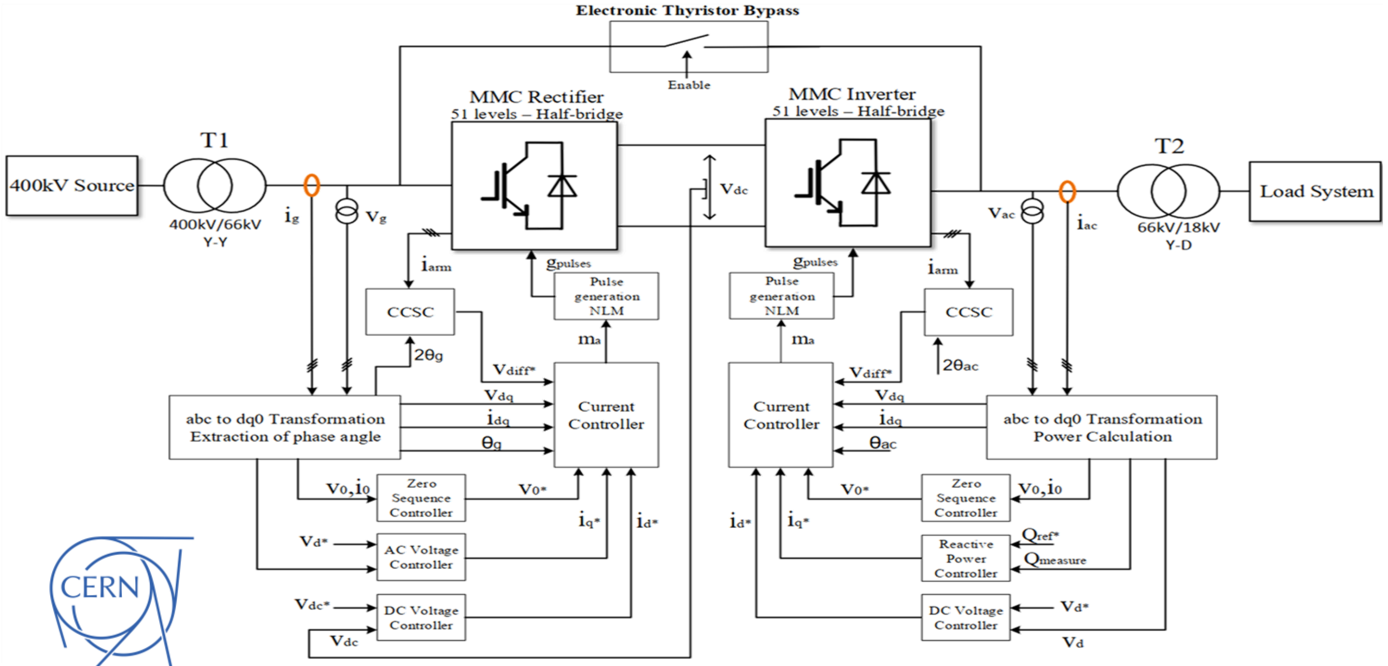


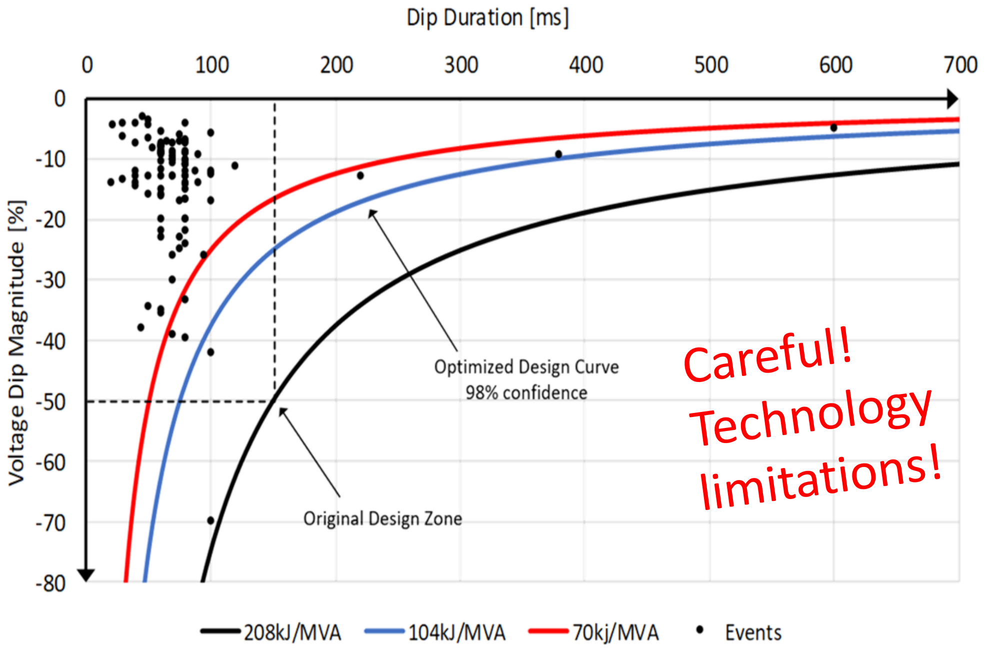
Technical challenges detected in research facilities related to power supply

Compensating a complete set of phenomena

Modular Multilevel Converters (MMC) with capacitors distributed in the modules. Is able to overcome: stability, reactive power compensation, filtering up to a certain harmonic and immunity against network transients)

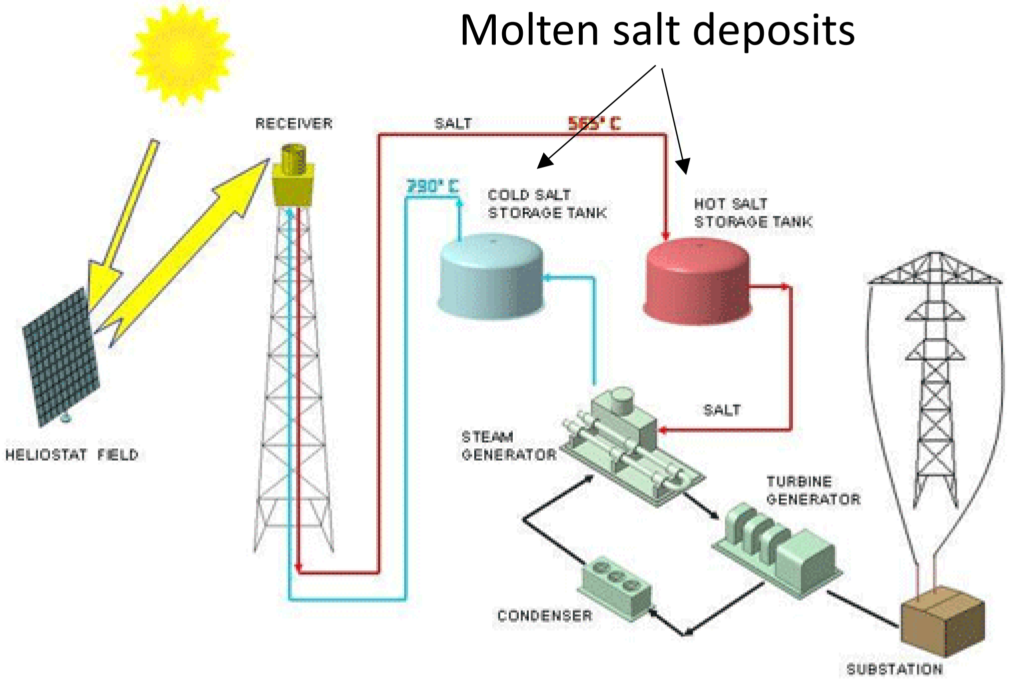
During the system design phase, the DC caps would need to be dimensioned considering also the aspect of transient mitigation



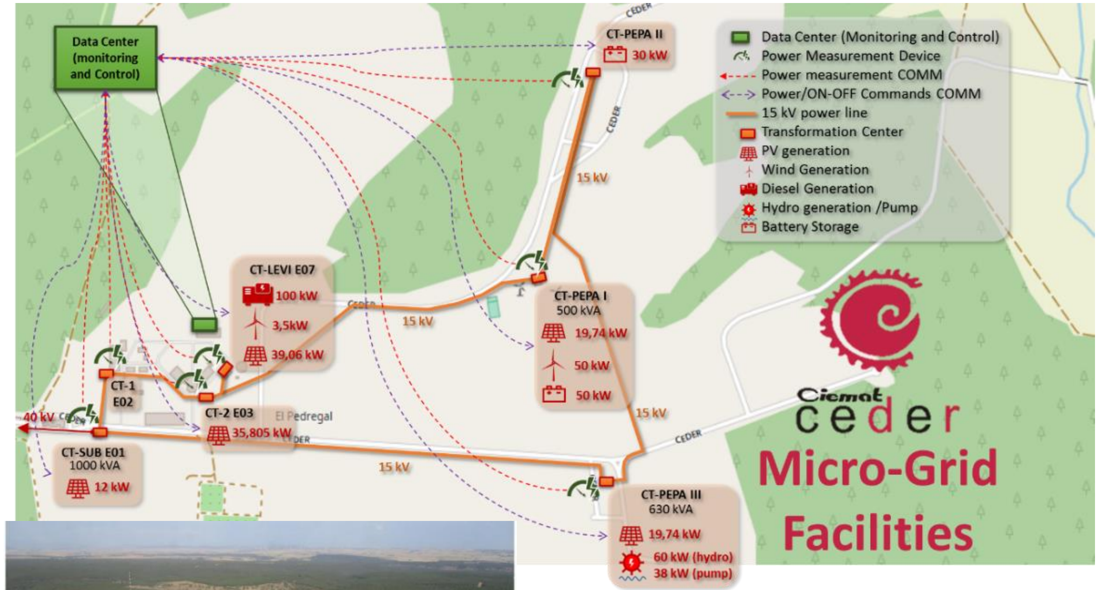


Examples of energy storage use in research facilities. Plataforma Solar de Almería (PSA)

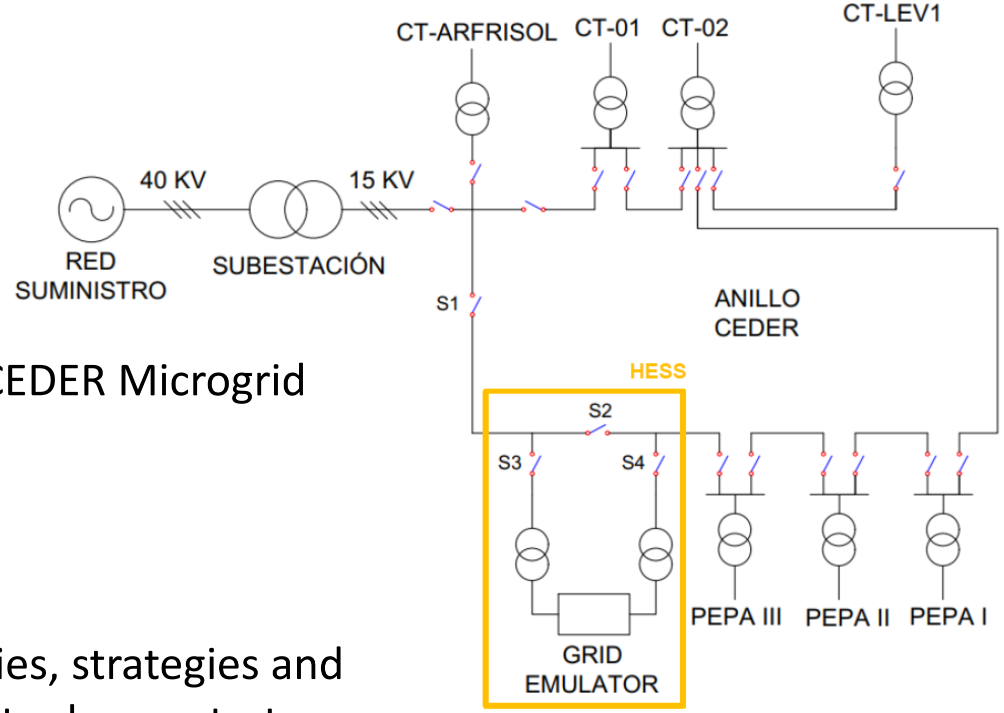
PSA is a scientific research center belonging to CIEMAT focused on research, testing & development of Concentrating Solar Thermal (CST) tech. and its applications.



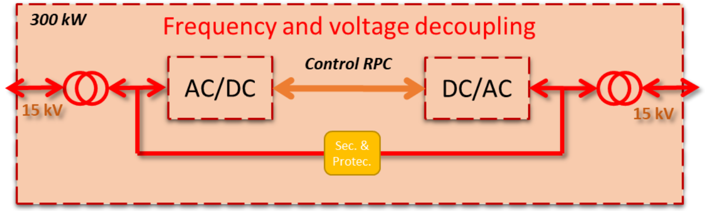
Validation of technologies to be used in research facilities under real conditions. Centro de Energías Renovables (CEDER-CIEMAT)



CEDER Microgrid



Ttest and validate new technologies, strategies and equipment under real conditions to demonstrate their reliability



A declloupling power converter permits the microgrid to behave as any grid.

CONCLUSIONS

1. Sustainability goes hand in hand with reliability.
2. Both the research facility and the electric grid must be considered.
3. Energy storage is one of the key issues to improve reliability in research facilities. In particular high-power technologies fit better the requirements.
4. Hybrid energy storage is taking very much importance since adds advantages of several technologies in particular applications.
5. Some case studies and experiences have identified the critical issues that compromise reliability (stability, reactive power compensation, filtering harmonics and get immunity against network transients). Energy storage is being used to overcome those challenges.
6. Flexible experimental plants are essential to validate technologies, equipment and operation strategies before being installed in a big research facility.

Thank you for your interest!

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