CLUB ESPAÑOL DE LA ENERGÍA
INSTITUTO ESPAÑOL DE LA ENERGÍA

accenture

CURSO DE GESTIÓN DE REDES ELÉCTRICAS INTELIGENTES

2 – LA TECNOLOGÍA AL SERVICIO DE LAS REDES INTELIGENTES

2.2 – Electrónica de potencia aplicada a las redes inteligentes

Junio 2014

CLUB ESPAÑOL DE LA ENERGÍA
INSTITUTO ESPAÑOL DE LA ENERGÍA

accenture

Ingeteam

CURSO DE GESTIÓN DE REDES ELÉCTRICAS INTELIGENTES

1 – EVOLUCIÓN HACIA LAS REDES INTELIGENTES

1.1 – El reto de las redes inteligentes para las empresas eléctricas

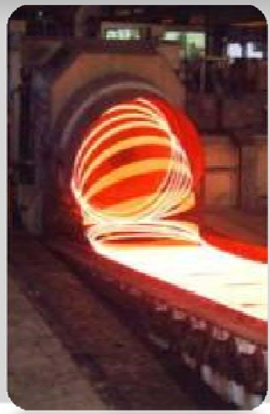
Junio 2014

Ingeteam Group Organisation Chart (Divisions)

Energy

Marine

Industry



Basic Tecnologies

Traction

Services

Power Grid Automation (PGA) Business Unit:

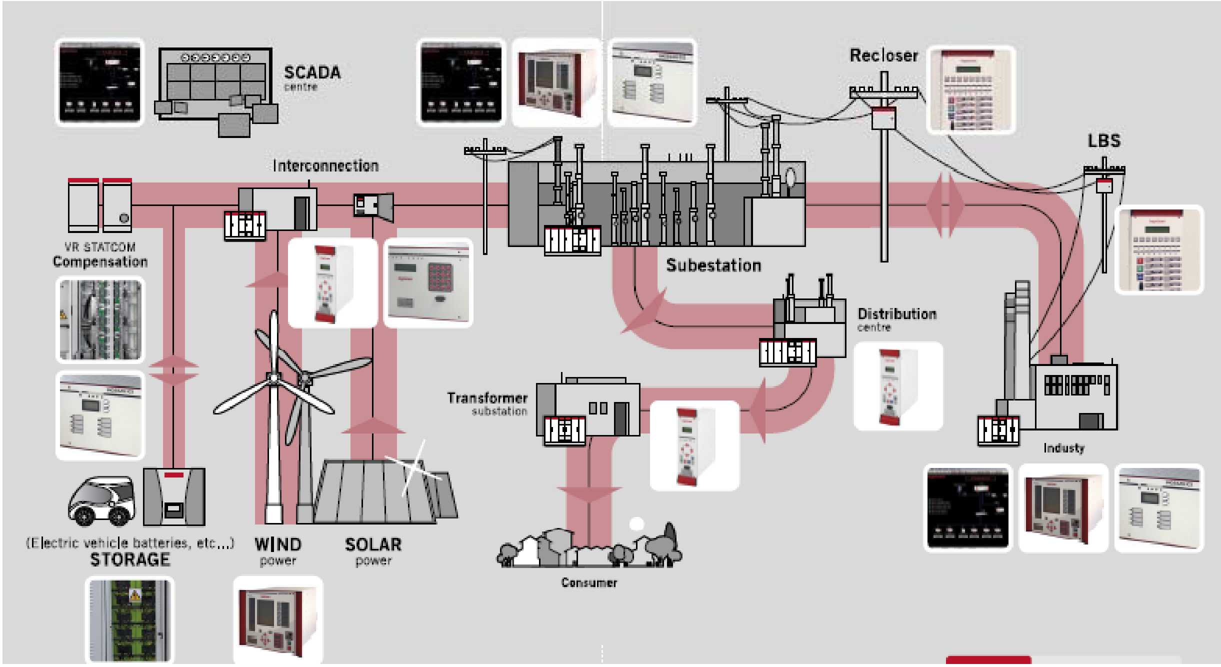
- Grid Automation
- Power Electronics Systems

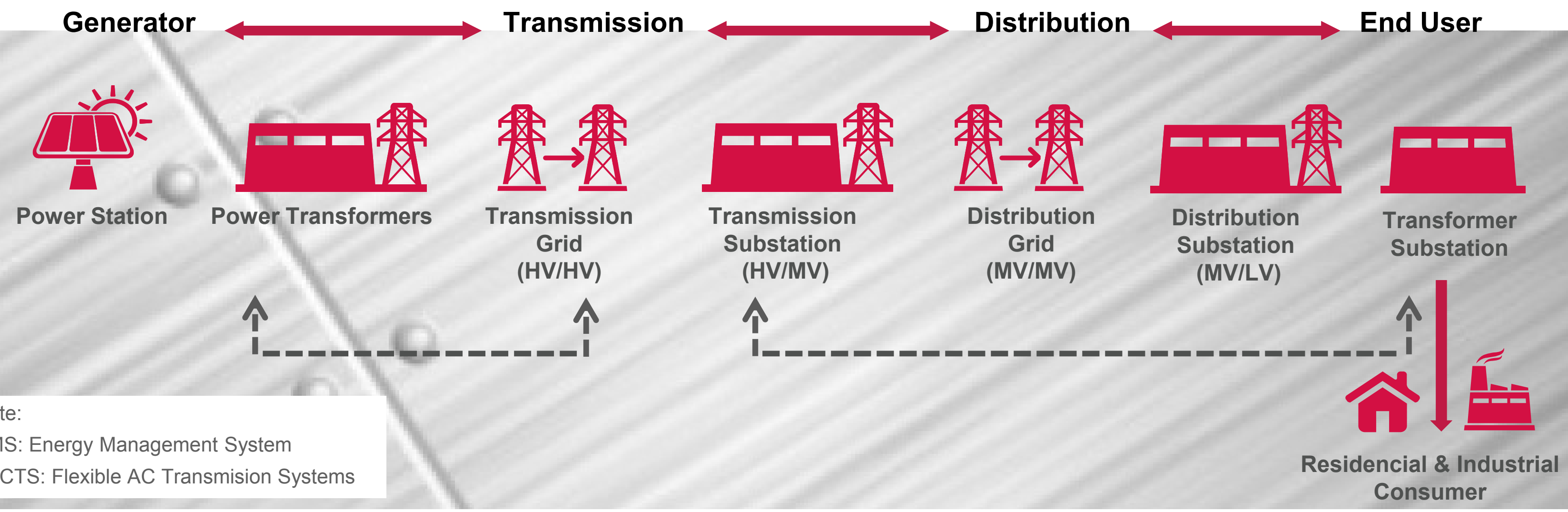
Power Grid Automation (PGA) in charge of Smart Grids Solutions

Ingeteam

Product Offering

- Substation Automation
- Distribution Automation
- FACTs & Custom Power
- EMS & Dispatching Centres
- Electric Mobility
- Energy Recovery Systems





Note:
EMS: Energy Management System
FACTS: Flexible AC Transmision Systems

Wide Experience and track record in Power Electronics-Renewables Business

Wind Generation

24 GW

Accumulated Power Installed

PV Generation

3,5 GW

Accumulated Power Installed

Hydro Generation

6,5 GW

Accumulated Power Installed

Power Grid Automation (PGA) INGEGRID: Storage, FACTS & Custom Power, SSSC

Ingeteam

Solutions

INGEGRID STORAGE

Energy Storage

INGEGRID QUALITY

Electrical Supply Quality

INGEGRID RENEW

Integrating Renewables

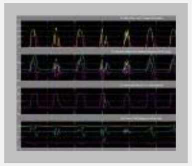
Products

INGEGRID SH B/U

STORAGE. For battery & ultracapacitor storage systems

INGEGRID SHS

STATCOM For STATic var COMpesation



INGEGRID SIM

Simultation Tools

INGEGRID is the product range that offers a **flexible**, **modular solution** for:

- Power Quality applications
- Power Flow management
- Storage applications: frequency regulation, peak shaving, integration of renewable energy

Ingeteam is an independent power electronics solutions partner that bridges the gap between

Electrical Grid ⟷ **Ingeteam** ⟷ **Battery / Super Capacitors / Inductances / Transformers**

- Transmission & Distribution grid operators
- Renewable energy producers
- Grid Service Providers
- End users

- Cells / Racks / Battery
- Supercapacitors
- Reactors/Inductances
- Transformers

Business Model Approach for Power Electronics Solutions

Ingeteam

1. Select partners attending to:
   - ✓ Geographical approach
   - ✓ Application or Technology
   - ✓ Financial Strength
   - ✓ Route to Market or Sales Entry
2. NDA, Confidential Agreement in order to protect IP, data, results,
3. Memorandum of Understanding to regulate next steps and intentions
4. Define the business model (Consortium or Buy/Seller)
5. Regulate and agree on exclusivity terms
6. Regulate leadership of the partnership
7. Define the scope of supply of each party to prepare joint proposal fo the customer
8. Present and defend together the joint proposal
9. Define and prepare supersedding agreements in case of award from the customer
10. Set basis for and enter into strategic alliance for future operations

- Select Consortium Agreement or Buy-Supply contract
  - ✓ Consortium Agreement> key futures
    - ✓ More competitive, not building up a company, etc.
    - ✓ Joint and solidaire liability
    - ✓ Diversify insurance coberture and possibility to the customer to sue any of the parties
    - ✓ Leadership to be entrusted
    - ✓ Important to regulate and tackle the overlappings between Scope of supply
    - ✓ Language and culture
    - ✓ Consortium legal scheme: AIE, UTE, cooperativa..
  - ✓ Purchasing Order from customer-> Key features clave
    - ✓ Contract between customer and consortium members
    - ✓ Extension and scope of supply of the EPC
    - ✓ Liabilities and penalties
    - ✓ Industrial Property
    - ✓ Performance KPI, Efficiency, Availability test, grid code compliance…
    - ✓ Terms& conditions and O&M Contract

SELECTING OPTIMUM TOPOLOGY BASED ON:

- APPLICATION (RRC, CPC, FC, etc)
- PLANT SIZE (xxkW, xxxkW, xxMW)
- REQUIRED FUNCTIONALITIES
- GRID CODES COMPLIANCE (LVRT, HVRT, MPR,..)
- PRELIMINARY STORAGE TECHNOLOGY
- TARGET PRICE / EFFICIENCY / REDUNDANCY

POSSIBLE TOPOLOGIES:

- DC-DC INTEGRATED
- COMPACT AC
- SEPARATED RENEW & STORAGE (DC-AC)
- SEPARATED RENEW & STORAGE (DC-DC-AC)
- OTHERS

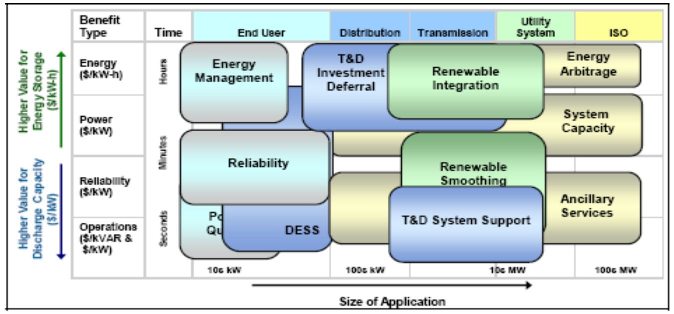
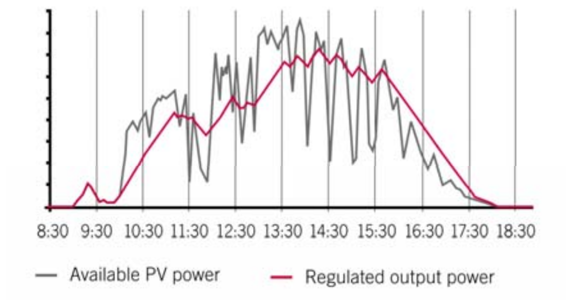
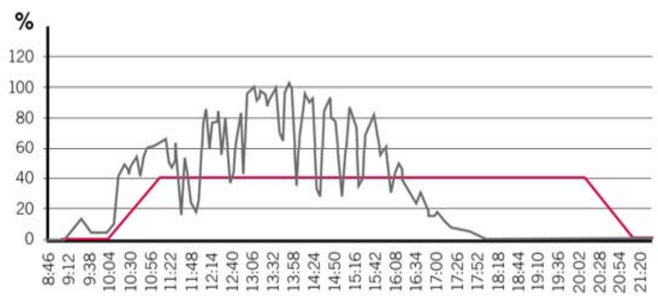


Figure 5
Operational Benefits Monetizing the Value of Energy Storage

Ramp Rate Control
Puerto Rico



Constant Power Control



INGEGRID™ SIM : SIMULATION TOOLS FOR THE APPLICATION

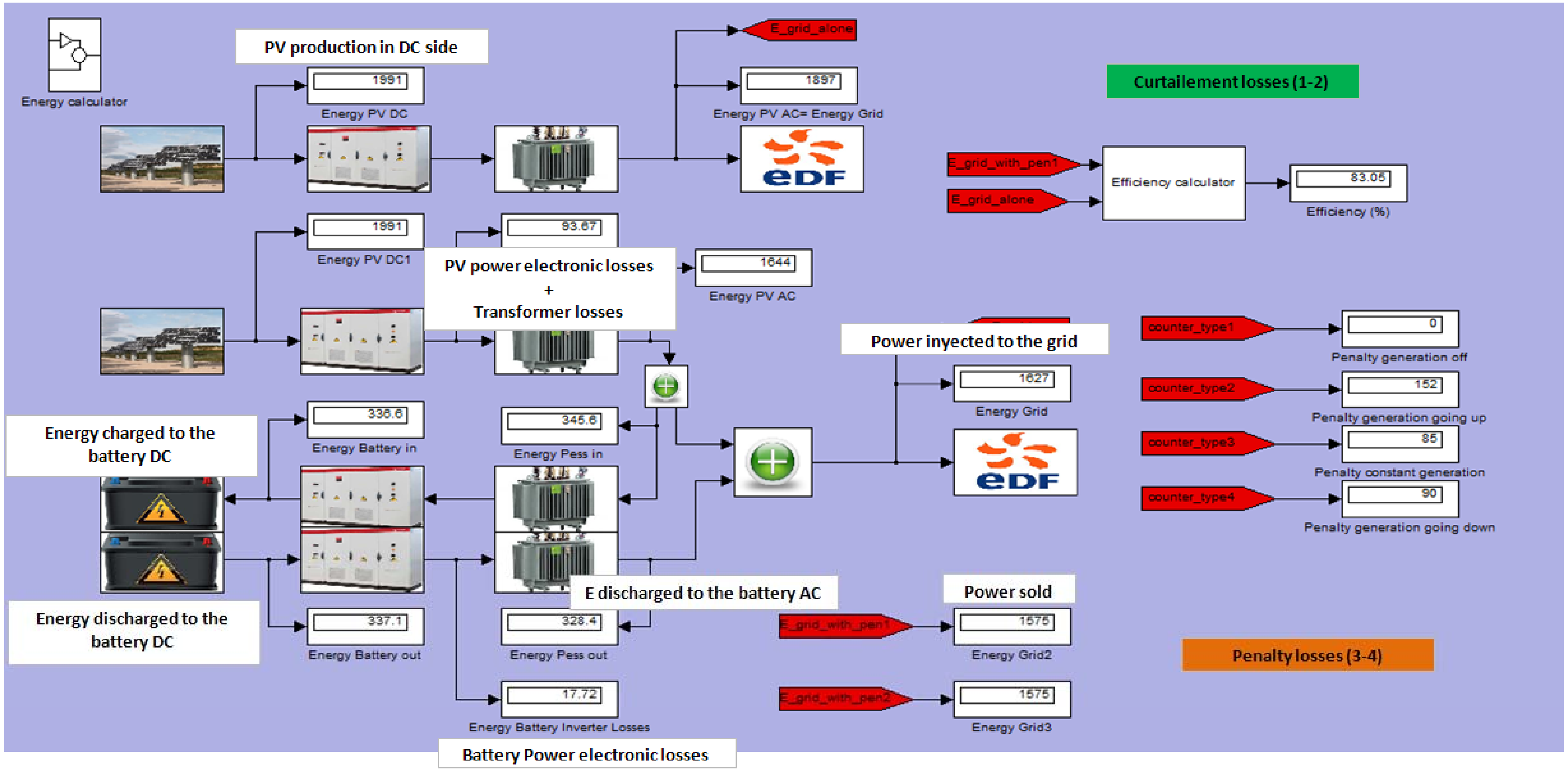
NECESSITY TO RUN SIMULATION MODEL FOR THE PLANT OPERATION TO VALIDATE EXPECTED OPERATION AND PERFORMANCE.

- **IMPORTANCE OF SITE ENERGY SOURCE INFORMATION ACCURACY, PRECISION AND TIME FRAME.**
- **RUN SIMULATIONS AND ANALYZE EFECT OF CURRENT PROFILES IN BATTERY LIFE (JOIN TASK WITH BATTERY MANUFACTURER).**
- **SELECT BEST PERFORMING BATTERY TECHNOLOGY.**
- **RUN DIFFERENT SIZING SIMULATIONS TO SELECT BEST BUSINESS CASE.**

Ingeteam

Simulation studies of Real Time Control Systems

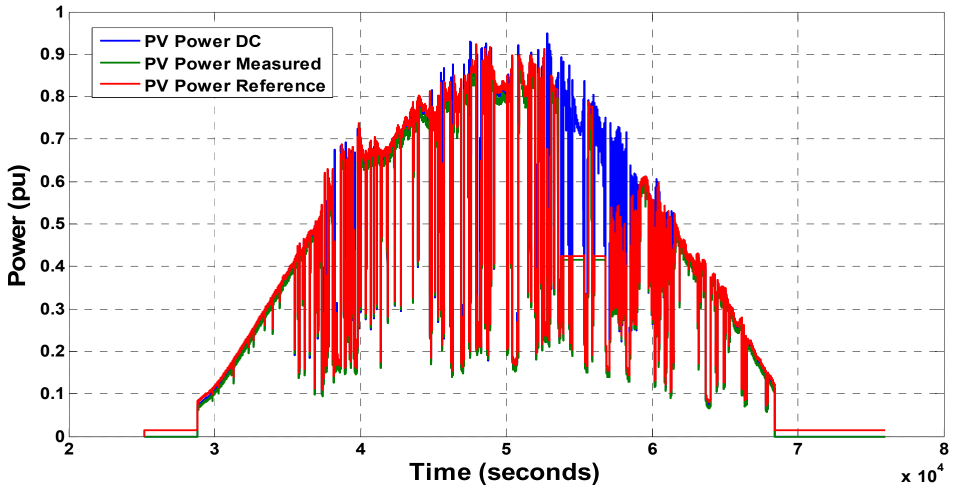
→ **Long term simulations: sample time of minutes with analysis of several years**

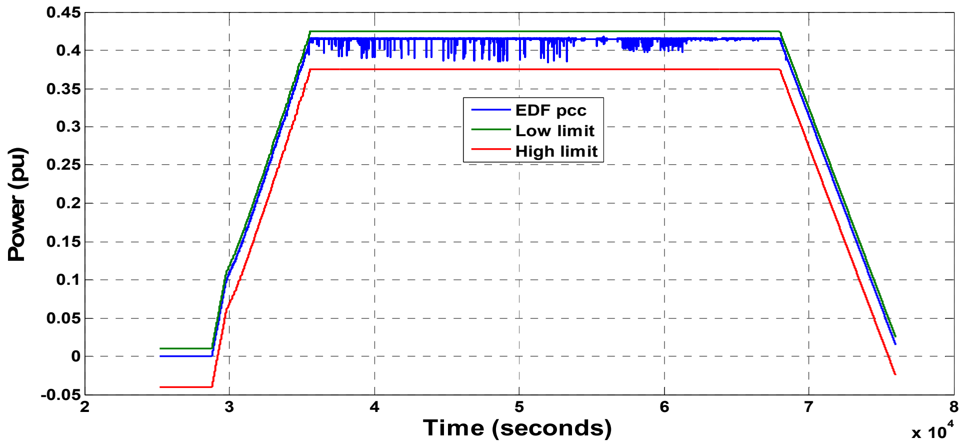


INGEGRID SIM PV

Simulation studies of Real Time Control Systems

→ **Short term simulations: sample time of milliseconds with analysis of hours / day**





INGEGRID™ STORAGE

Ingeteam

Li-ION Battery Storage System in transportable container

Ingeteam Confidential

Present Value of the storage applications

Table 3
Representative Benefit PVs of Selected Energy Storage Benefits (expressed as $/kW-h and $/kW)

Value Chain	Benefit		PV $/kW-h		PV $/kW	
			Target	High	Target	High
End User	1	Power Quality	19	96	571	2,854
	2	Power Reliability	47	234	537	2,686
	3	Retail TOU Energy Charges	377	1,887	543	2,714
	4	Retail Demand Charges	142	708	459	2,297
Distribution	5	Voltage Support	9	45	24	119
	6	Defer Distribution Investment	157	783	298	1,491
	7	Distribution Losses	3	15	5	23
Transmission	8	VAR Support	4	22	17	83
	9	Transmission Congestion	38	191	368	1,838
	10	Transmission Access Charges	134	670	229	1,145
	11	Defer Transmission Investment	414	2,068	1,074	5,372
System	12	Local Capacity	350	1,750	670	3,350
	13	System Capacity	44	220	121	605
	14	Renewable Energy Integration	104	520	311	1,555
ISO Markets	15	Fast Regulation (1 hr)	1,152	1,705	1,152	1,705
	16	Regulation (1 hr)	514	761	514	761
	17	Regulation (15 min)	4,084	6,845	1,021	1,711
	18	Spinning Reserves	80	400	110	550
	19	Non-Spinning Reserves	6	30	16	80
	20	Black Start	28	140	54	270
	21	Price Arbitrage	67	335	100	500

Note: each benefit is modeled in isolation using a consistent battery configuration of 1 MW of discharge capacity and 2 MWh of energy storage capacity, with a 15-year life and a 10% discount rate. Here we introduce the nomenclature "$/kW-h" used throughout this report. In this table it is the present value of the benefits divided by the useable kWh of the energy storage device.

- **Maximize Value of each appl. And thus the IRR so,**
- **Incorporate all benefits in the business case**
- **Prove value through simulation**
- **Benefit from simultaneous modes operation**
- **Minimize CAPEX through engineering evaluation**
- **Minimize OPEX through preventive and corrective O&M contracts**
- **Minimize penalties to Regulator through EMS**
- **Achieve suitable pay back**
  - **Storage < 5 years (depends)**
  - **Storage fast response < 1y**
  - **Power Flow < 5 years**

- **Each business case linked to local regulation and prices**
- **Run away from "commoditization"**

Ingeteam

Ingeteam Confidential

Technology	Stored Energy	Max Power	Time
Super capacitors LS	~ 10 kWh	4 MW	6 seconds
Li – Ion / Valence	105 kWh	100 kW at 1 C	1 hour
High-Temp. / Zebra	70 kWh	35 kW at 0,5 C	2 hours
Li – Ion / SAFT	3000 kWh	1000 kW at 0,37 C	3 hours
Li – Ion / SAFT	560 kWh	1000 kW at 1,75 C	0,5 hours
Li – Ion / SAFT	38 kWh	100 kW at 2,6 C	0,3 hours
Li – Ion / SAFT	9000 kWh	4500 kW at 0,5 C	2 hours
Li – Ion / Confidential	400kWh	1000 kW at 2,5C	0,4 hours
Li – Ion / SAFT	2000 kWh	1000 kW at 0,5 C	2 hours

Grid Support+ peak shaving +reactive power mgmt. application




INGEGRID™ STORAGE : Case Study 1: Aldea de San Nicolás – Gran Canaria

Ingeteam

What is the PROBLEM we are facing?

Aldea de San Nicolás is situated on the western side of Gran Canary island and it is connected to the generation power plants via a single overhead transmission line which runs across a protected area - the Tamadaba Natural Park. The village is located in an industrial area. Consumption using the existing line is at its maximum limit and investment into new infrastructure (generation plant, new transmission line, etc.) is restricted by both financial costs and by the environmental impact that it may have.

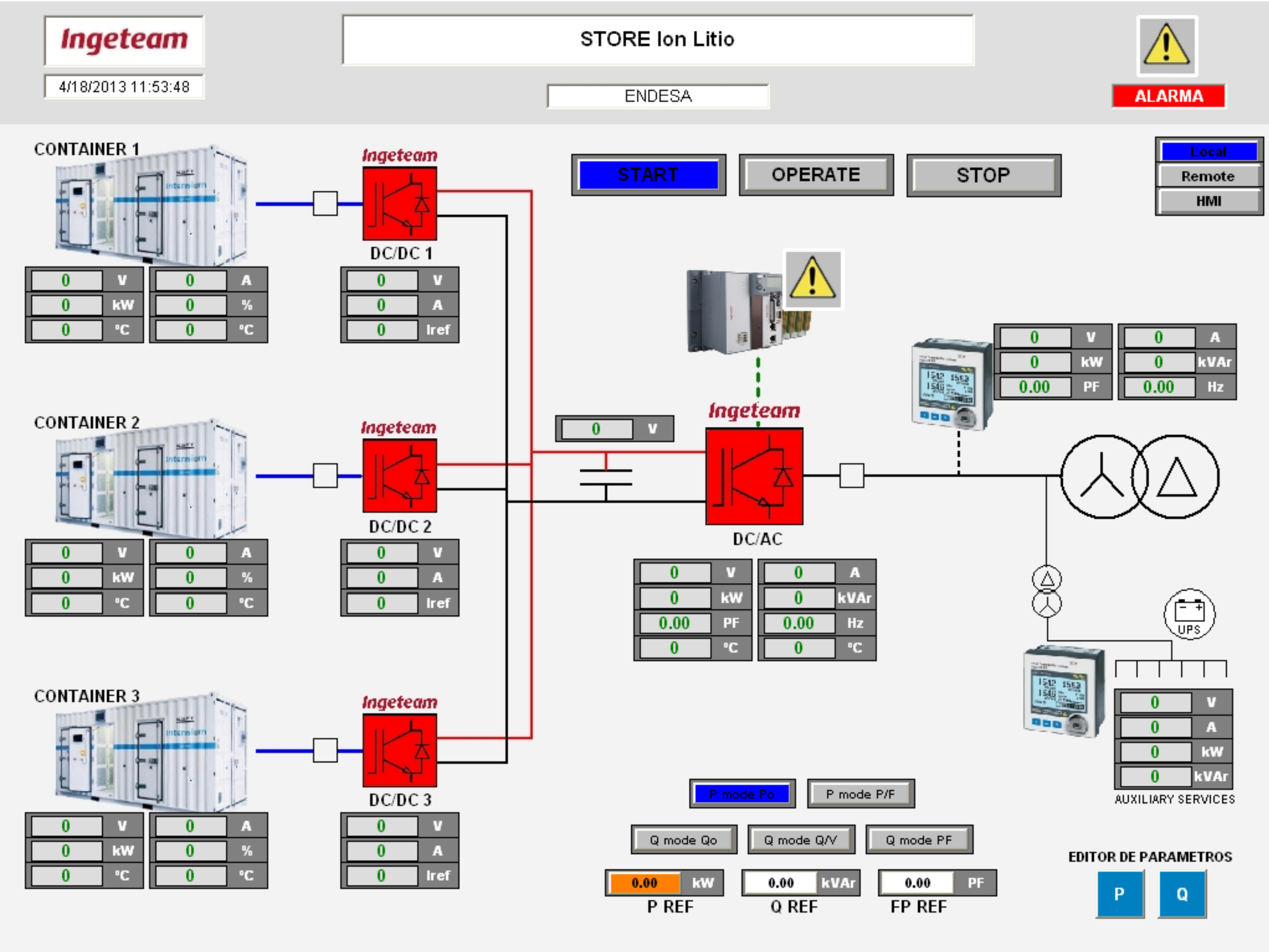
What is the primary Objective?

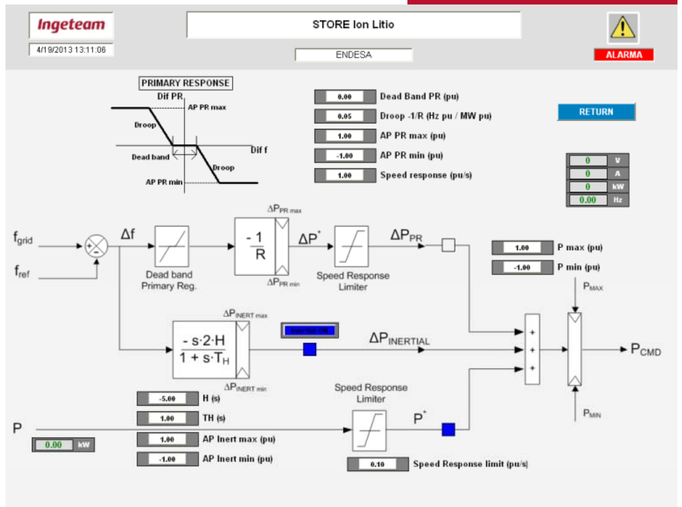
- ***To demonstrate the technical and financial viability of large-scale storage systems***
  - ***<u>improving the reliability and operation of the grid</u> in island networks.***
  - ***<u>managing temporary unbalances</u> between generation and demand, thus helping to make transmission grids more flexible and reliable and enhancing both quality of supply and system operation.***
- ***Storage systems can also help <u>solve the problems inherent in isolated systems</u>, such as island networks, <u>where the grid's stability is affected by unpredictable technologies as is the case with renewables (*),</u>***
  - ***and where conventional generation costs are higher than in the mainland system due to variable costs such as fuel.***
  - ***These technologies are particularly useful in isolated systems with low installed capacity as is the case with the Spanish non-mainland systems.***

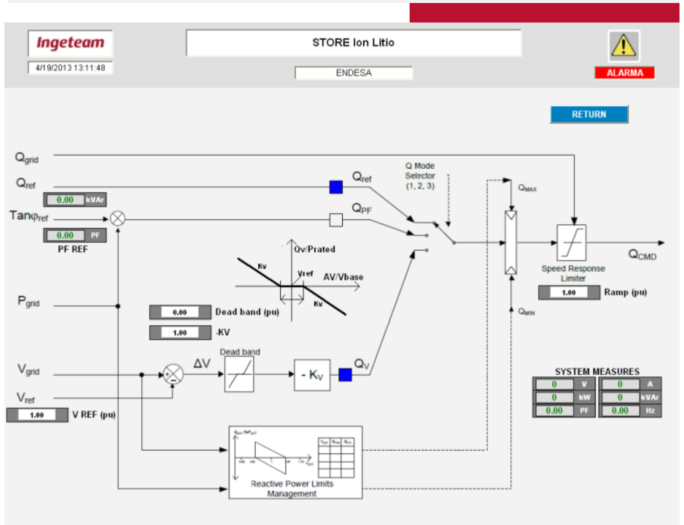
Source : http://www.endesa.com/en/saladeprensa/noticias/energy-storage

INGEGRID™ STORAGE : Case Study 1: Aldea de San Nicolás – Gran Canaria

Li-ION Battery Storage System in transportable container







DC side

3 x 1MW hour / 3 x 335 kW

AC side

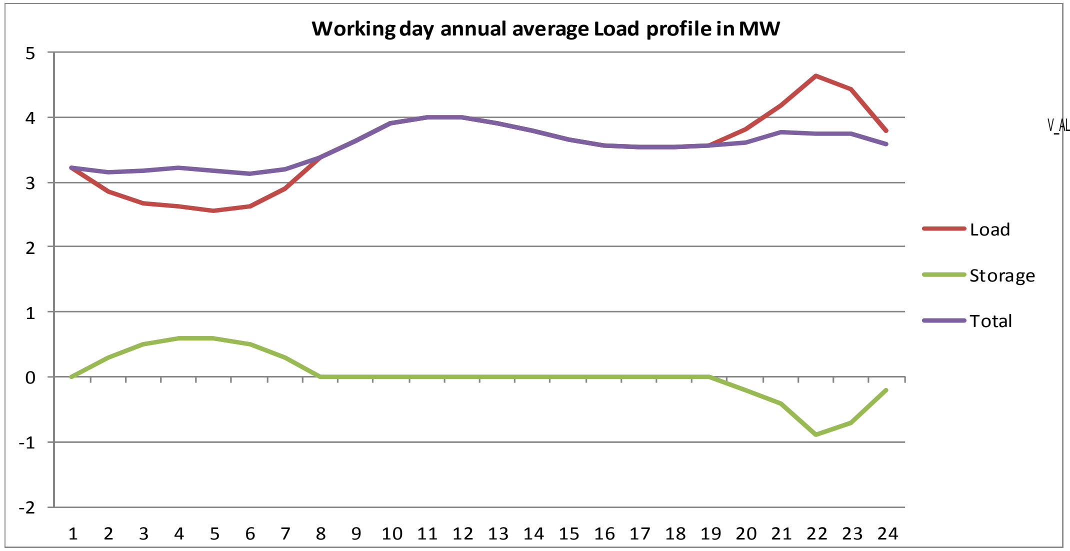
400 V / 1MW

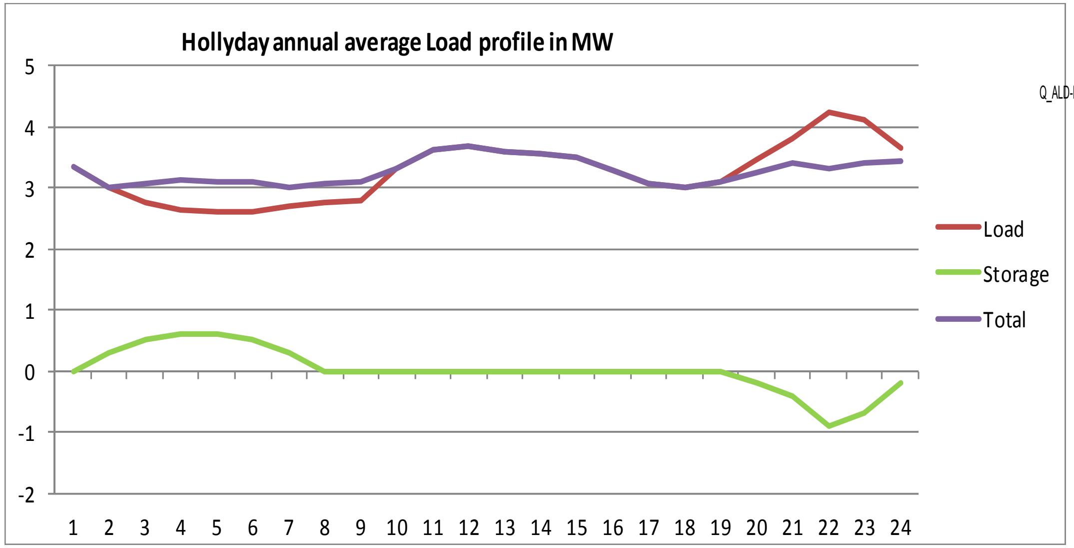
INGEGRID™ STORAGE : Case Study 1: Aldea de San Nicolás – Gran Canaria

Ingeteam

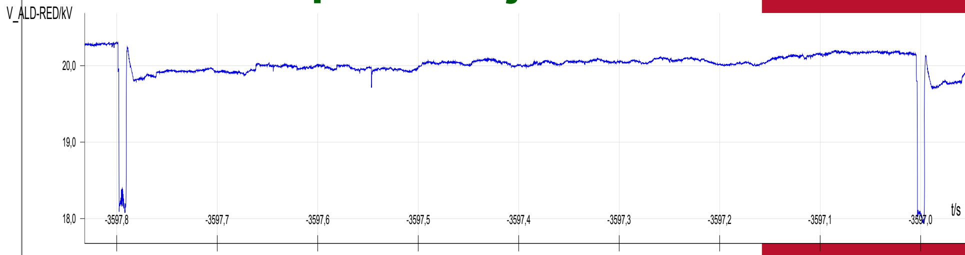
Li-ION Battery Storage System in transportable container

Peak Shaving in an overloaded feeder

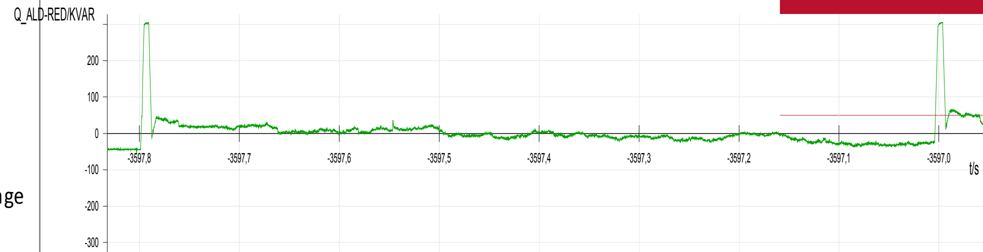




Reactive power control & Reactive power injection

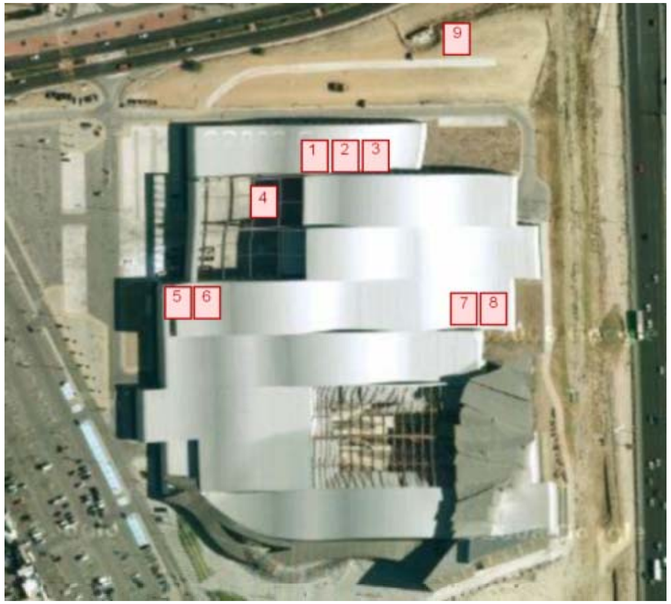


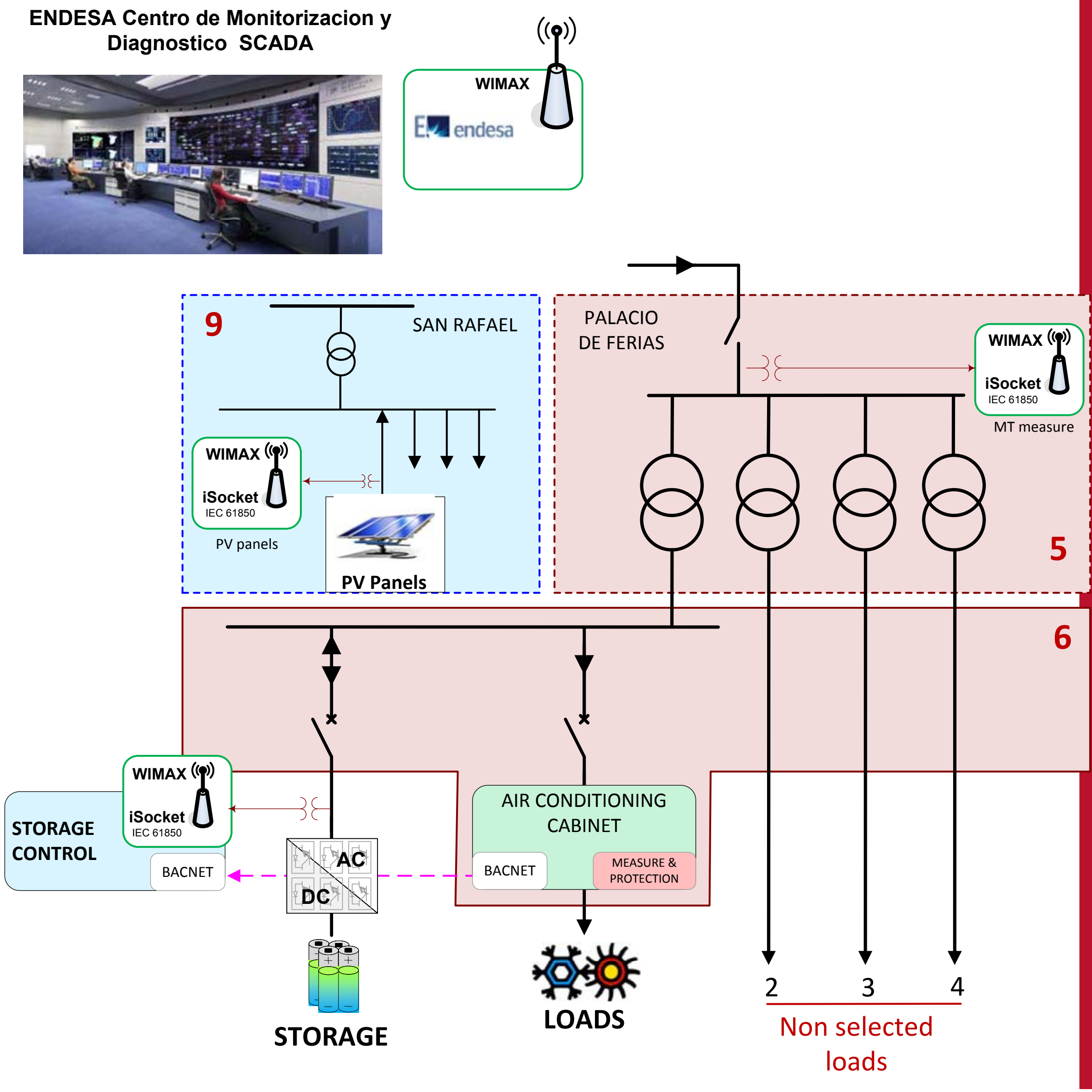
Pump DOL connection



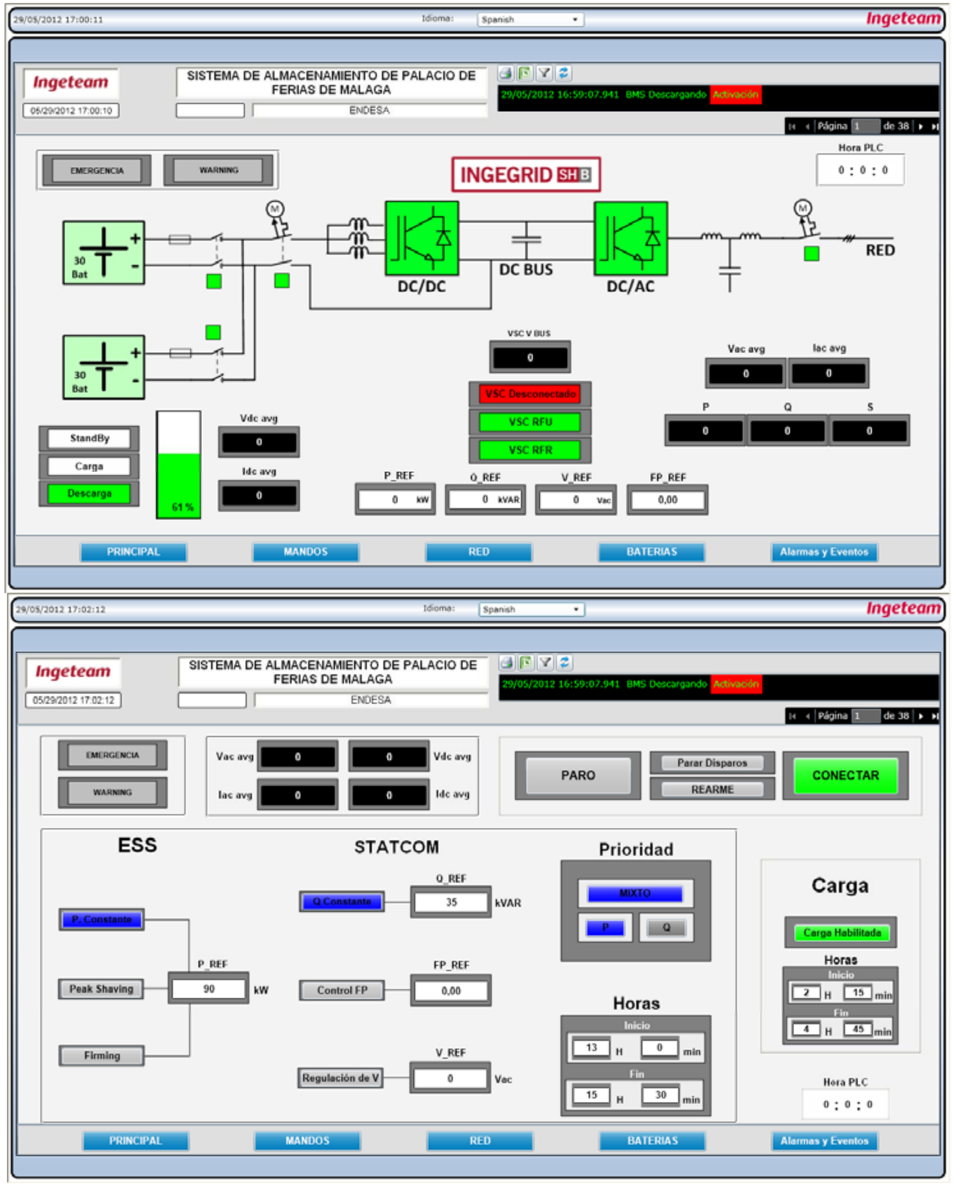
Ingeteam Confidential

Peak Shaving & Load shifting application





Ingeteam



End User use cases

- Peak shaving of HVAC system
- Firming of 100 kW solar plant
- TOU of energy
- Power factor regulation

Distribution Grid Operator use cases

- MV Voltage control
- Line power flow control – price sensitive

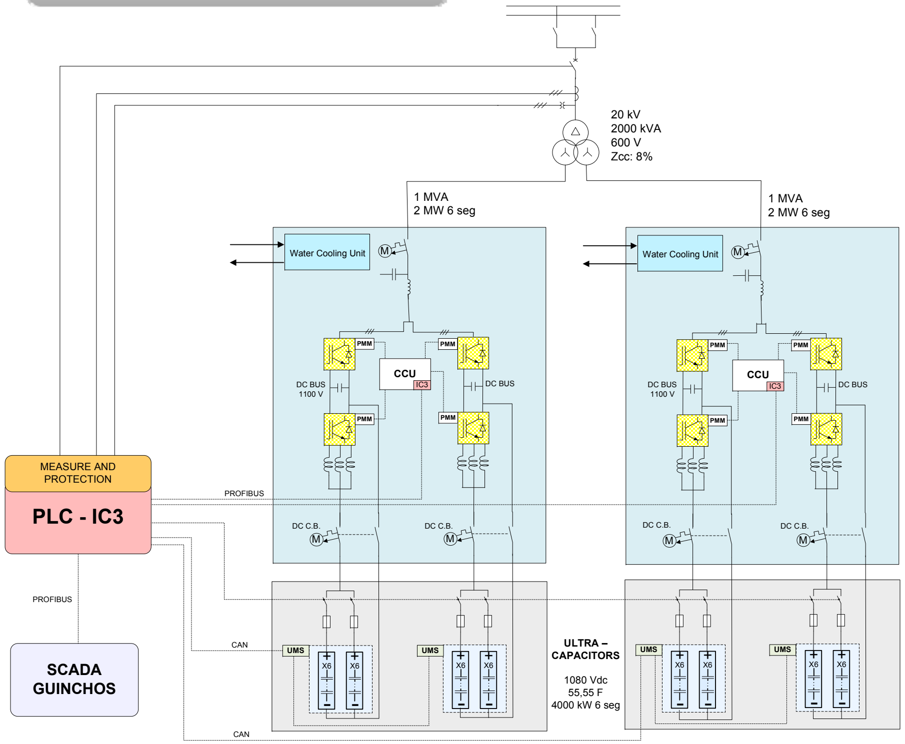
Primary Objective:

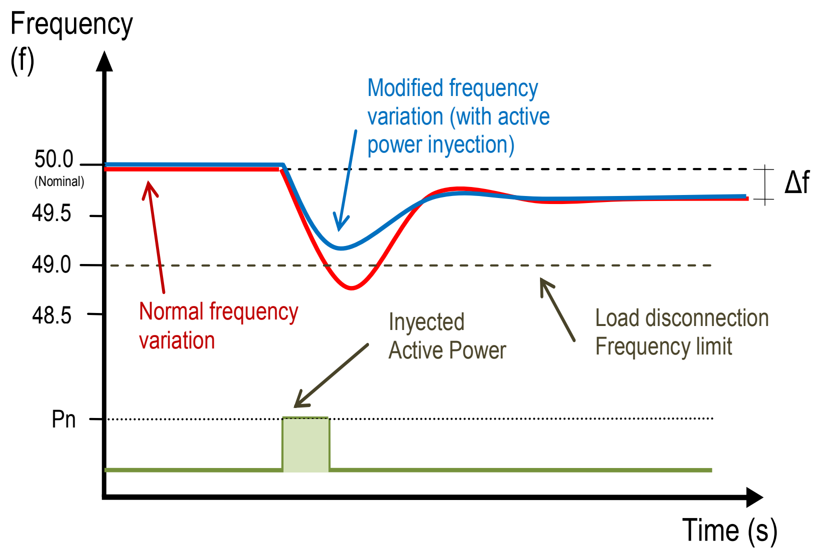
Reduce the overall electricity cost to the end user

Frequency Response application

INGEGRID™ STORAGE : Case Study 3: Guinchos Power Station (FAST) – La Palma

Super Capacitors





PAY BACK less than 1 year (one blackout pays it back*)

1. After a generation unit disconnection, the system injects active power
2. The rest of generation sets have enough time to respond (inertial response and speed regulator).

Objectives:

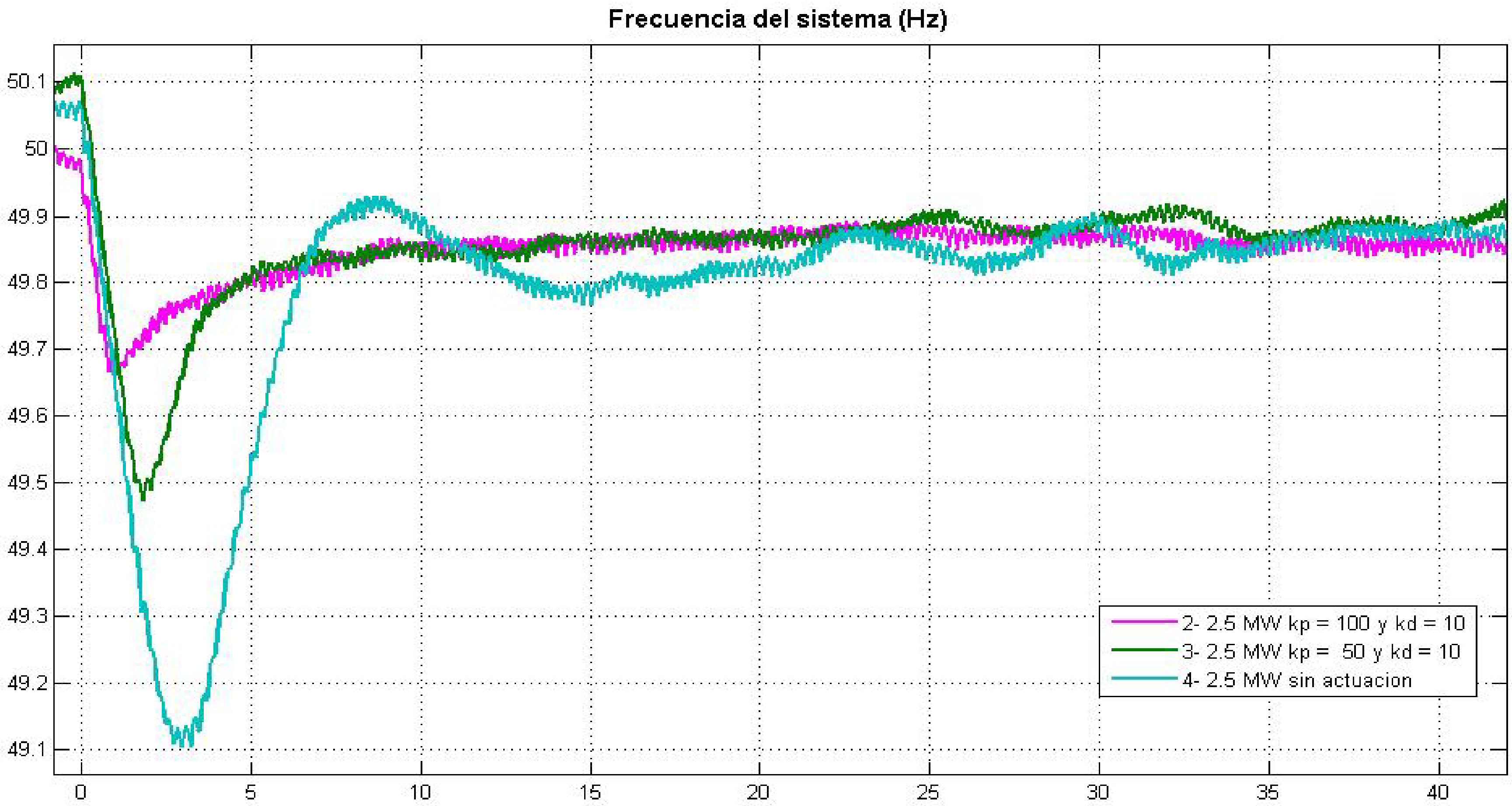
a) Minimize the load seeding (customer disconnection) increasing service quality.
b) Avoid new generation units investments.

Ingeteam

Super Capacitors

July test: Loss of generation 2500 kW

Prueba	kd	kp
1	100	10
2	50	10

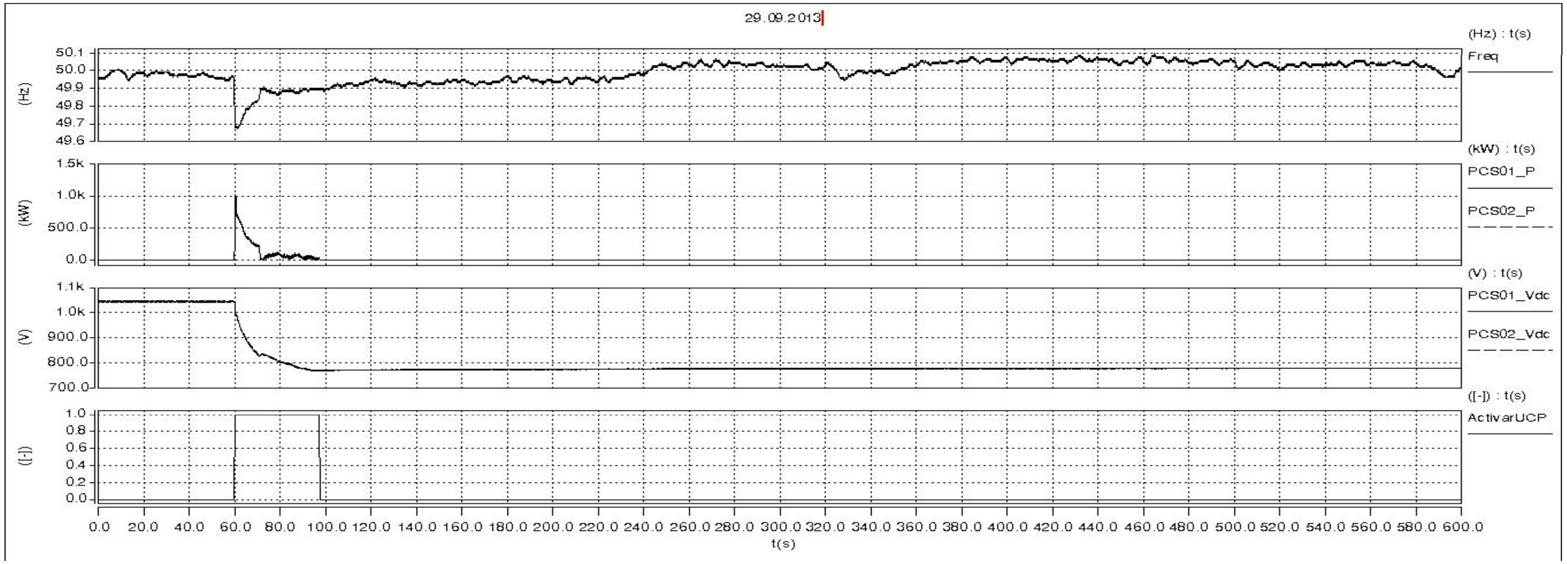


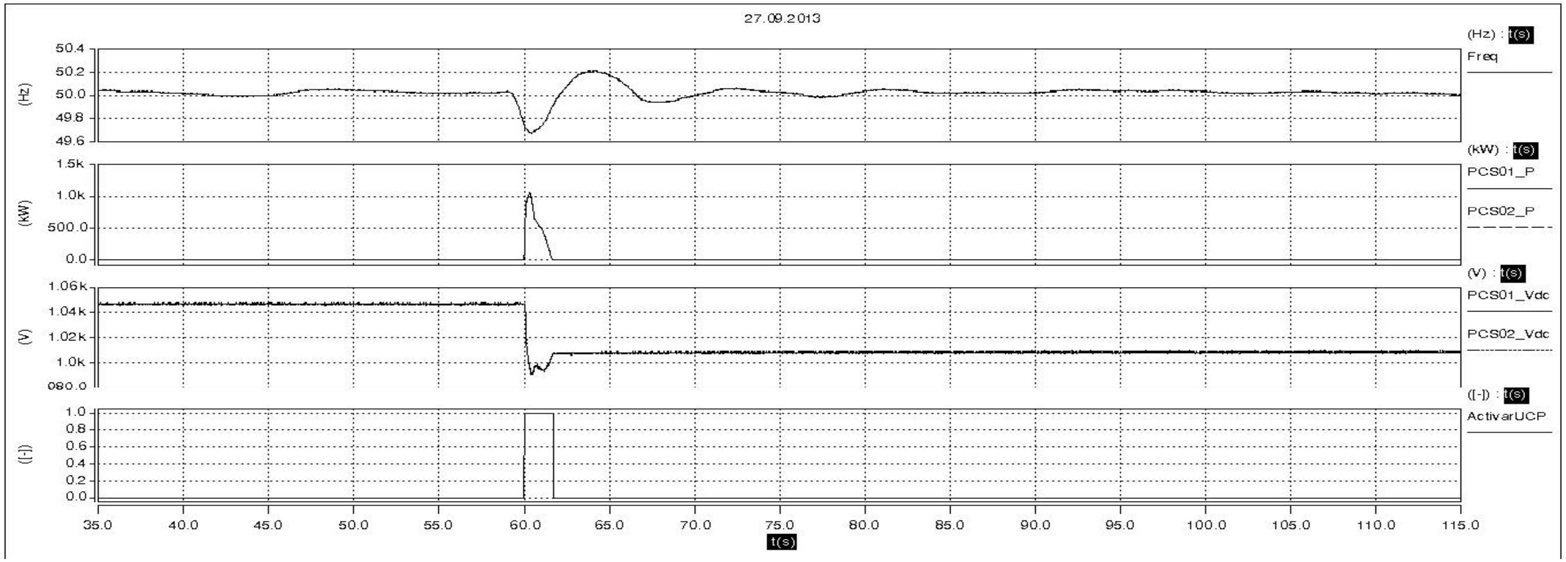
INGEGRID™ STORAGE : Case Study 3: Guinchos Power Station – La Palma

Ingeteam

Super Capacitors

October 27 & 29, Automatic Operation





Ingeteam Confidential

Ingeteam

RED ELÉCTRICA DE ESPAÑA

Renewable Integration application & power flow management

RED ELÉCTRICA DE ESPAÑA

Scope of Supply

- Pre engineered building
- Chiller, Air Conditioning and Fire Extinction
- Electrical engineering
- Static and Dynamic simulations and modeling

- 2 x MV500, total rated 32
- Intermediate magnetic components
- Thyristor and breaker by-pass
- MV electrical cabinets.

- Substation control Automation.
- SCADA system
- FACTS projects management and leadership

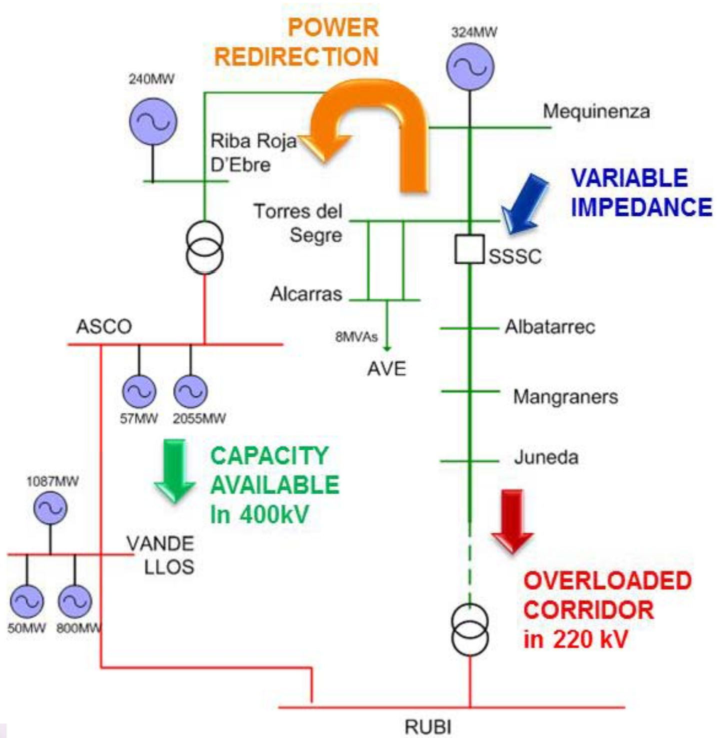
Now on commissioning

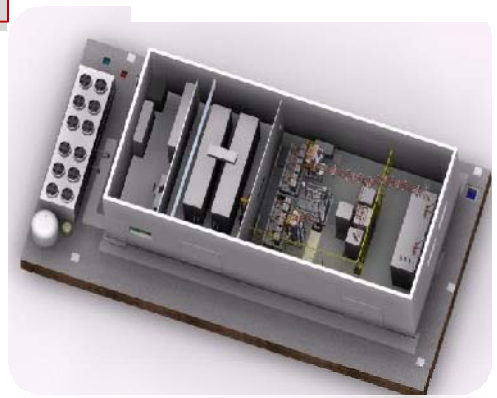
Conditions

Line Voltage:	220kV
Line Current :	1250A
Transmission Line Capacity:	476 MVA
SSSC Power:	47,8 MVAR
SSSC Voltage:	12..500V
SSSC Impedance*:	-4Ω a 10 Ω

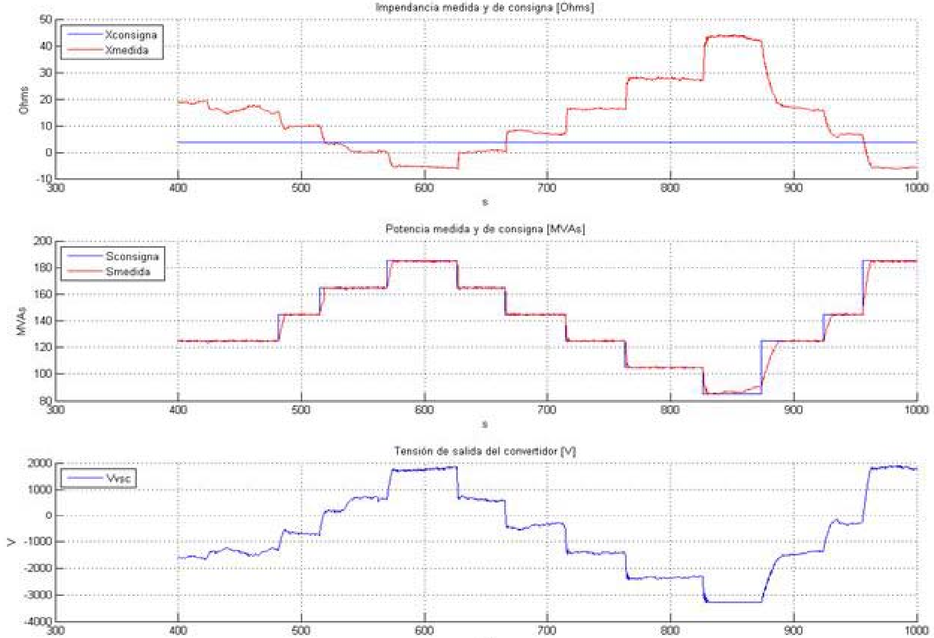
* Note: (with Maximum line current, 1250A):

APPLICATION: Optimal Power Flow

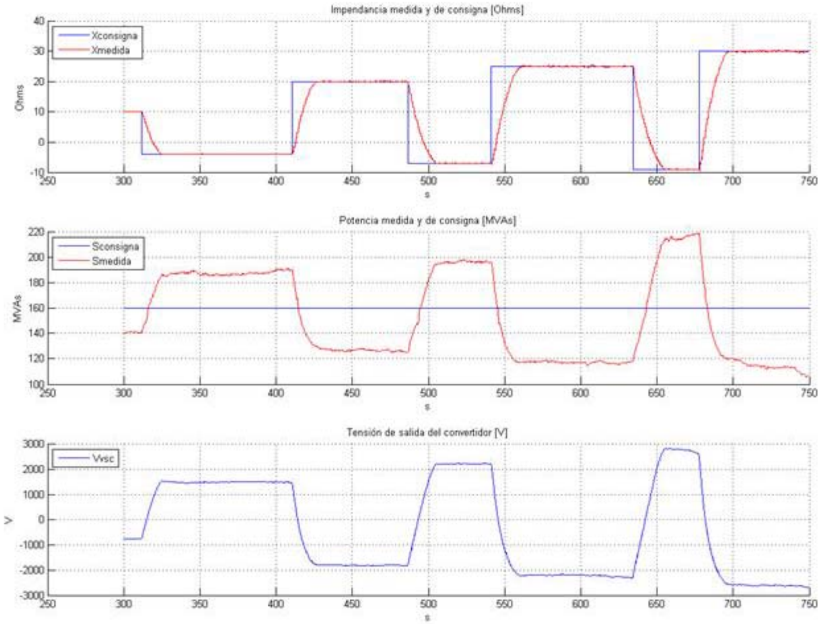




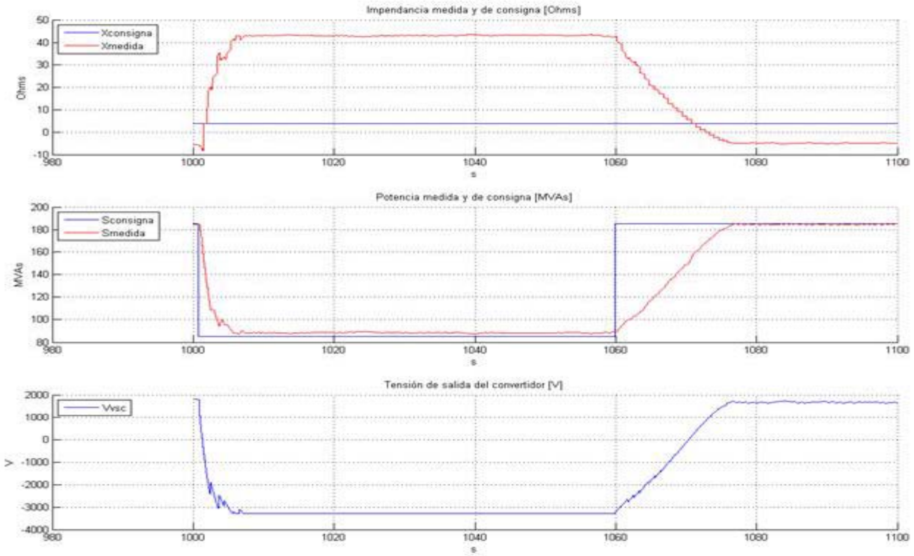
Line power regulation



Impendance Regulation



Maximum Regulation Dynamic

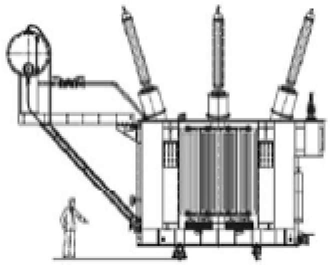


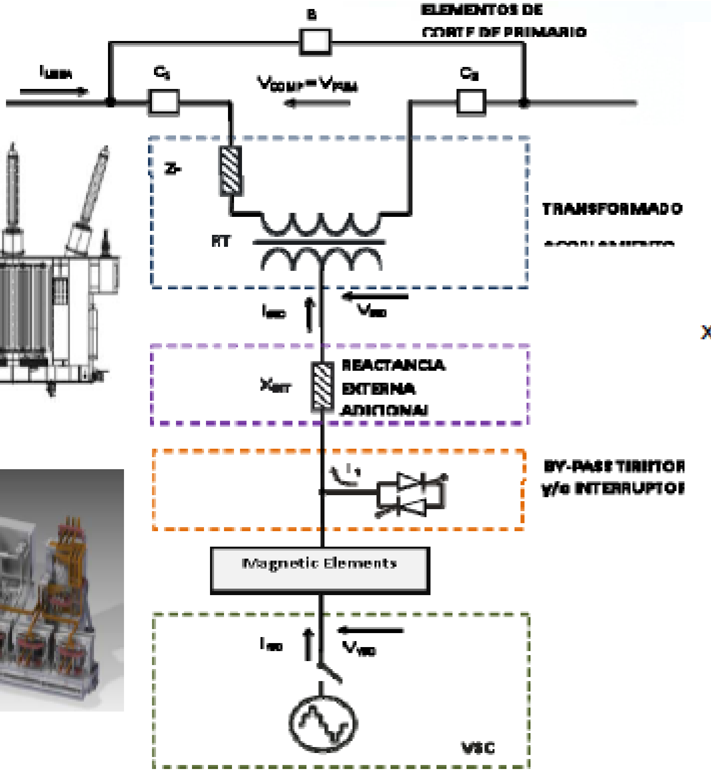
Conditions

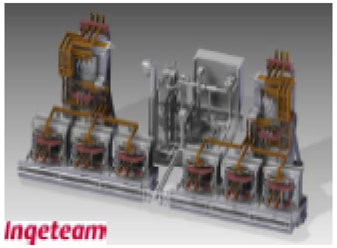
Line Voltage:	**220kV**
Line Current :	**1250A**
Transmission Line Capacity:	**476 MVA**
SSSC Power:	**47,8 MVAR**
SSSC Voltage:	**12..500V**
SSSC Impedance*:	**-4Ω a 10 Ω**

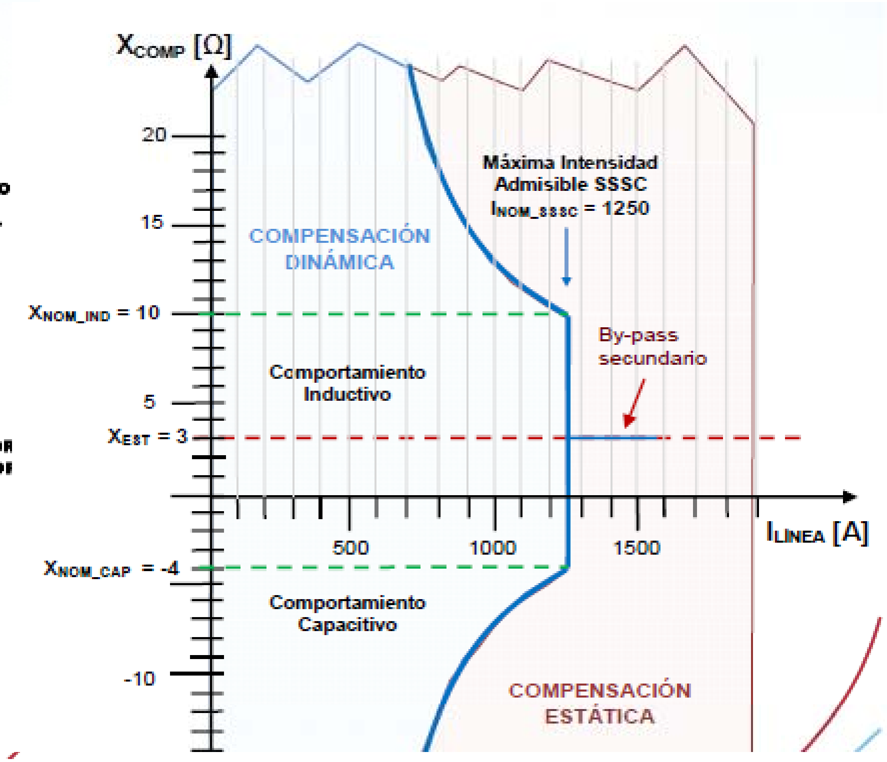
*** Note: (with Maximum line current, 1250A):**

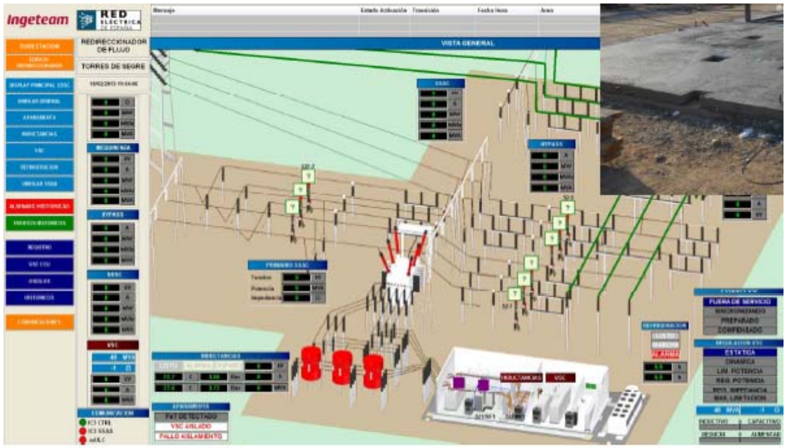
INGEGRID™ PFLOW : Case Study: SSSC Red Eléctrica de España

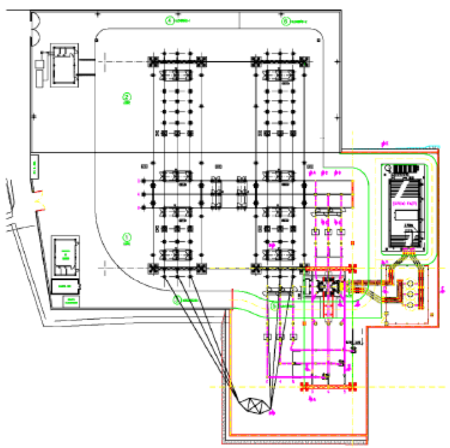












Present Value of the SSSC applications

PV comes trough incorporating income and reduce costs by:

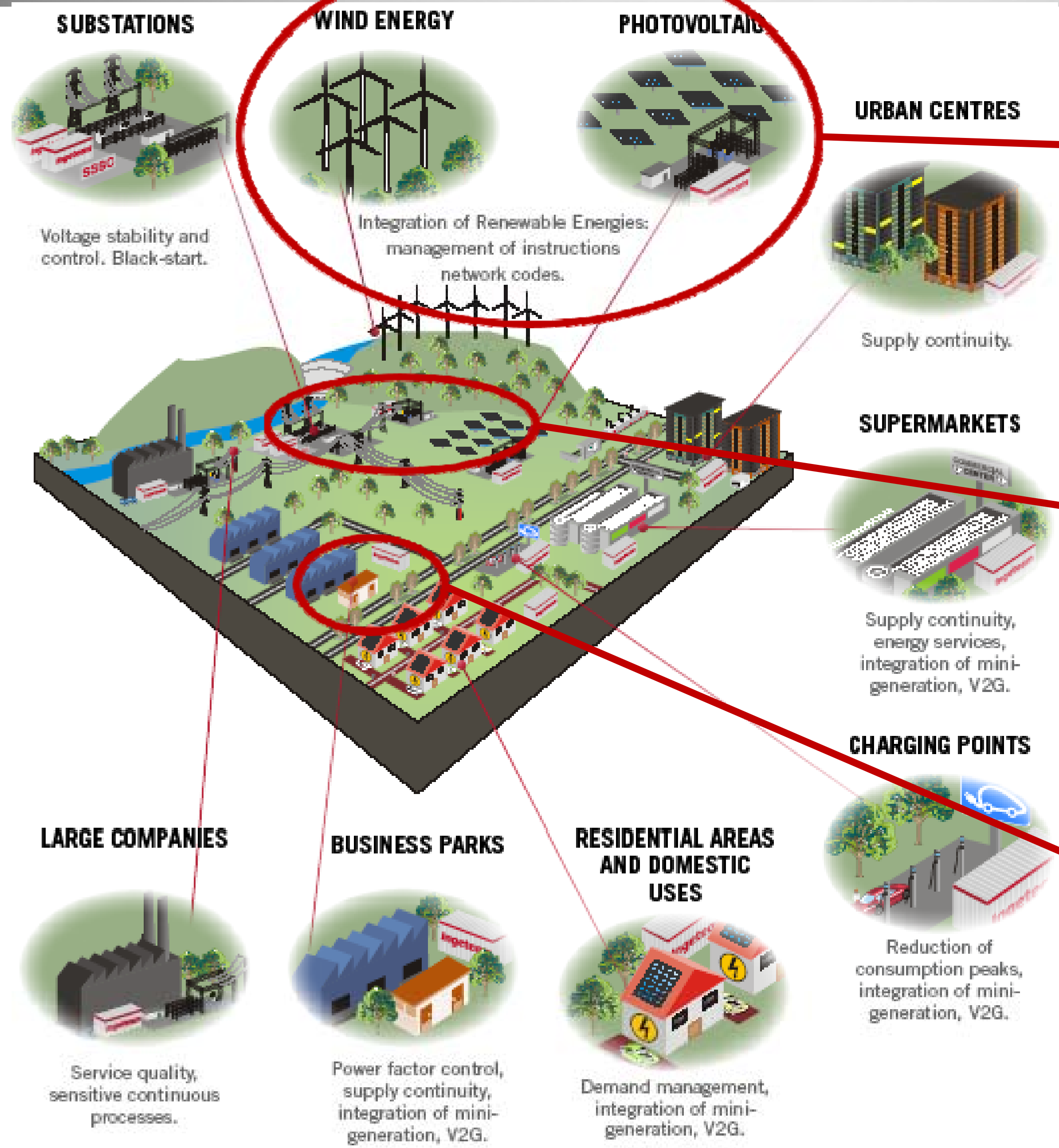
- **Fewer number of generation re dispatching**
- **Lower technical losses in the system**
- **Increase security in the management of n-1 scenarios so lower penalties**
- **Reducing IPP curtailment when corridors are overloaded so avoids to pay por energy curtailed**
- **Higher integration of renewable power capacity dropping energy spot price**
- **Less emission of CO2**
- **Financial Cost by differing investments on new assets**
- **Project management and legal issues of alternative solutions (permits, approvals, expropiations, etc..)**
- **Other attractive KPI to be taken into account**

Achieve suitable pay back < 5 years

- **Maximize Value and Incorporate all benefits in the business case**
- **Prove value through simulation and dummy project (small scale size)**
- **Benefit from simultaneous modes operation (voltage control, power flow,..)**
- **Minimize OPEX through preventive and corrective O&M contracts**
- **Life cycle of these assets are 30 years**

INGEGRID™ QUALITY: STATCOM Applications

Ingeteam



Voltage and Power factor control at PCC

Intermittent generation power plants, wind and PV kVAs – MVAs

Voltage control:

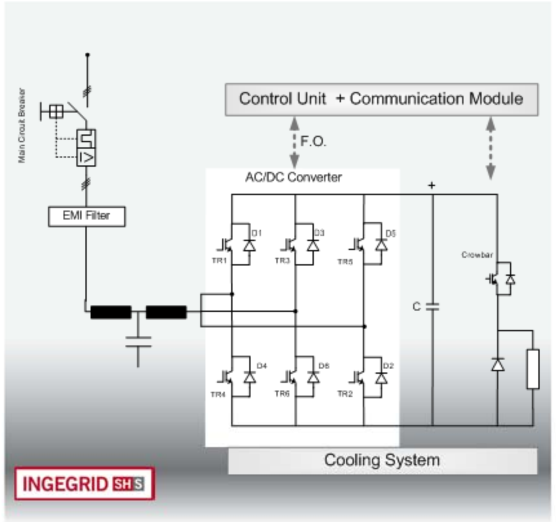
Overhead Rural distribution lines with distributed generation kVAs – MVAs

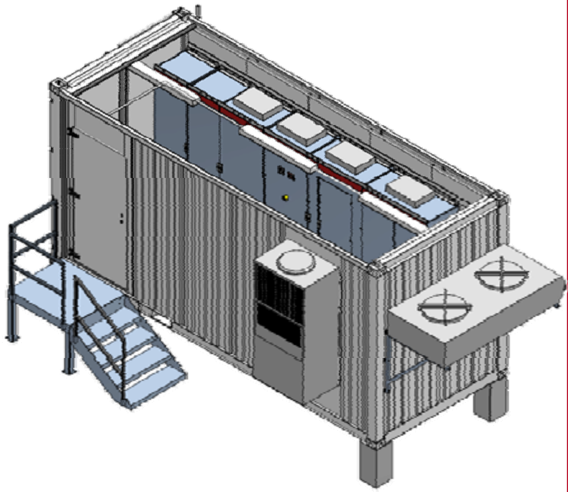
Power factor control at end users MV to LV Substations

Owned by the end user(commercial centers, industry)
Distribution company owned
kVAs

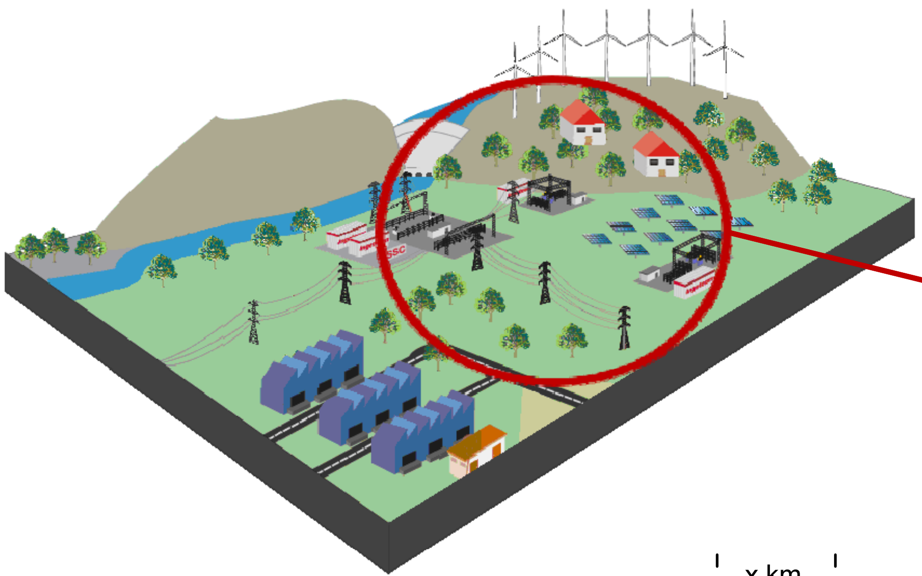
Ingeteam

Reactive Power management with high penetration of DG





Ingeteam

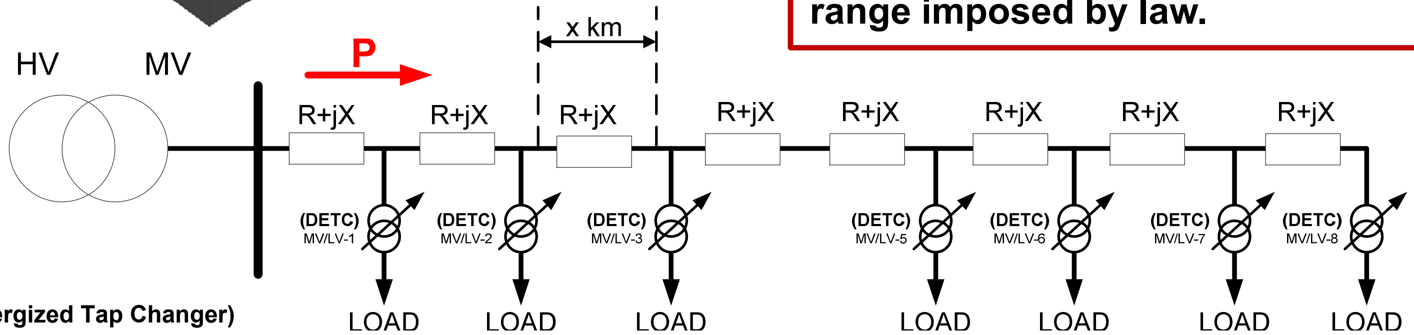


Rural grids

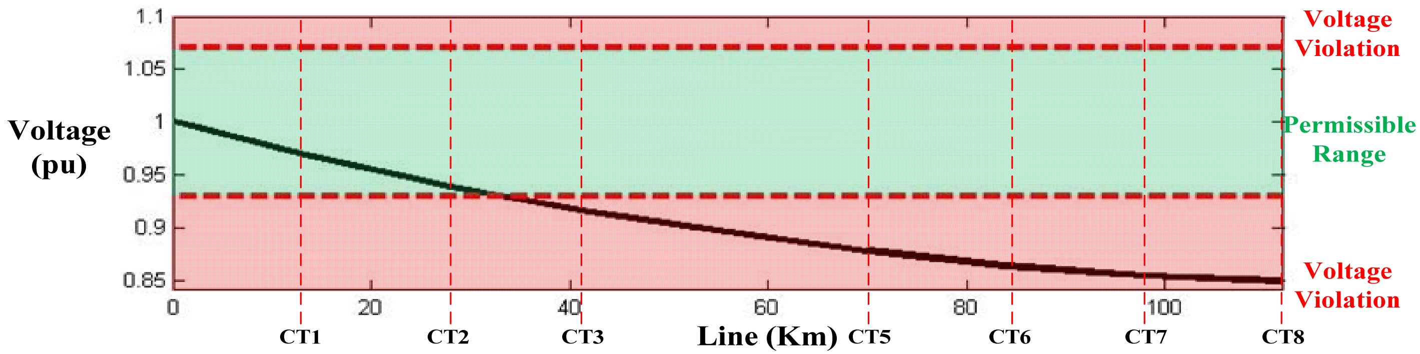
Rural Networks are composed usually by long lines, (10-50 km), and this lines usually are overhead lines.

The overhead lines have bigger X/R ratio than the underground lines, typical value X/R of a overhead line is 1 to 2.

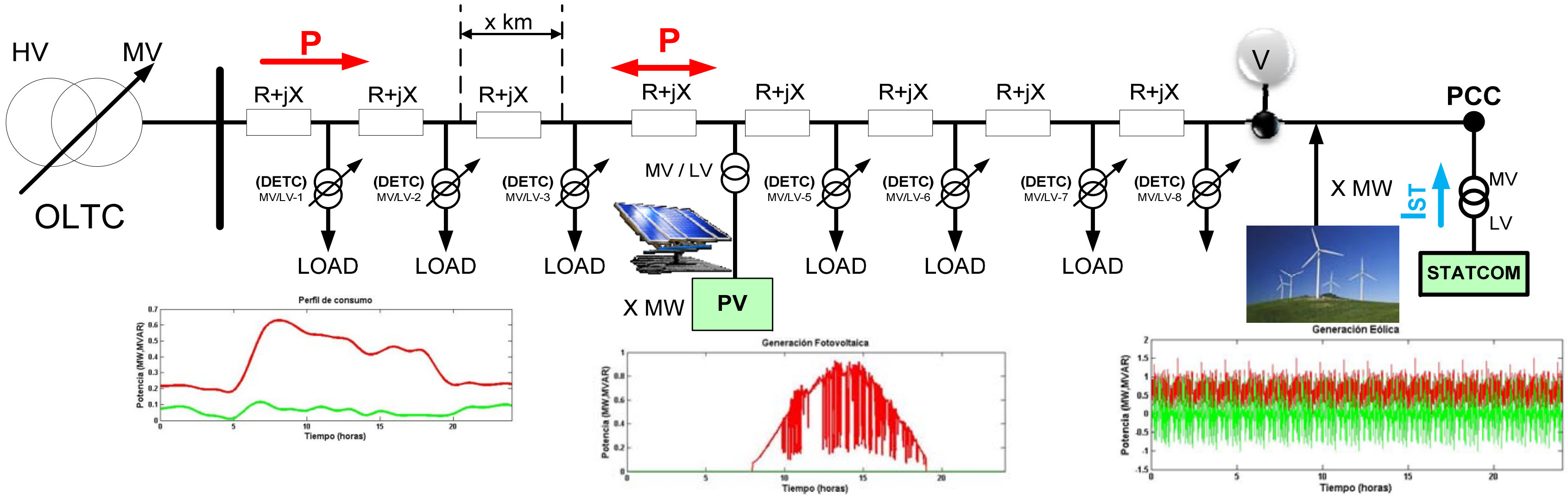
In Rural Network-s usually is NOT enough with the capacity of the OLTC to maintain the Voltage of the all feeder within the range imposed by law.



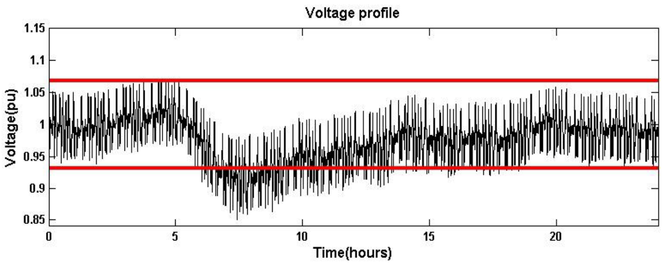
DETC (De Energized Tap Changer)



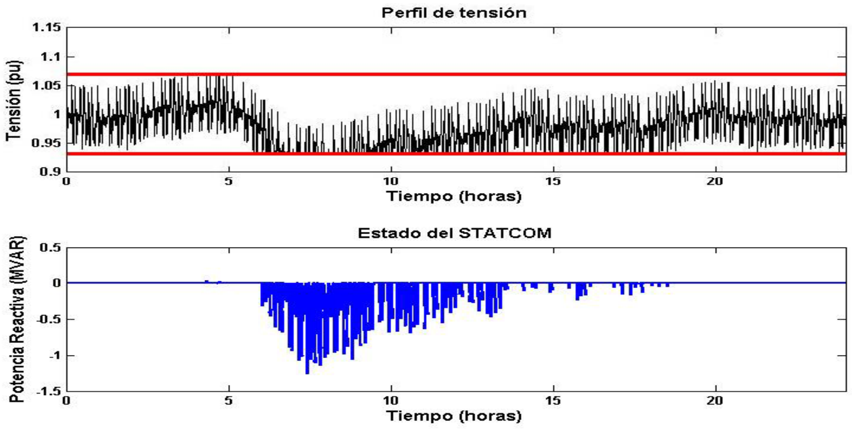
INGEGRID™ QUALITY: STATCOM Applications to voltage control in rural grids



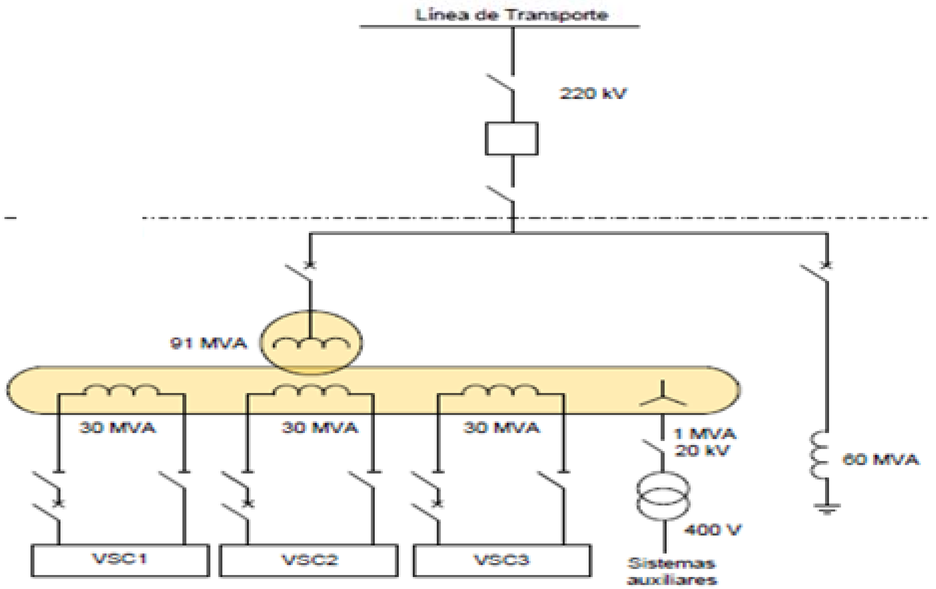
Without STATCOM



With STATCOM



INGEGRID™ QUALITY: STATCOM Application in transmission grid and PCC



Voltage control at PCC (Point of Common Coupling)

Voltage control at PCC (Point of Common Coupling)

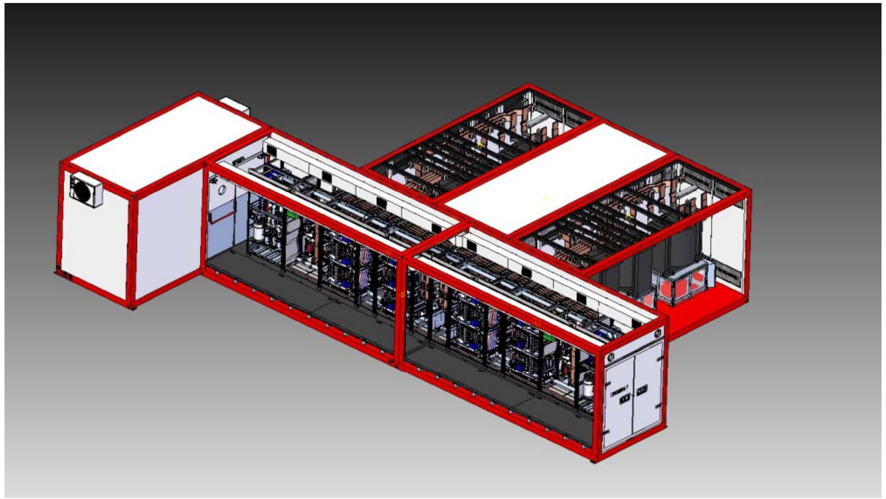
Makes the voltage profile more stable:
- Minimizes voltage fluctuations
- Compensates reactive power
- Optimal power flow transfer

HV STATCOM characteristics

- IGCT or IGBT power converters based
- 8MVArs up to 100MVArs STATCOM
- From 20 kV to 245 kV grids
- Modular and containerized

- Dynamic and Static simulations with power flow system tools. Transient studies.
- Substation control Automation.
- SCADA system
- FACTS projects management and leadership

3D Container design



Ingeteam

Ingeteam

READY FOR YOUR CHALLENGES