Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

Final workshop H2020 SmartNet| 16.05.2019 Arona

WP5 - Pilot A

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691405

Energy Framework

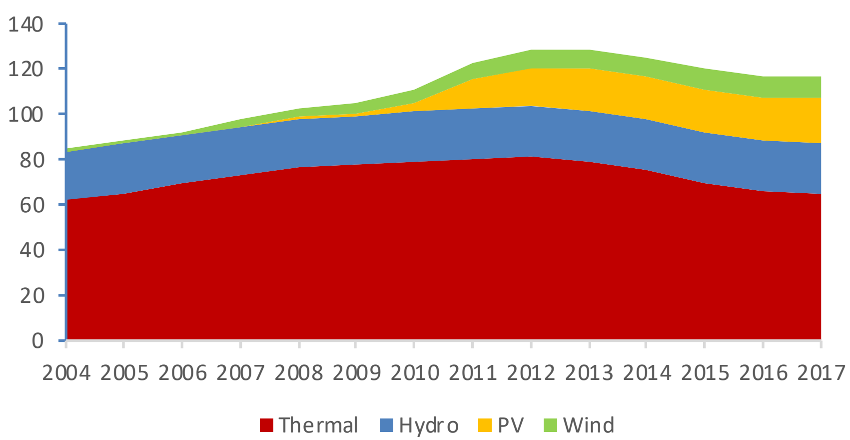
International agreements regarding Climate&Energy and national implementations aim to reduce greenhouse gas emissions and pose challenges to the energy system management

Clean Energy Package

Paris Agreement

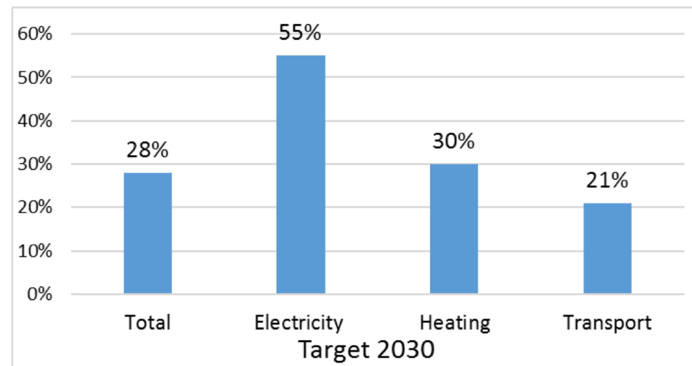
Strategia Energetica Nazionale

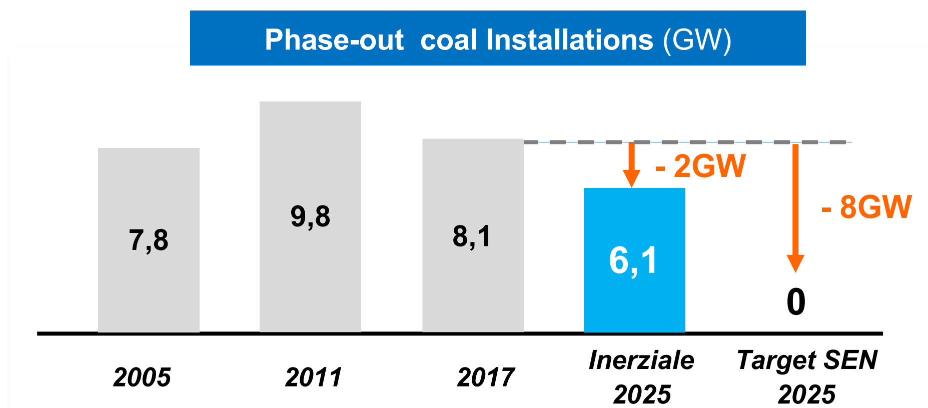
SEN



Approximately 24% of the installed generation capacity in Italy (approx. 28 GW) is located on MV/LV distribution networks, outside the Terna perimeter. This share is expected to grow strongly in the coming years.

2030 target aims to ensure a secure, economical and environmentally friendly energy supply. The electricity sector is essential to achieve these objectives:





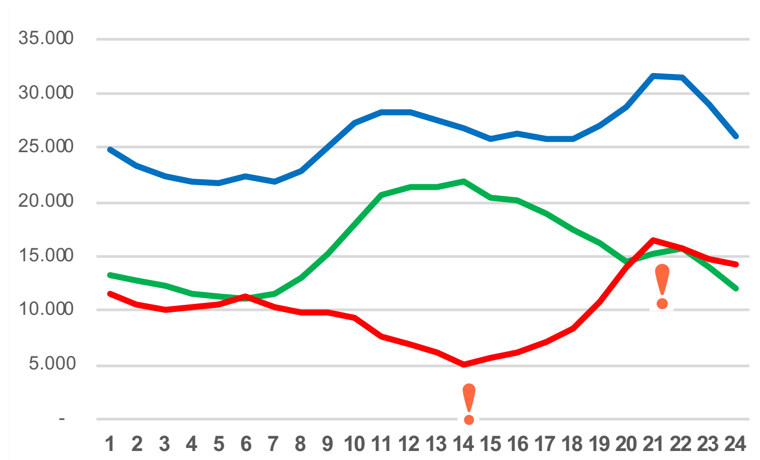
Impact on the management of the electrical system

The growing penetration of **RES** and the **decommissioning** of **coal** power plants introduce criticisms in the management of the grid by Terna.

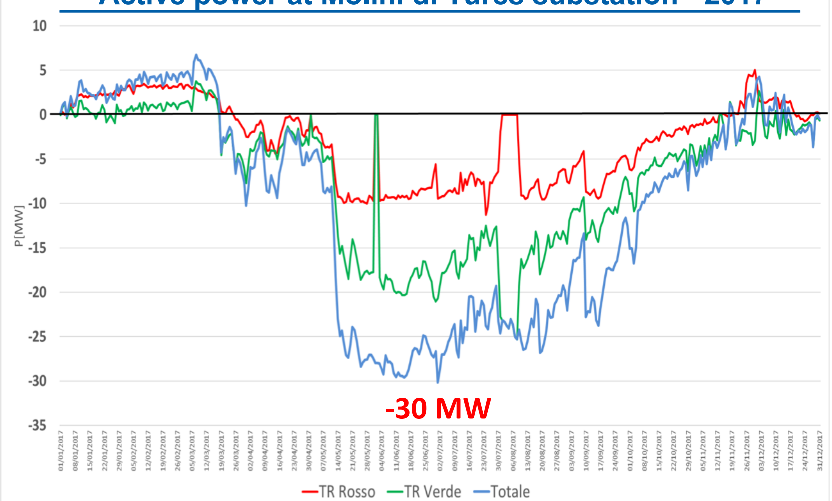
Main impacts

- **Difficulty to follow the evening load ramp,** due to the sudden reduction of photovoltaic production
- **Reserve margin reduction,** because RES don't provide ancillary services and due to the decommissioning of thermo power plants
- **Frequency and Voltage regulation issues**, due to the unpredictability of RES that can't guarantee a power exchange with the grid

April 25th 2016: demand load and residual load (GW)



Active power at Molini di Tures substation - 2017



- **Reverse flow** from MV to HV grid, due to high penetration of DG that leads to **high voltages** in transmission grid, **reduction of selectivity** and efficiency in the load curtailment in emergency state and inadequacy of the current automation and **monitoring** devices
- **Congestion,** due to the not uniform installation of RES across the country
- Increase of **instability phenomena**
- **Inertia reduction** as most RES don't provide inertia contribution to the system

Pilot A within this context

The SmartNet project started before this sudden energy evolution; the purpose of the Italian pilot was not to solve the management problems described in the previous slide but to test technological solutions to allow a centralized activation of dispersed generation (connected at subtransmission or MV grid). If well-tested, these tools can help to increase system flexibility in the future.

The partners and the main tasks

Terna Rete Italia

Pilot leader and deliverable project management

Functional specification

Technical specification coordinator

Data flow design and implementation

Testing and commissioning

edyna

Grid portion identification (HV,MV) and site inspection

Control System updates coordination (with SELTA)

Data Flow implementation

Testing and commissioning

SELTA / SIEMENS

Technical specification and implementation

Functional specification support

Data flow design and implementation

Testing and commissioning

RSE

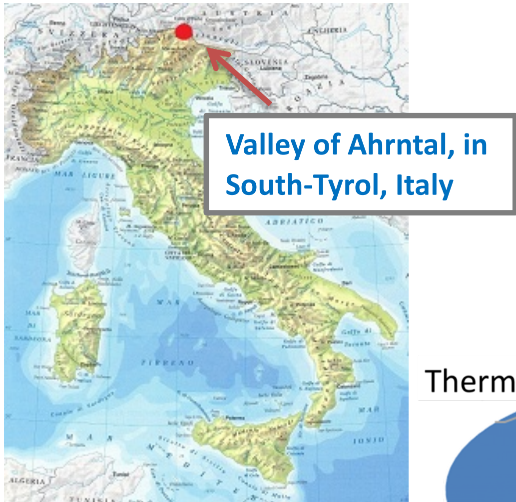
Project supervisor

Pilot coordinator (with Technalia)

Dissemination coordinator

Italian Pilot Project - Implementation in field

Experimentation in an area characterized by frequent **reverse flow** and **renewable** generating modules of **different sizes** connected to **all voltage levels**:



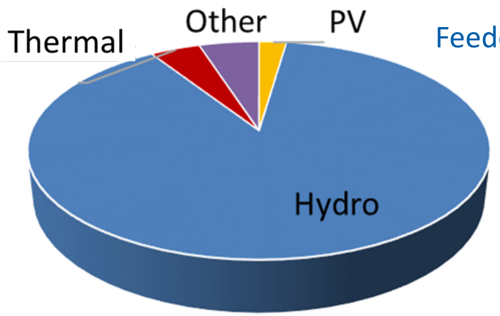
<u>Substation of Molini di Tures:</u> 2 HV hydroelectric generators (20MW), 2 x TR 40 MVA 132/20 kV, 6 feeders.

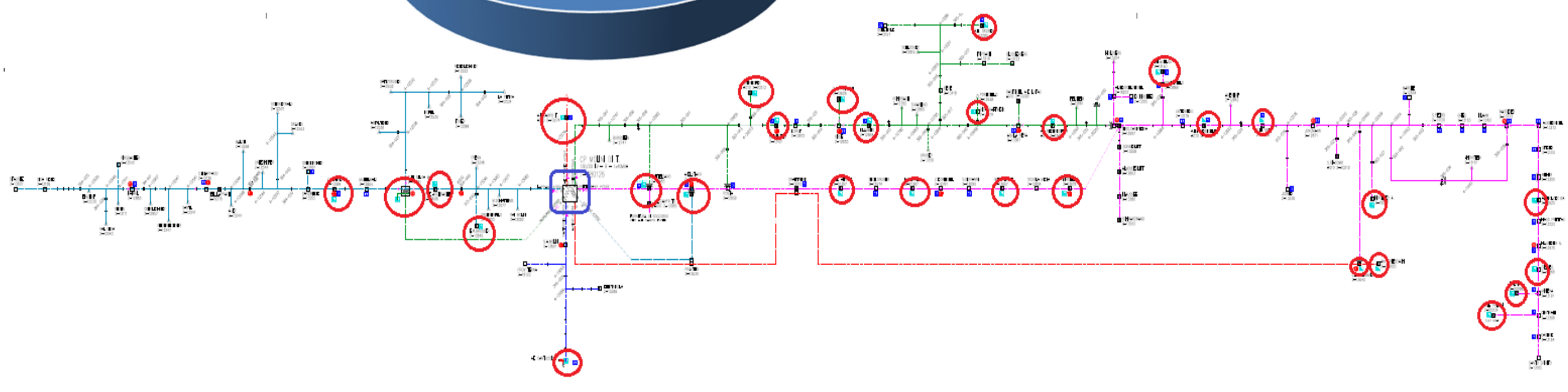
<u>MV generation:</u> 33 generators with 43,5 MW of power (41,7 MW hydro, 1,5 MW thermo, 0,2 MW FV).

Others 0,85 MW of generation in LV (0,73 MW FV).

Also there are 9,6 MW of generation waiting to connect to the grid.

Feeders without reverse current feeding





Substation of Molini di Tures

Goals of Italian Pilot A

The Italian pilot project aims to implement new features for an innovative experimentation in field

Power-frequency regulation (aFRR)
development of an architecture and implementation in field of a system for the frequency/power regulation by generators connected to MV grid

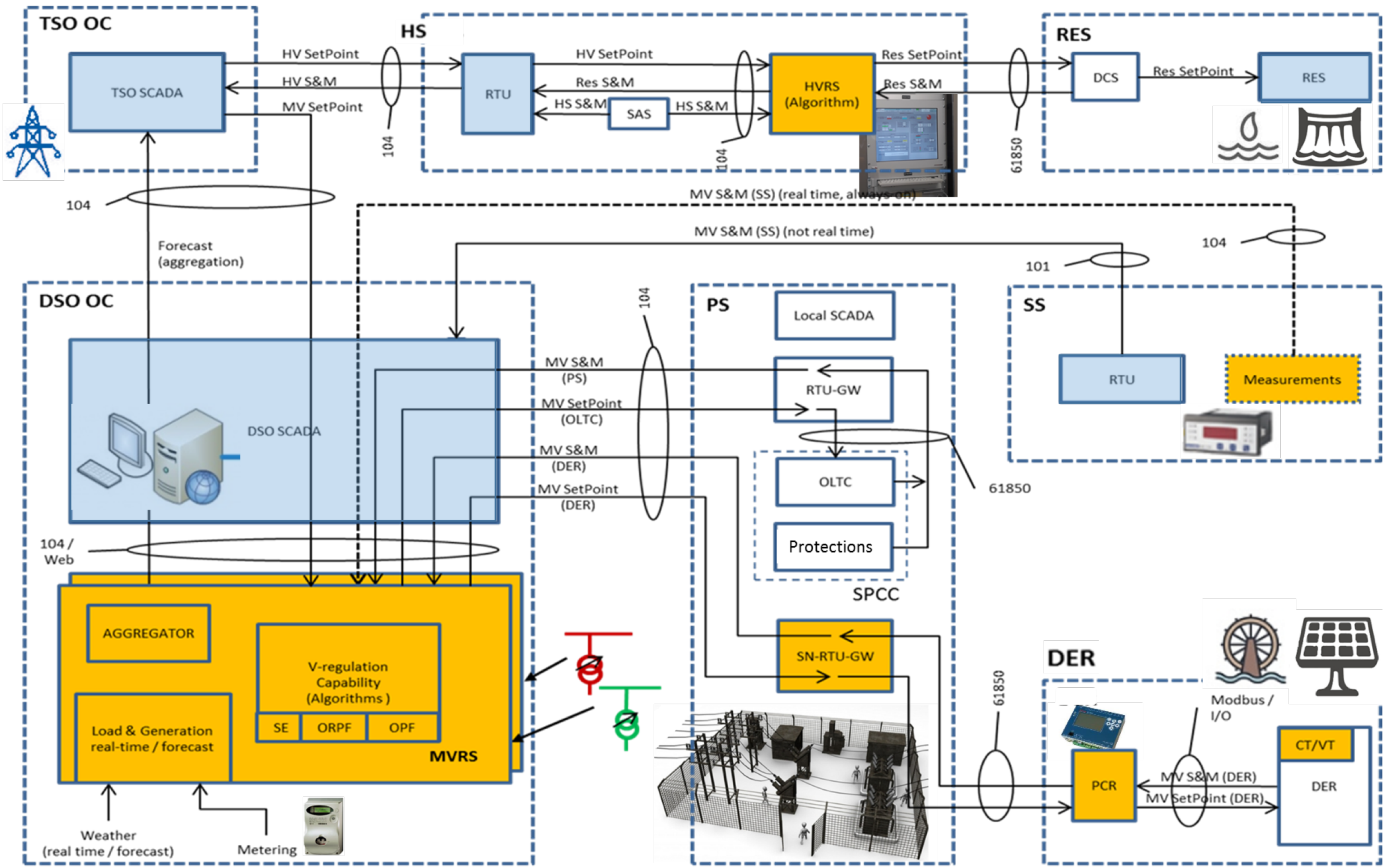
Voltage regulation
development of an architecture and implementation in field of a system for the hierarchical voltage regulation by generators connected to subtransmission HV grid and small plants at MV levels

Aggregation of information
to aggregate the measures to be supplied to the TSO at the interconnection point differentiated by source.

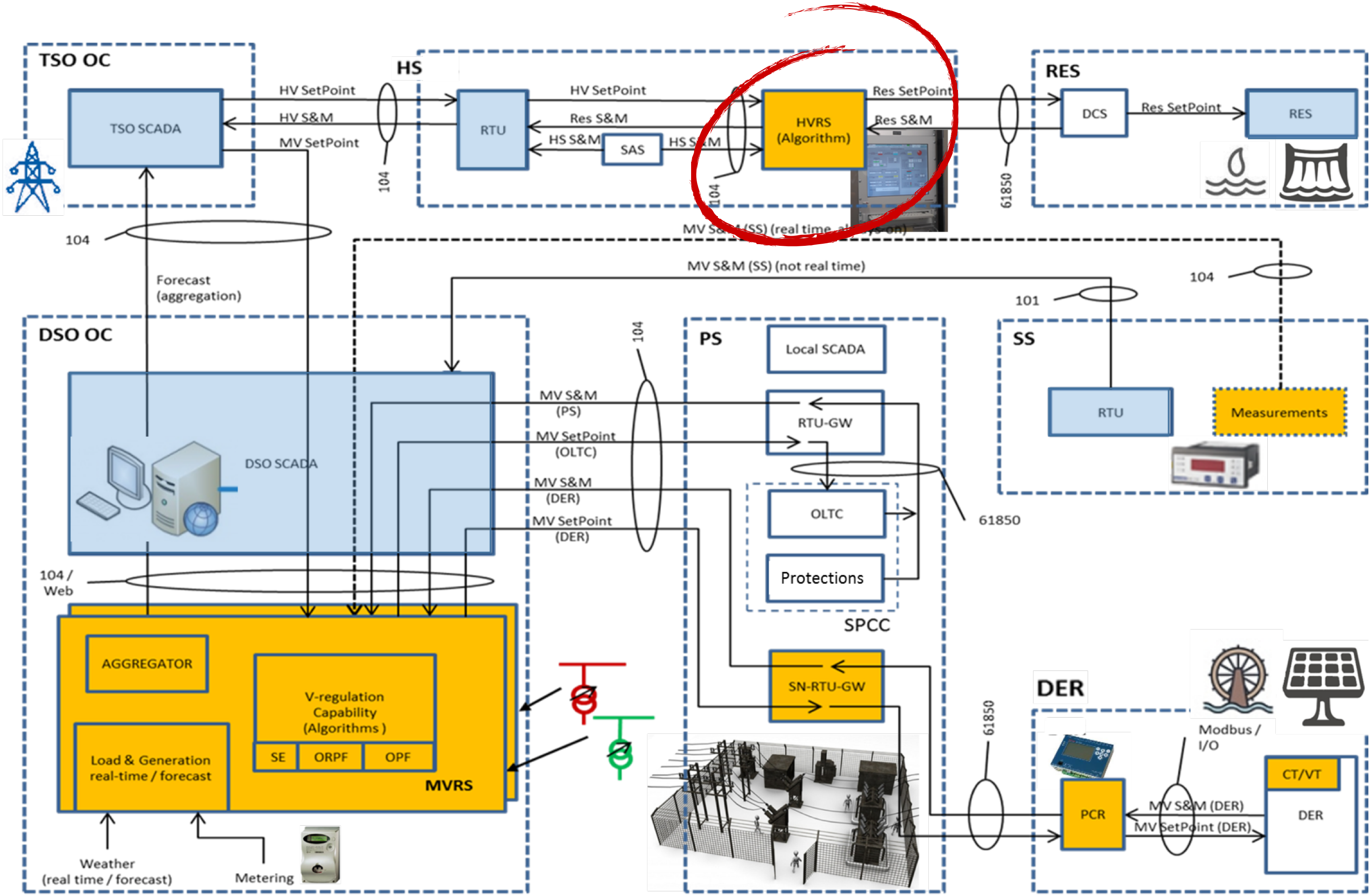
The functionalities described above are implemented in two systems:

- **HVRS** (High Voltage Regulation System) installed in Terna's substation for voltage regulation
- **MVRS** (Medium Voltage Regulation System) installed in Edyna's Control Center to monitor and control embedded generation

System architecture



HVRS



TSO OC
TSO SCADA
HV SetPoint
HV S&M
MV SetPoint
104
HS
RTU
HV SetPoint
Res S&M
HS S&M
SAS
HS S&M
HVRS (Algorithm)
104
Res SetPoint
Res S&M
61850
RES
DCS
Res SetPoint
RES
104
Forecast (aggregation)
MV S&M (SS) (not real time)
104
101
DSO OC
DSO SCADA
104
MV S&M (PS)
MV SetPoint (OLTC)
MV S&M (DER)
MV SetPoint (DER)
PS
Local SCADA
RTU-GW
OLTC
Protections
SPCC
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SS
RTU
Measurements
104 / Web
AGGREGATOR
V-regulation Capability (Algorithms)
SE
ORPF
OPF
Load & Generation real-time / forecast
MVRS
SN-RTU-GW
61850
DER
Modbus / I/O
CT/VT
PCR
MV S&M (DER)
MV SetPoint (DER)
DER
Weather (real time / forecast)
Metering

HVRS: Coordinated Voltage Regulation

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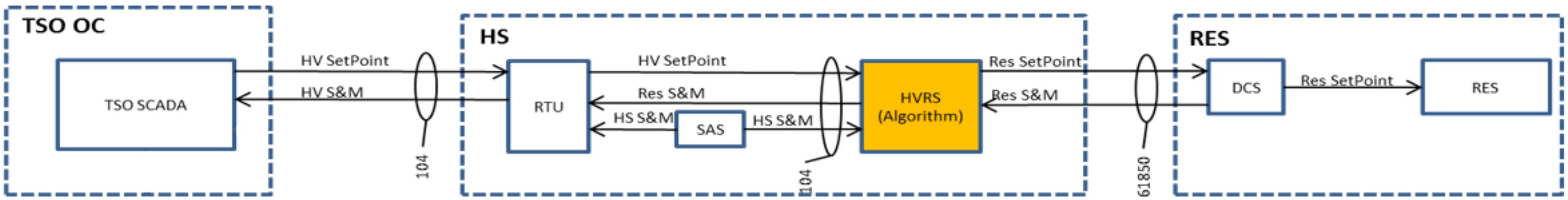
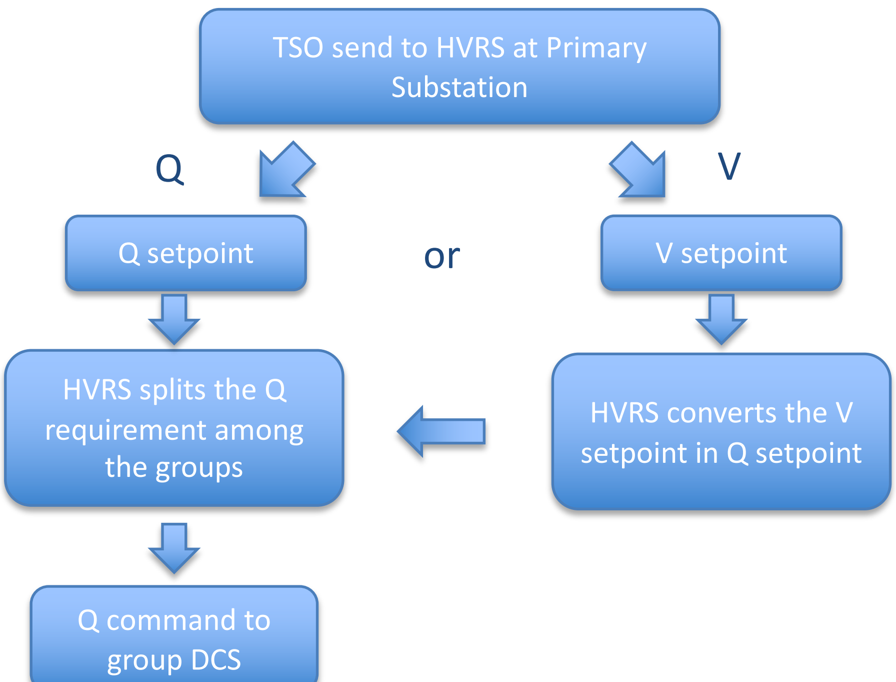
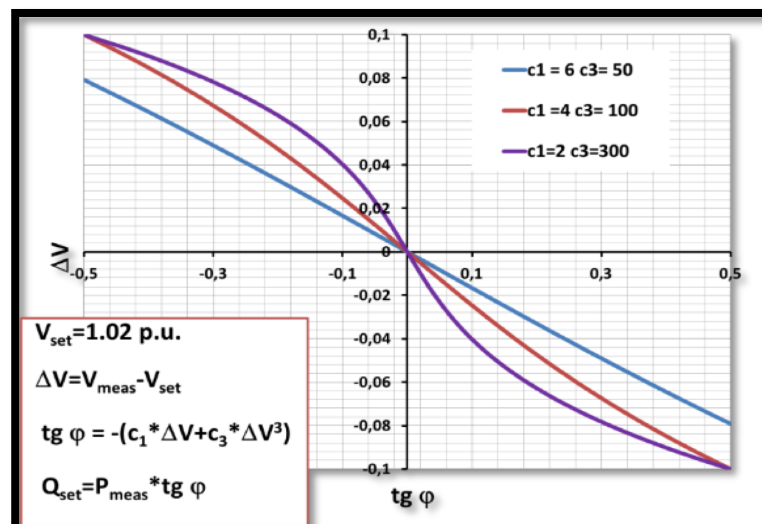
Current status : Secondary Voltage Regulation service provided by big programmable power plants equipped with specific devices

Novelty: Coordinated voltage regulation through hydro power plants connected at 132kV grid





Cubic correlation law



HVRS: HV busbar voltage regulation test

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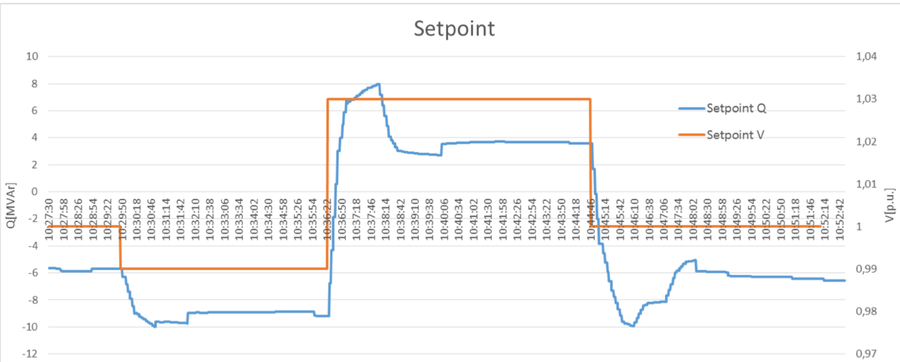
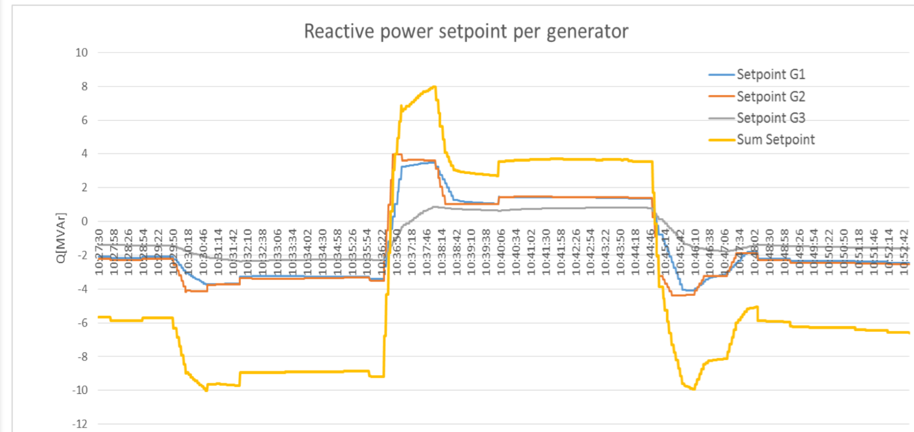
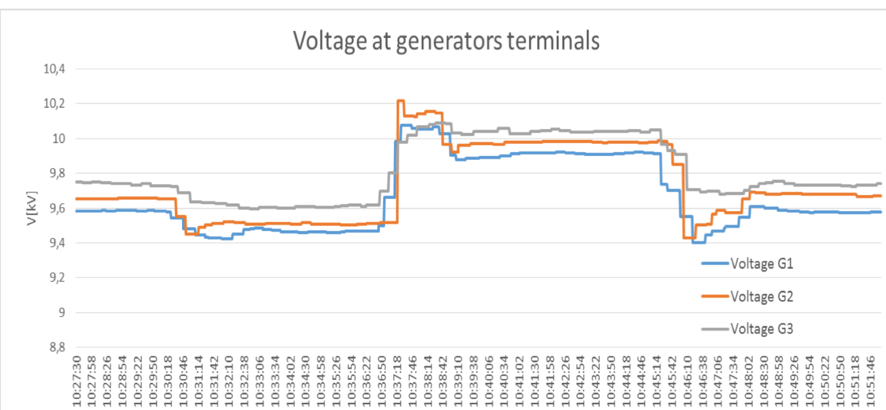
1 Setpoint conversion Q(V)



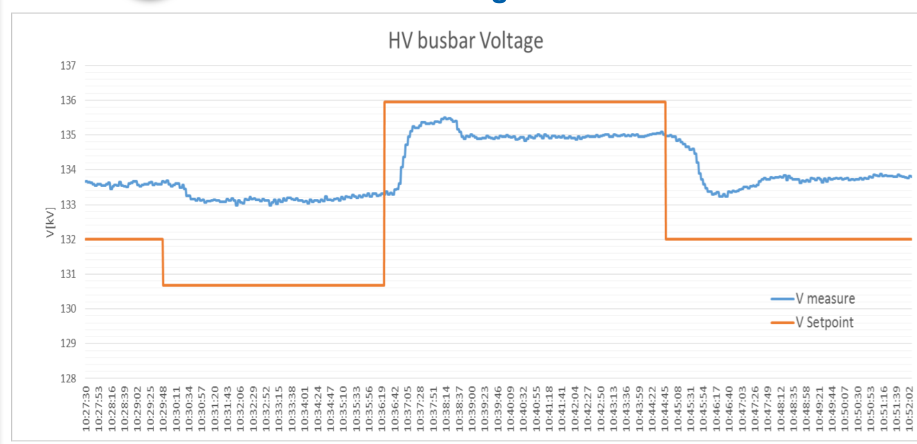
2 HVRS split the requirement 3 generators



3 Effect on MV voltage at generators terminals



4 Effect on voltage of HV busbar

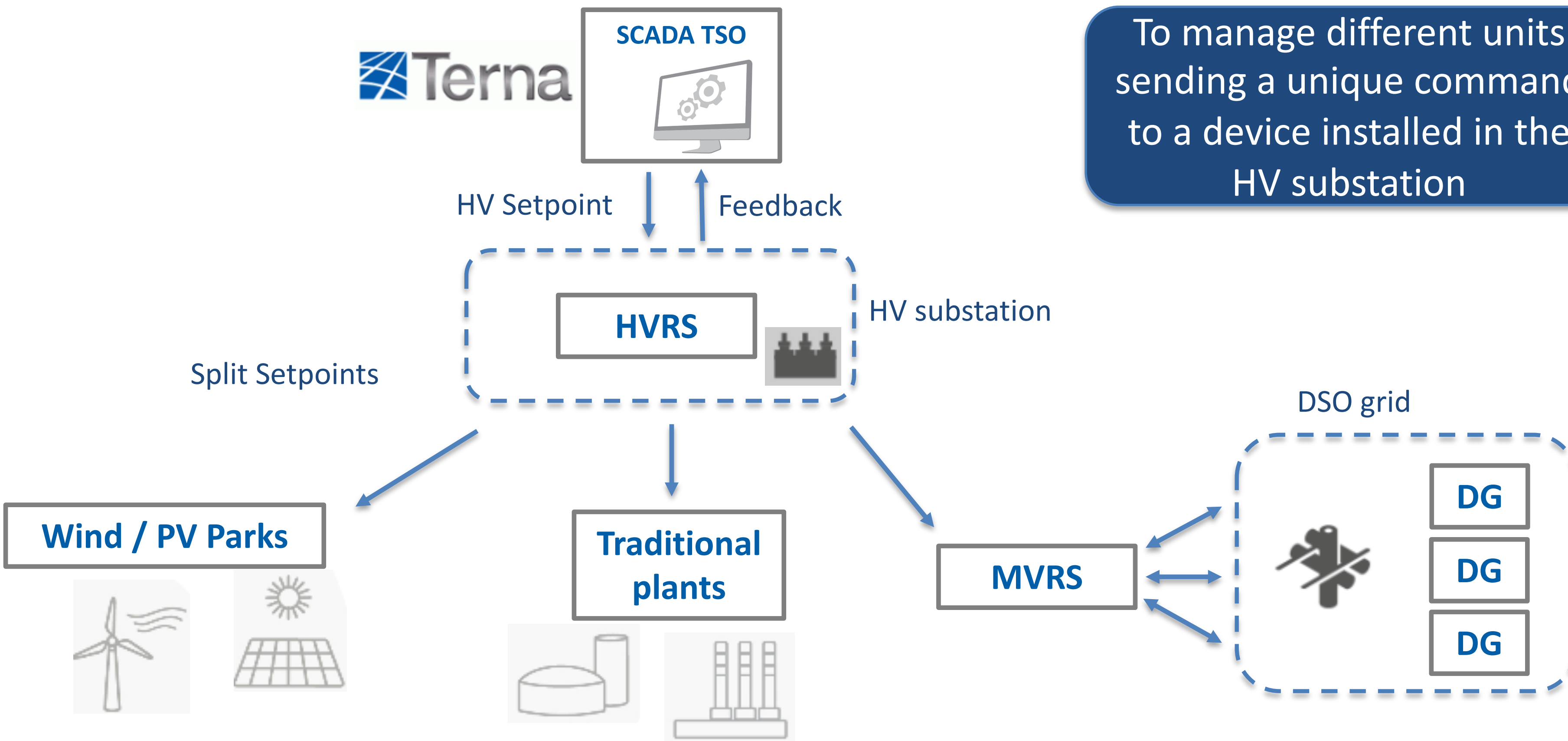


HVRS – Possible exploitation

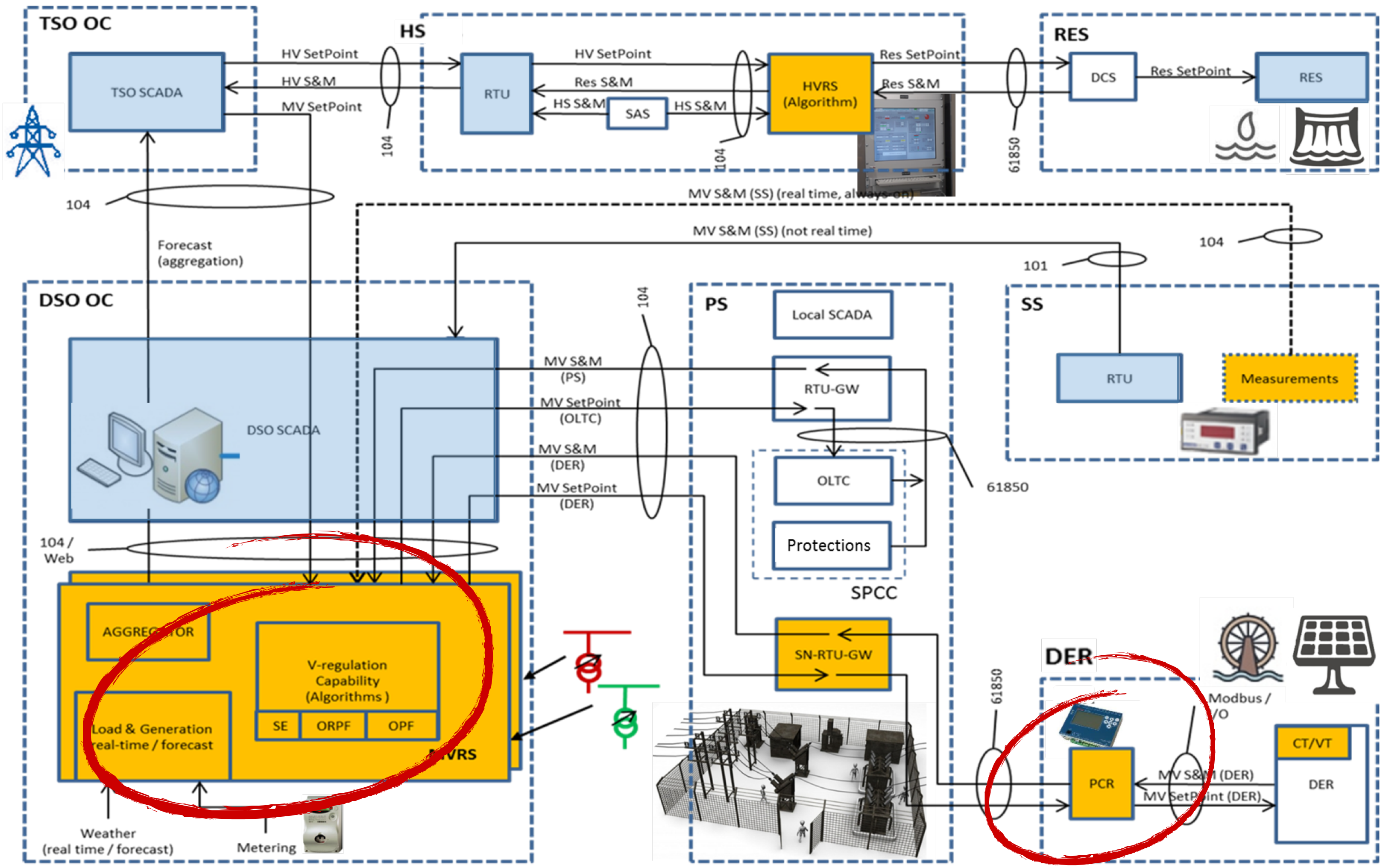
Field test have shown **technical feasibility** of controlling the reactive power exchange of the power plants connected at 132 kW grid; the effect and performance are not comparable with service (delays and overshoot) and may still need refinements but the coordination allows to **avoid reactive power loop**

Potential

To manage different units sending a unique command to a device installed in the HV substation



MVRS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MV S&M (PS)
MV SetPoint (OLTC)
MV S&M (DER)
MV SetPoint (DER)
PS
Local SCADA
RTU-GW
OLTC
Protections
SPCC
SN-RTU-GW
SS
RTU
Measurements
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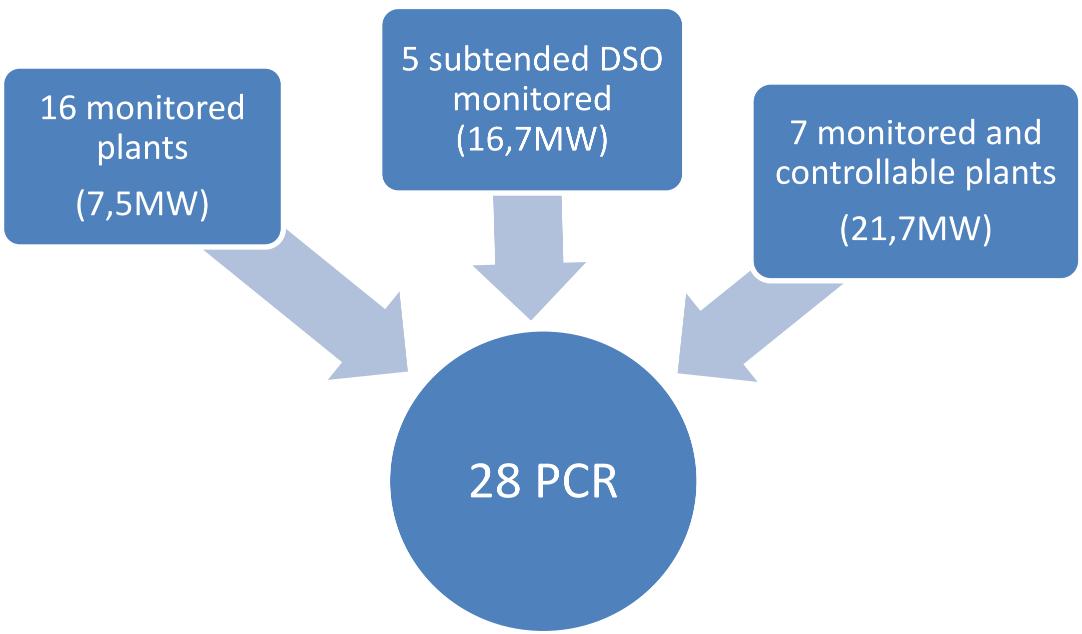
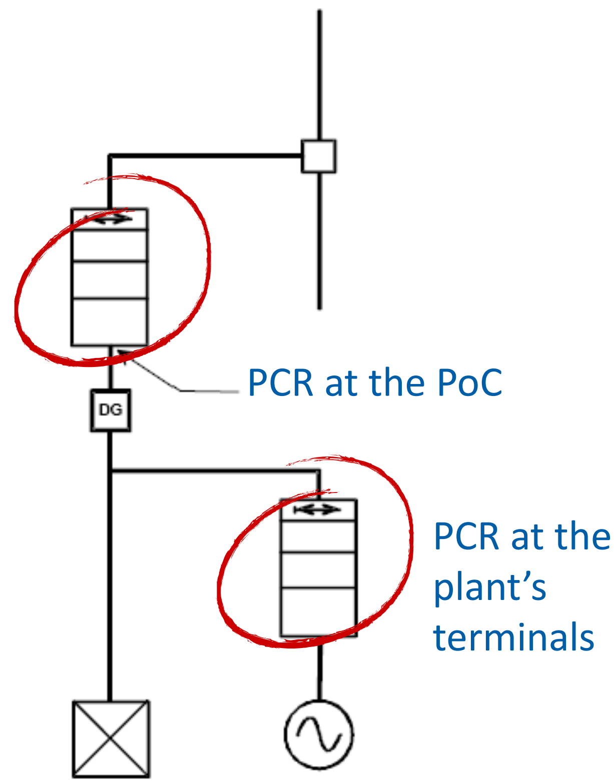
V-regulation Capability (Algorithms)
SE
ORPF
OPF
Load & Generation real-time / forecast
MVRS
Weather (real time / forecast)
Metering
DER
Modbus / I/O
CT/VT
DER
PCR
MV S&M (DER)
MV SetPoint (DER)

MVRS: Data aggregation

PCR (Plant Central Regulator):

- Monitor interconnection points
- Monitor and control plants involved in the voltage regulation and in the frequency/power regulation





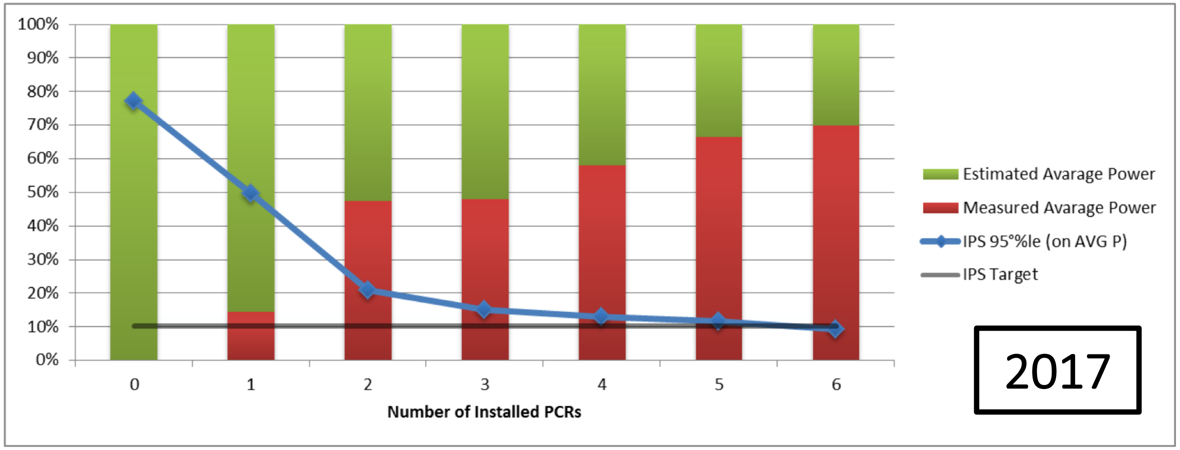
Reverse engineering of data aggregation

The installation of 28 PCRs in almost all MV generators points of connection and at the interconnection point with subtended DSOs allowed to obtain the accuracy required to test the devices and to ensure a safe and reliable management of embedded generation.

An exercise of reverse engineering has been carried out simulating a reduction of the number of meters in field to analyze the number of measurement needed to comply with the requirement.

Results

- The number of meters depends on the type of source;
- High number of measurements are required to estimate hydro power plants' active power with the required accuracy (more than 60% of the installed power);
- The choice of the sentinel measurement significantly influences the result and it is not based solely on size of power plants.



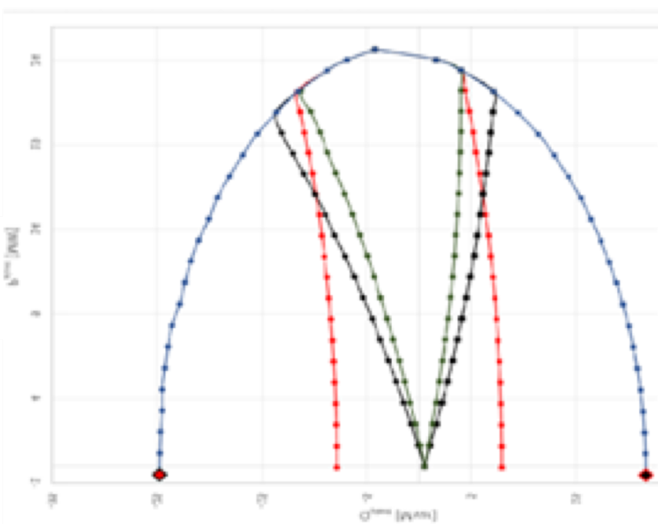
MVRS: Virtual capability computation

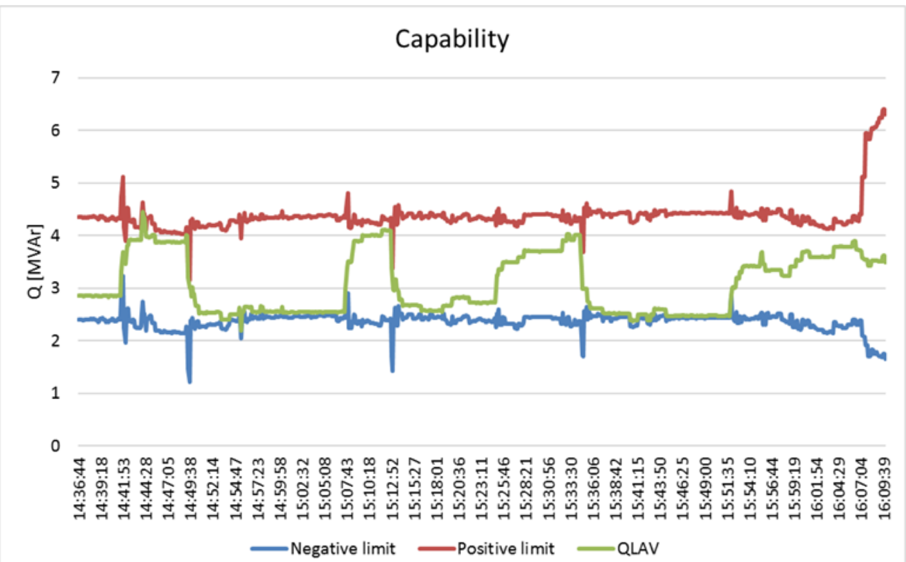
Virtual capability allows to know the **active and reactive availability** for the voltage and the f/P regulations considering the **distribution grid constraints**.

Virtual capability: it represents the **operational limits** in terms of P and Q, updated also considering **the operation point in real time** at the interconnection point. The calculation of virtual capabilities considers the **information about the topology** and the **constraints** of the distribution network

Active power limits define the availability of the virtual plant for the **f/P regulation**

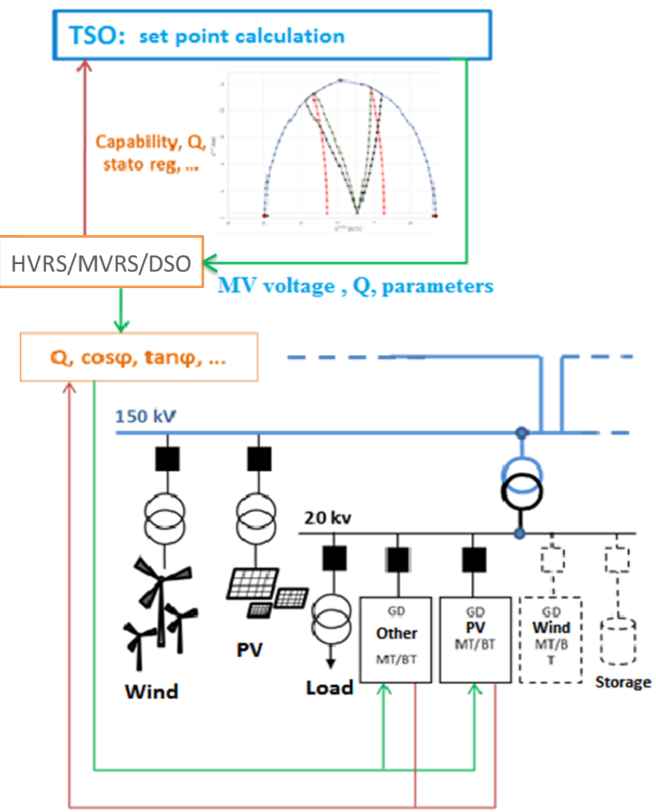
Reactive power limits define the availability of the virtual plant for the **voltage regulation**



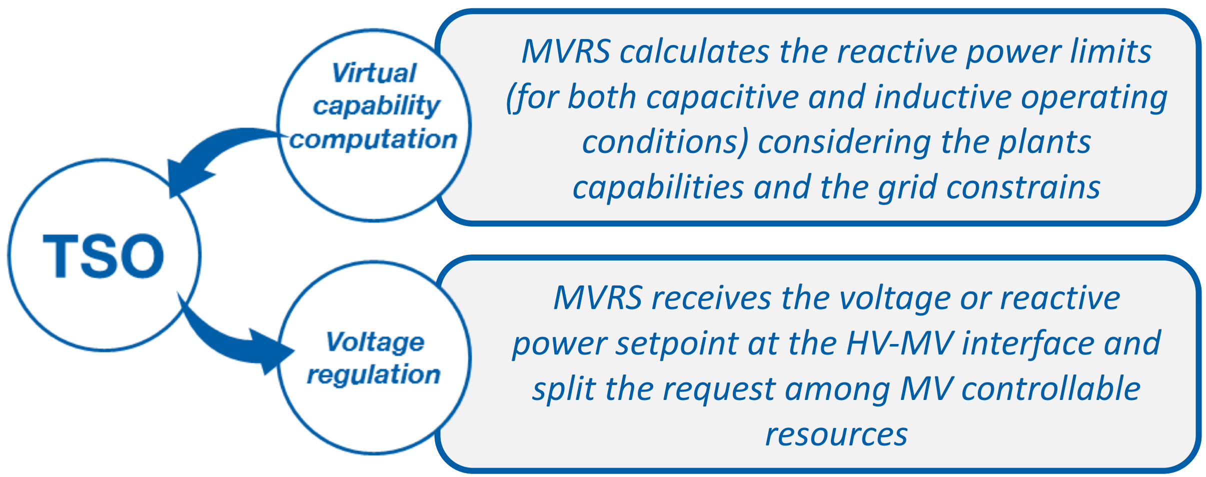


MVRS: Voltage regulation

- MVRS provides **the reactive power availability of the virtual plant** at the interconnection with TSO, taking into account the single generators capabilities and the DSO grid constrains.
- TSO provides a **voltage** or a **reactive power setpoint** considering the available capability of DG (as virtual plant) in order to obtain a centralized control of the HV busbar voltage of the primary substation



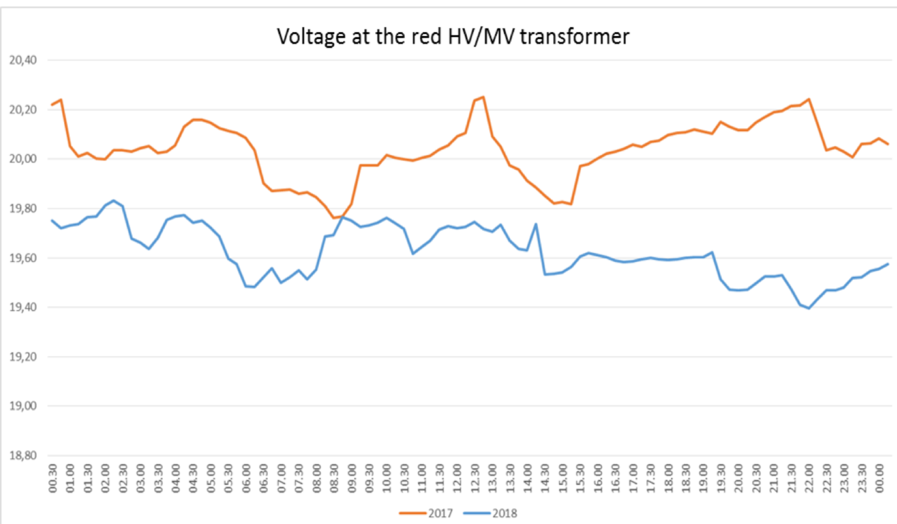
- MVRS receives a unique setpoint and splits the command among the DG taking into account the distribution grid constrains
- The plant receives the command through PCR (Plant Central Regulator) and provides its contribution.

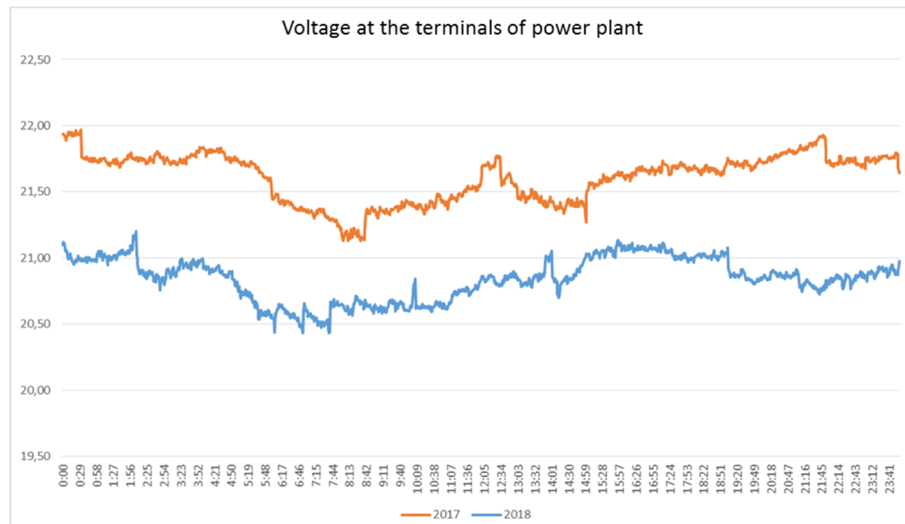


MVRS: local regulation of DSO feeder voltage

The functionality has benefits for the DSO for the **local control** of the voltage rise effect along the feeders of the distribution grid: MVRS is always in operation to maintain the voltage profiles of DSO grid **within standard limits** even when it is not operated by the TSO.

Effect of local voltage regulation





MVRS: HV busbar voltage regulation

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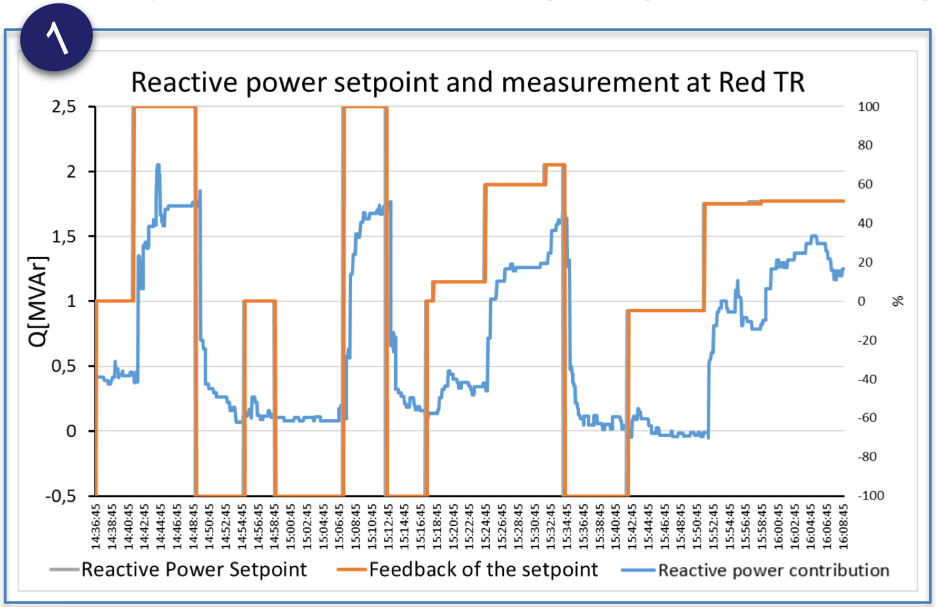
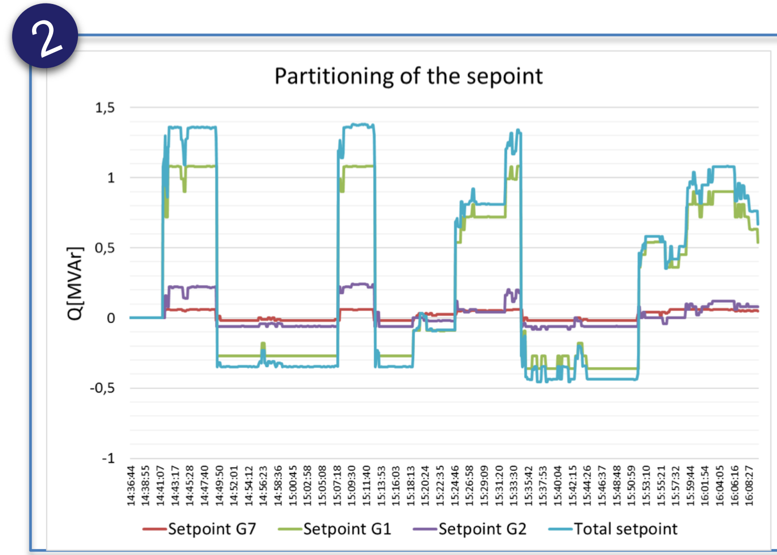
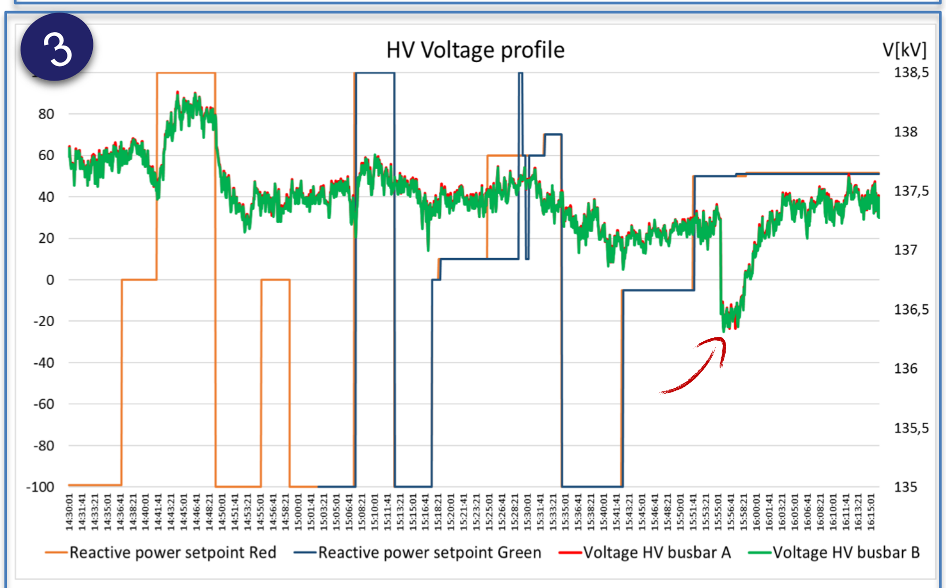
Novelty: Coordinated voltage regulation through embedded generation







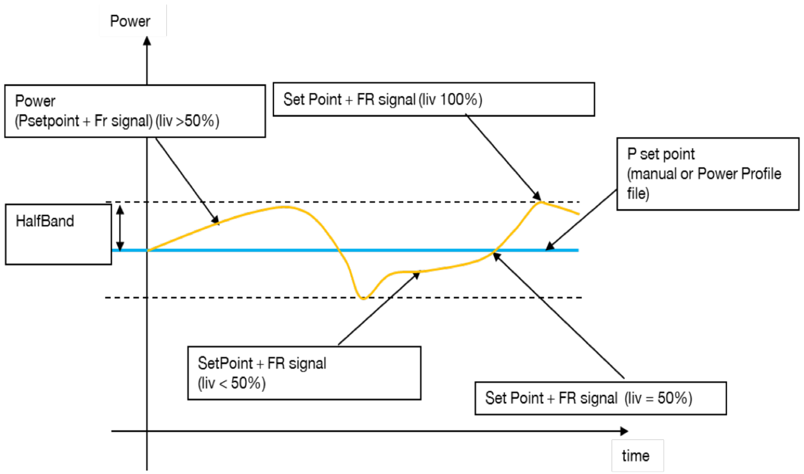
- The reactive regulation is not effective on the HV busbar and voltage variations can depend on other elements of the grid
- The coordination allows to avoid reactive power loop and improves the efficiency of the use of the reactive resources enabled to the voltage regulation service

MVRS: f/P regulation (aFRR)

Current status : Regulation UVAM (NRA resolution 300) to open the RR to DG

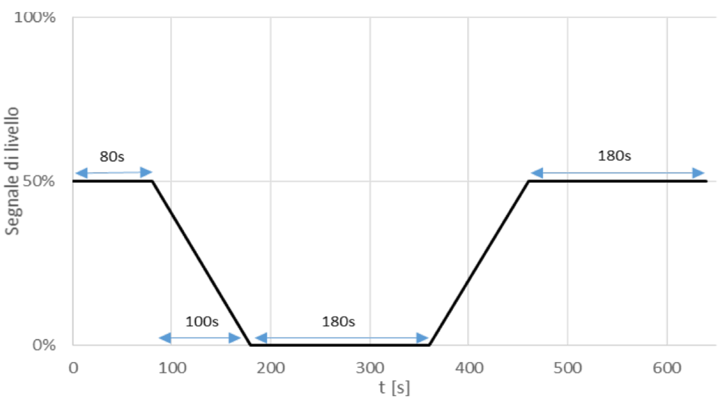
Novelty: Technical tests and alaysis on f/P regulation through aggregation of MV hydro power plants

- The frequency/power regulation (aFRR) is carried out by the **modulation of the injected active power**, around the scheduled value.
- MVRS has been developed to calculate the **program** and the **half-band** available for the regulation of the DG aggregation and to receive and transmit to controllable DG the TSO setpoint.
- The half-band is calculated by MVRS considering the band made available by each generator and the grid constraints.
- The typical timing for f/P regulation is in order of seconds; an actuation delay of, roughly, more than 10s is not allowed considering the closing of the loop with return measurements.



Ad hoc test with volunteer hydroelectric plants' owner connected at MV grid

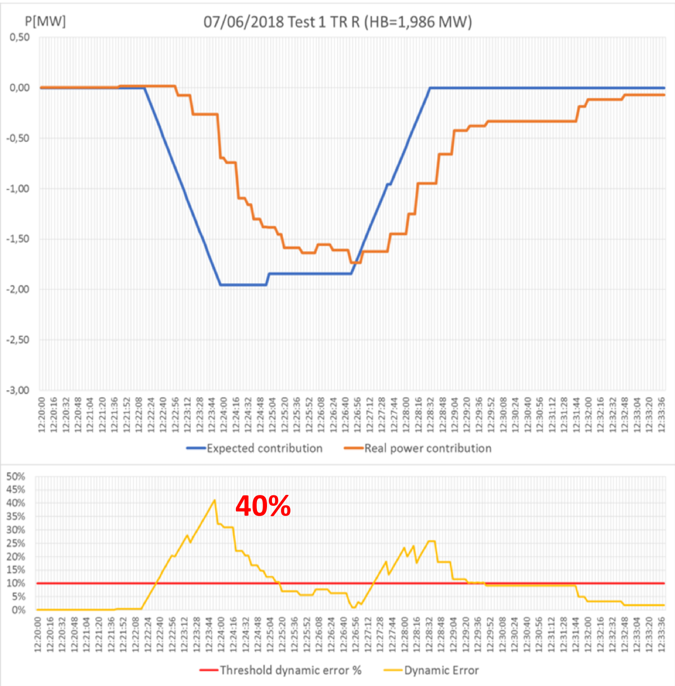
Ramp level signal profile for the downward service tests



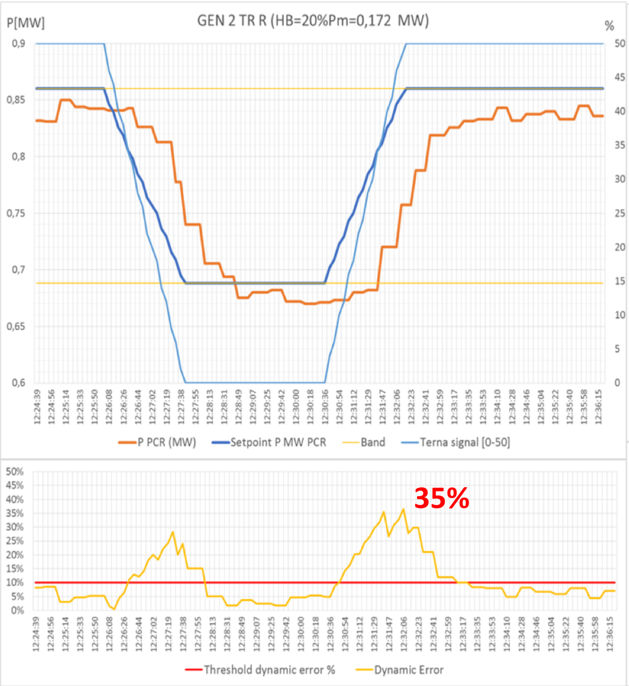
MVRS: f/P regulation tests

- Analysis of the expected and real contribution at the interconnection point
- Analysis of the comparison between setpoint and measurement at each power plant terminals
- Comparison of dynamic error with the threshold required for the service

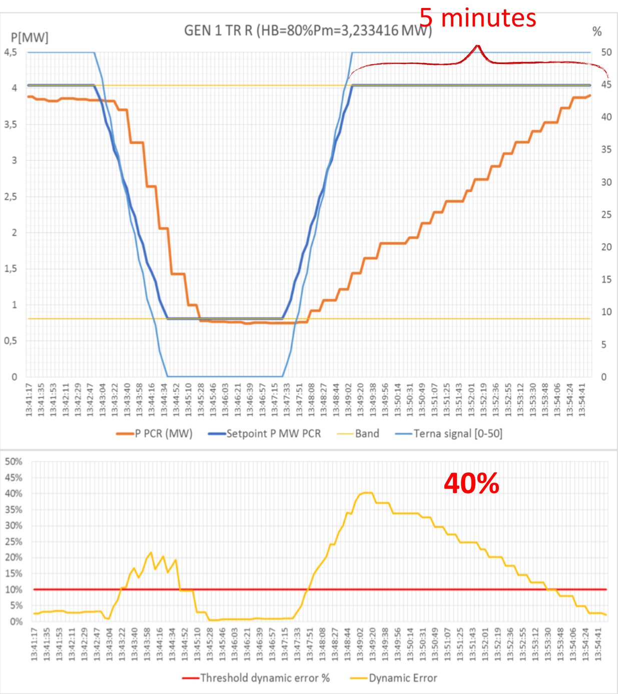
Performance at Transformer level



Performance at generator terminals



Performance at generator terminals



MVRS: f/P regulation tests

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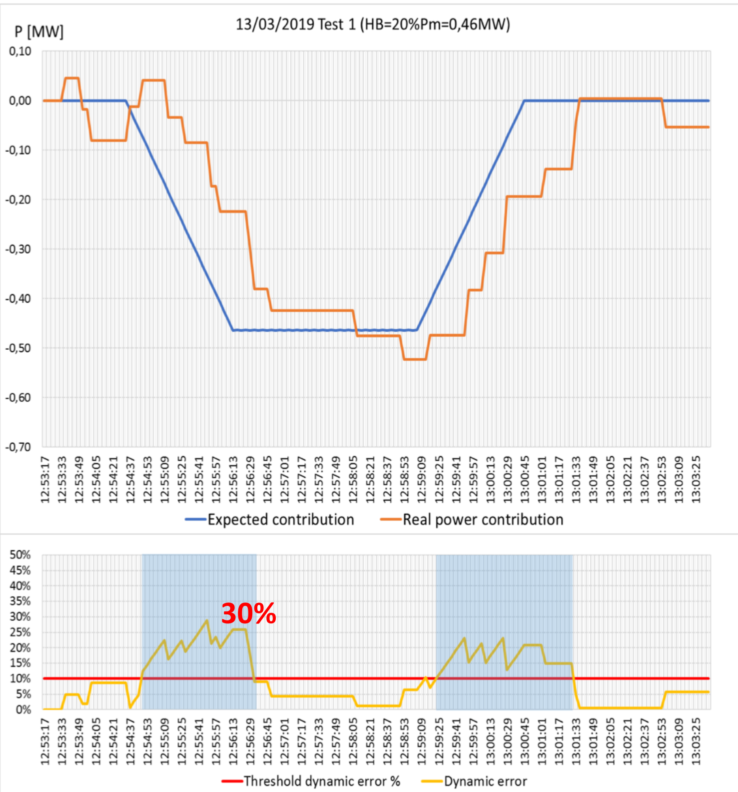
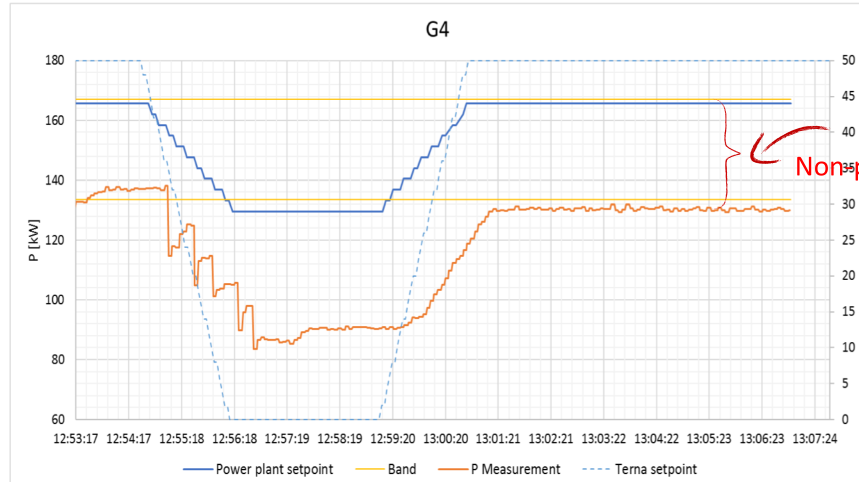
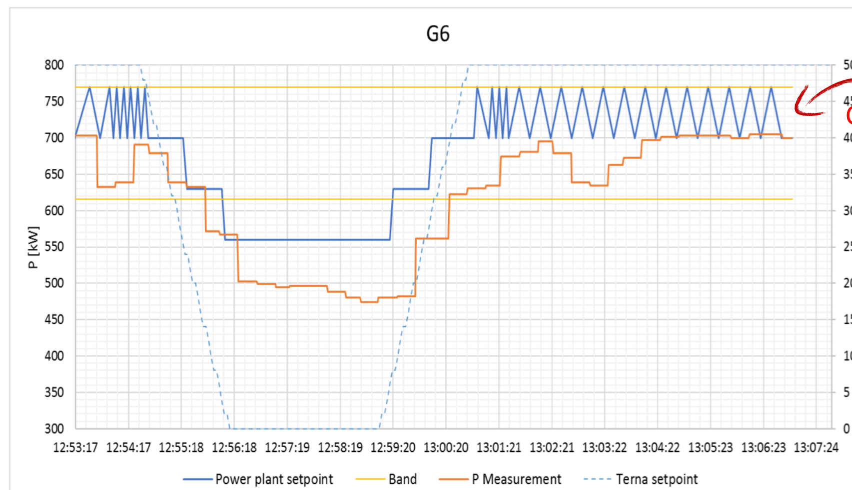
Performance at Transformer level



Performance at power plants terminals



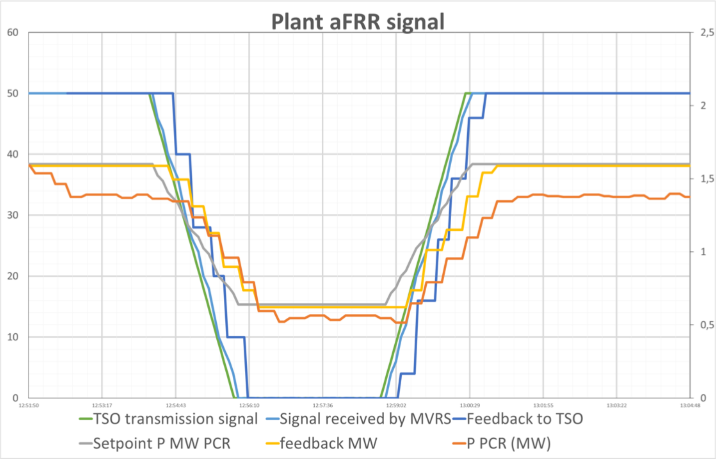
Non-programmable



Communication chain

MVRS: f/P results

- f/P tests carried out with embedded generation demonstrated the technical feasibility to control active power sending a unique setpoint from TSO to a Virtual Power Plant.
- Dynamic performance does not comply with the service requirement and shows high delays due to the long communication chain and the performance of governors of the power plants.
- The unpredictability of the production of the hydro power plants involved in the tests and therefore of the program value increases the error also in the restoration of the initial active power measurement.
- Analysis of the correlation between power plant and virtual power plant performance are necessary
- The 20 s update of the aggregated measurements at the interconnection point is not coherent with the 4 s setpoint and it is not compatible with safety assessments and closed-loop regulations, such as that of the aFRR



Conclusions

- Significant results were obtained from the experimentation.
- Although the performances are not in line with the service requirements, the feasibility of centralized remote control has been demonstrated in the field, without particular limitations, both in active and reactive power, from generation connected to the subtransmission grid and from embedded generation.
- The coordination of reactive power between TSO and DSO can be achieved through coherent reactive activations; the TSO has a virtual capability that allows to know the availability of resources in real time.
- The local voltage regulation along MV feeders has proved to be effective and useful.
- The possibility of activating services from DG respecting MV network constraints was verified by checking in real time the availability of active and reactive power.
- As mentioned in the introduction, the results require a new contextualization in the changed energy context.

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Thank you for your kind attention!

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Terna Rete Italia
TERNA GROUP

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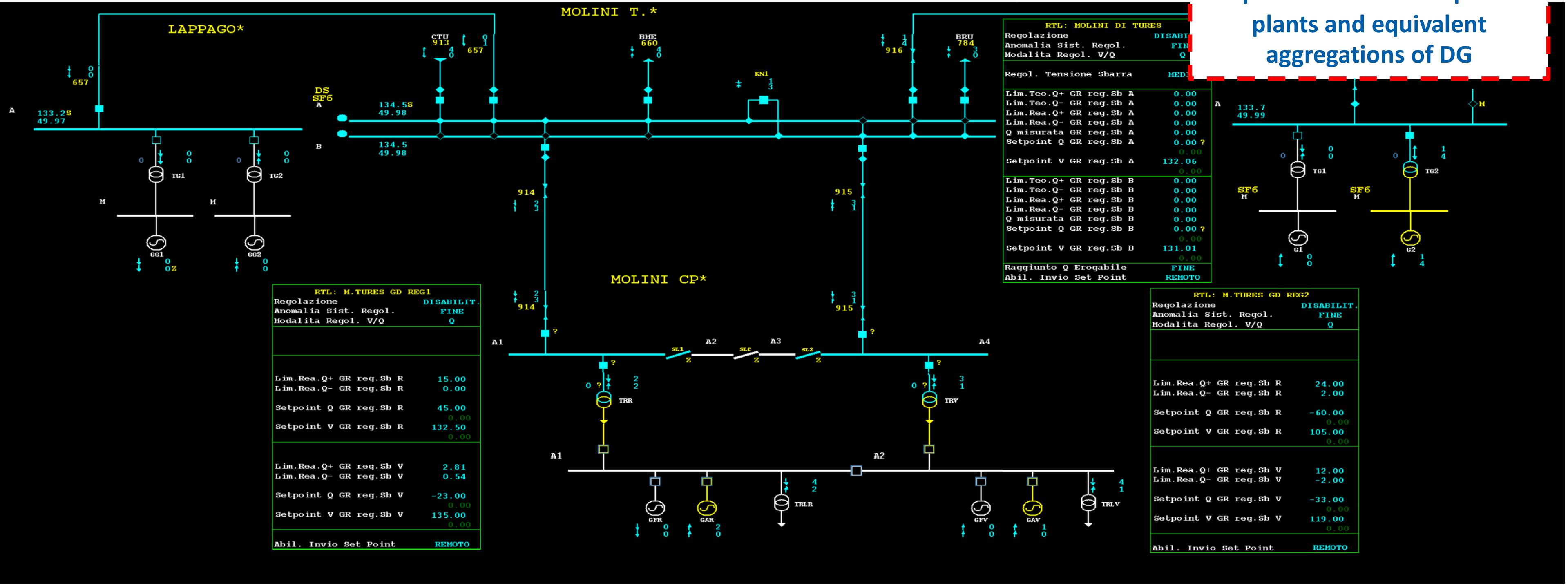
System architecture

Legend

TSO OC	TSO Operation Center (Terna)
DSO OC	DSO Operation Center (Edyna)
HS	HV Substation
PS	Primary Substation
SS	Secondary Substation
RES	HV Generation/Customer
DER	MV Generation/Customer
SPCC	local protection, command and control system (system installed in substation for the protection, command and control functions at local level)
OLTC	On Line Tap Changer
PCR	Plant Central Regulator (device to interface the power generation module control system to the MVRS)
HVRS	High Voltage Regulation System (device which performs functions and algorithms for the aggregation and the control of generation at high voltage level)
MVRS	Medium Voltage Regulation System (device which performs functions and algorithms for the aggregation and the control of dispersed generation)
S&M	State & Measures
CT/VT	Current/Voltage Transformers

Interface of TSO Control System

Representation of HV power plants and equivalent aggregations of DG



Interface of DSO Control System

Plants involved in the pilot (PCR)

SmartNet

7 controllable plants

MT Line	Tr	Plant	Nominal Power
Mühlwald	R	C.le Selva dei Molini	Hydro 5425 kW
Aurino	R	Klamme	Hydro 9000 kW
Drittelsand	R	PEG	Hydro 2030 kW
Drittelsand	R	C.le Predoi	Hydro 360 kW
Drittelsand	R	Seggiovia Cadipietra	Hydro 850 kW
Predoi	G	Mairhofer	Hydro 2100 kW
Predoi	G	Rotbach	Hydro 1968 kW
			733 kW

5 monitored subtended DSO

MT Line	Tr	Plant	Nominal Power
Drittelsand	R	Aurino Energia	700 kW
Drittelsand	R	AE Luttago	2900 kW
Lutago	G	AE Luttago	8500 kW
Predoi	G	Kirchler	1600 kW
Cantuccio	G	AE Cantuccio	3000 kW
			16˙700 kW

16 monitored plants

MT Line	Tr	Plant	Nominal Power
Drittelsand	R	Drittelsand (Speikboden)	Hydro 180 kW
Drittelsand	R	C.le Koflaue	Hydro 750 kW
Drittelsand	R	Innerbichler	Hydro 550 kW
Drittelsand	R	W.E.Ahrntal	Biomass 600 kW
Drittelsand	R	AE Moelgg	Hydro 145 kW
Drittelsand	R	C.le RBI	Hydro 110 kW
Drittelsand	R	AE Holzerbach	Hydro 220 kW
Aurino	R	Griesbach	Hydro 976 kW
Predoi	G	Oberhofer	Hydro 720 kW
Predoi	G	Klammer	Hydro 180 kW
Predoi	G	AE Gruber	Hydro 610 kW
Predoi	G	Bio Kraftwerk	Biomass 895 kW
Predoi	G	Niederkofler	Hydro 720 kW
Lutago	G	E.W.Brugger	Hydro 315 kW
Lutago	G	C.le Energy	Hydro 350 kW
Lutago	G	C.Le Aschbacher	PV 190 kW
			7˙511 kW

Main activities and tasks assignment

Here following are listed the main activities and the corresponding partner leaders:

1. Site inspection and identification of HV station suitable for the project: **EDYNA (collaboration: all partners)**
2. Identification of MV station suitable for the project, power generation involvement and first feasibility evaluation: **EDYNA**
3. Site inspecition on MV station: **EDYNA (collaboration SELTA)**
4. Functional specification of the three project tasks**: TERNA (collaboration: all partners)**
    1. Aggragation;
    2. Voltage Regulation;
    3. FRR regulation.
5. Detailed project specification**: SIEMENS/SELTA (collaboration: all partners)**
6. NRA involvement/ information sharing: **TERNA (collaboration: EDYNA)**
7. Algorithm implementation of the three project tasks: **SIEMENS/SELTA**
8. DSO control system updates (if needed): **EDYNA (collaboration: SELTA)**
9. Data flow implementation: **TERNA (collaboration: EDYNA, SELTA, SIEMENS)**
10. Supply of equipments to be installed at the power generation facilities: **SELTA**
11. Supply of equipments to be installed at DSO station: **SIEMENS/SELTA**
12. Test and commissioning: **TERNA/EDYNA (collaboration: all partners)**
13. Operational experimentation : **TERNA/EDYNA**
14. Experimentation reporting: **all partners**