SUMMER SCHOOL
“ENABLING DRES TO OFFER ANCILLARY SERVICES”
20TH – 24TH SEPTEMBER 2021

Testing of Ancillary Services

Milos Cvetkovic // 24.09.2021.

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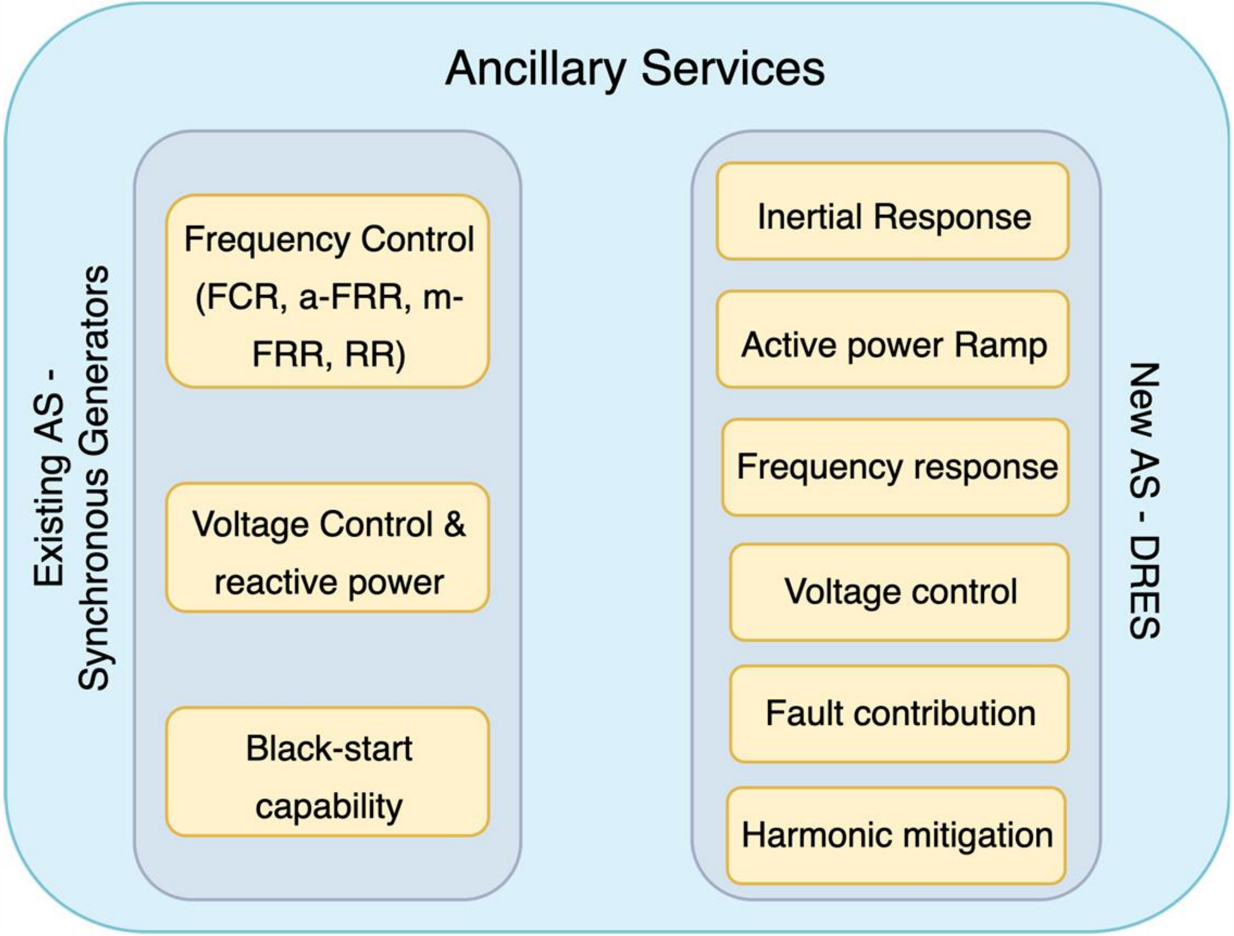
Agenda

- Ancillary services
- Evaluation approaches
- Testing procedures

Ancillary services (AS)

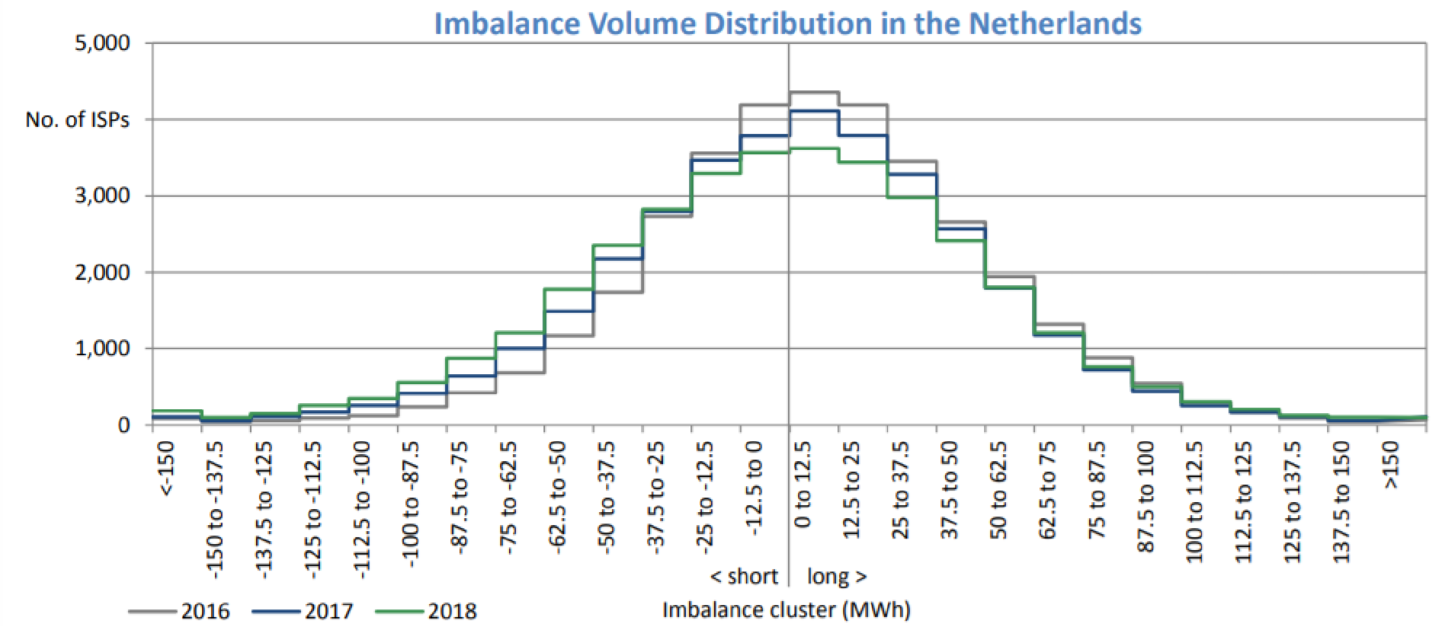
- Support services for supplying electrical energy to its users
- Defined by the regulation authorities (in consultation with the grid operators)
- Procured by the grid operators via organized market places or bilateral contracts
- Obliged to be followed by all (or selected) energy assets



FCR – frequency containment reserve
aFRR – automatic frequency restauration reserve
mFRR – manual FRR
RR – replacement reserves
DRES – distributed renewable energy sources
SG – synchronous generators

D. K. Oureilidis, K. Malamaki, K. Gallos, A. Tsitsimelis, C. Dikaiakos, S. Gkavanoudis, M. Cvetkovic, J. M. Mauricio, J. M. Maza Ortega, J. L. Martinez Ramos, G. Papaioannou, C. Demoulias, "Ancillary Services Market Design in Distribution Networks: Review and Identification of Barriers", MDPI Energies 2020.

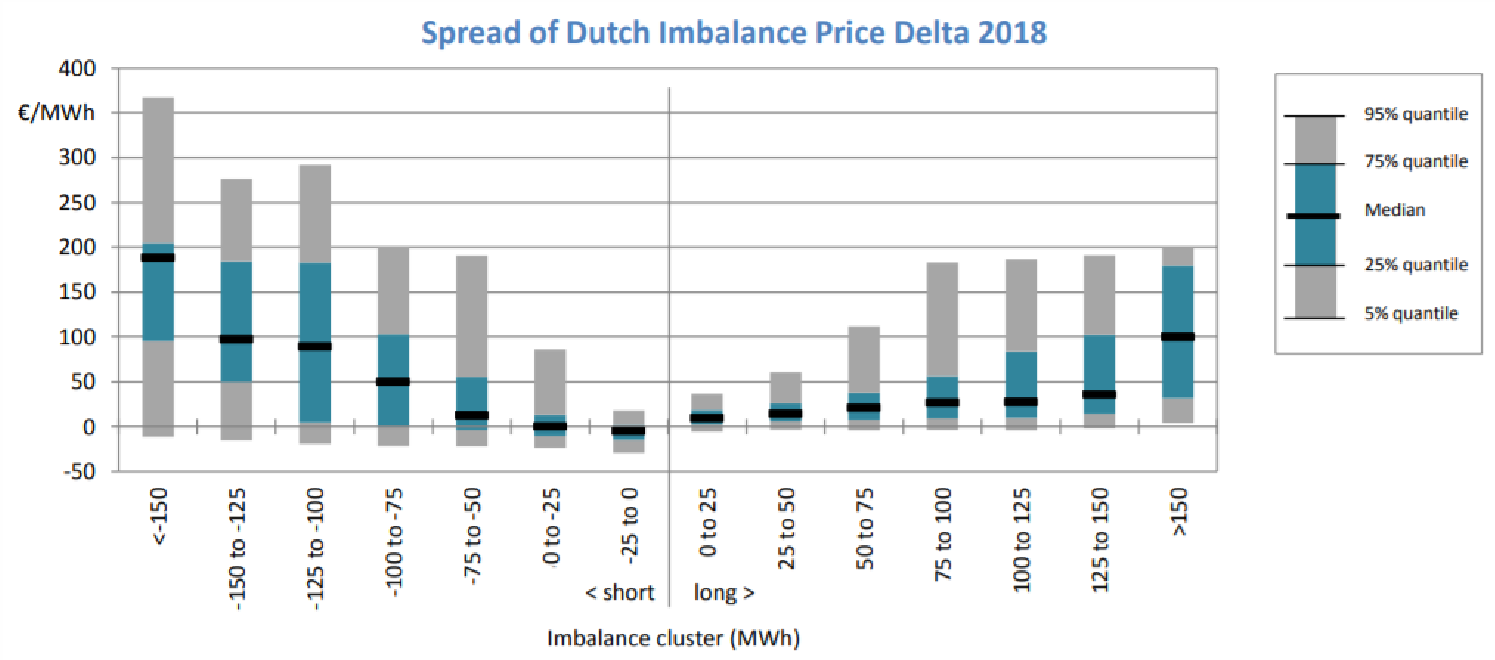
Imbalance from balancing responsible parties



ISP – imbalance settlement period

Tennet annual market update 2018

Price of imbalance

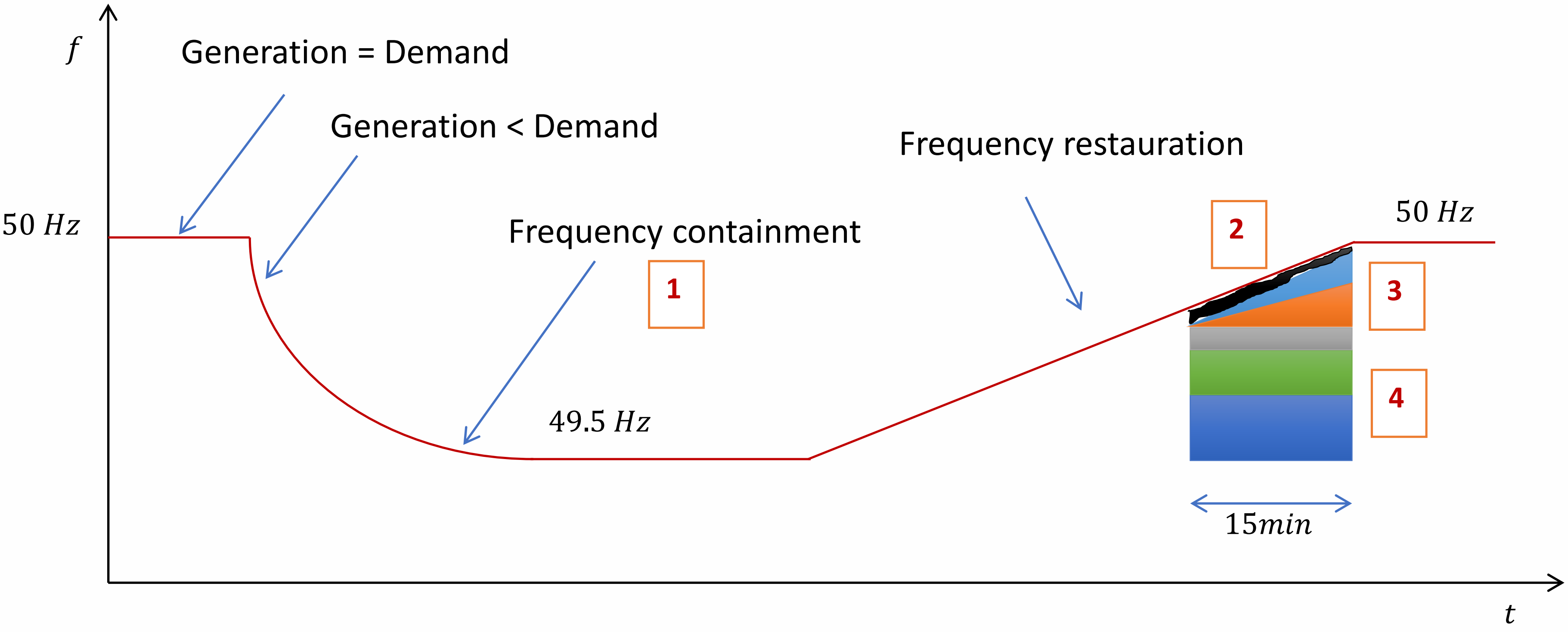


ISP – imbalance settlement period

Market volume of ~10 mil euro

Tennet annual market update 2018

Frequency control stages



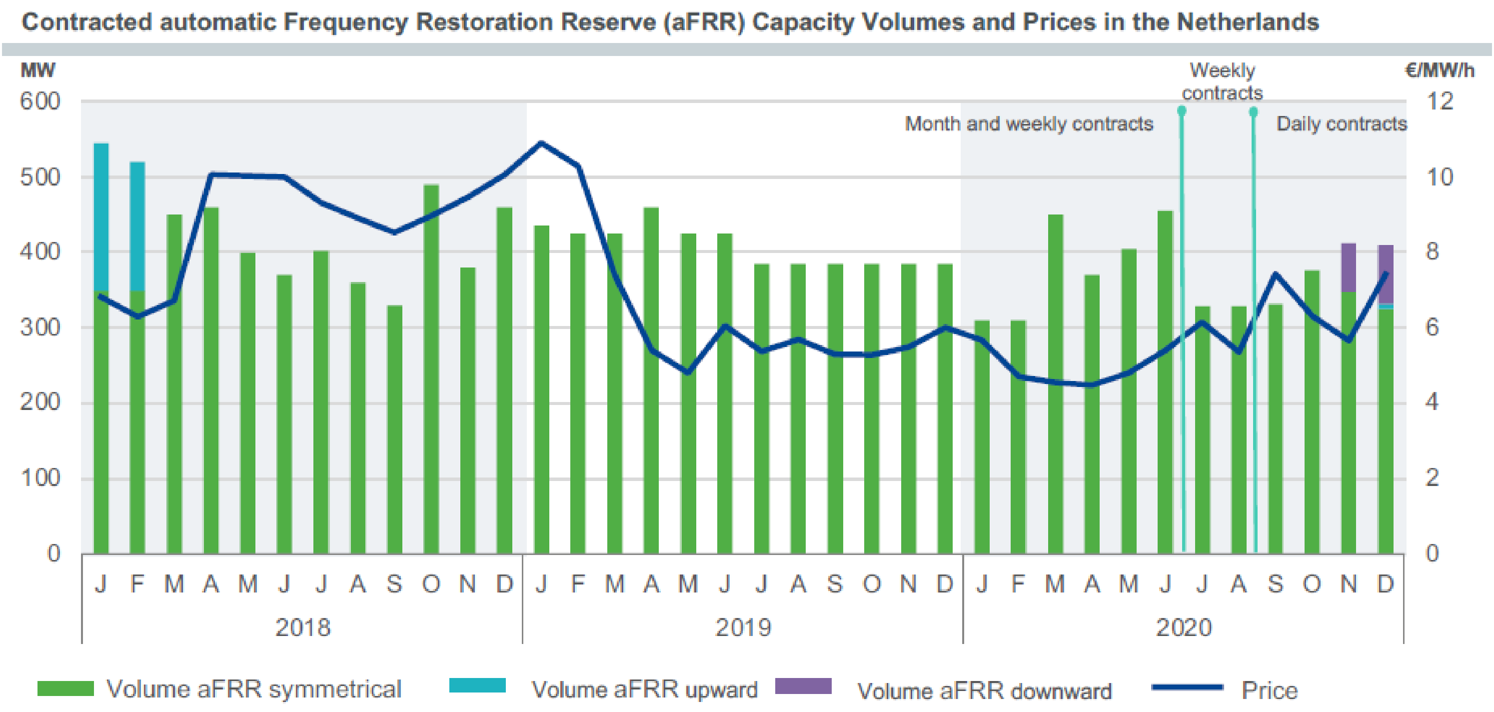
Frequency control markets

FCR – frequency containment reserve
aFRR – automatic frequency restauration reserve
mFRRda – manual FRR directly activated
mFRRsa – manual FRR schedule activated

	Service	Technical characteristic	Activation time	Implementation	Bidding quantity	Dutch grid req in 2018 (on average per hour)
1	FCR	Primary frequency response	Immediate (milliseconds to seconds)	Local	>1MW	111 MW
2	aFRR	Secondary frequency response	~5 sec set-points	Centralized (control room)	>1MW	320-425 MW
3	mFRRda (up/down)	Incident/ramping reserves	5min response	Centralized (control room)	>20MW	Up: 650-750 MW Down: 629-712 MW
4	mFRRsa	Step reserves	Next PTU (15min)	Centralized (control room)	>1MW	Not known

aFRR historic trend

Market volume of ~18 mil euro in 2020



Tennet annual market update 2020

Steps for establishing ancillary services (AS)?

- Defining the AS
- **Quantifying the required volume of AS by the grid operator**
- Standardizing the minimal technical requirements for participating units
- **Testing and certifying units that can provide such minimal technical requirements**

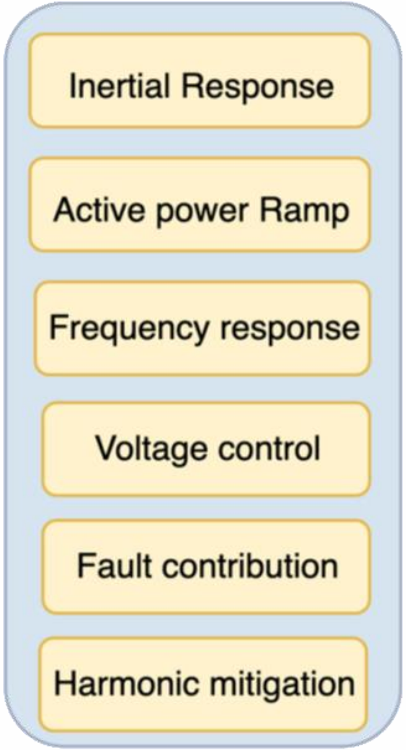
- Defining the costs for AS provision
- Quantifying the market volume
- Defining the market products, settlement periods, etc.

Quantifying the required AS volume

- Inertial Response
- Active power Ramp
- Frequency response
- Voltage control
- Fault contribution
- Harmonic mitigation

Same (or more?) as in the system with the synchronous generators

Key performance indicators of EASY-RES



KPI 1: Increase the average system inertia by at least 1.5% for every 10% increase in DRES capacity.

KPI 4.1: $\Delta P/min \leq 30\%$ of DRES rated power
KPI 4.2: $\Delta P/min \leq 10\%$ of HV/MV transformer rating
KPI 4.3: $\Delta P/min \leq 10\%$ of MV/LV transformer rating

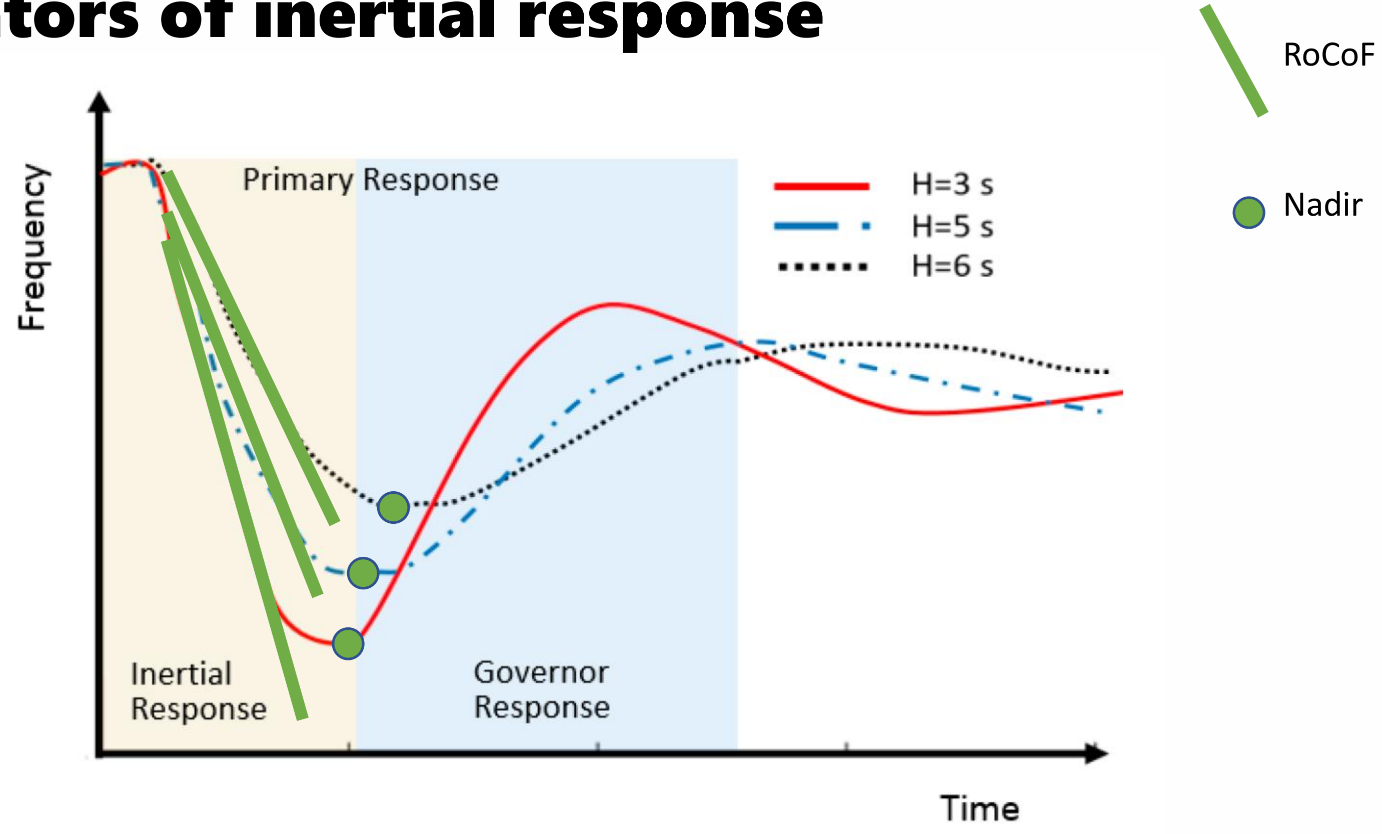
KPI 2: For every 3 MW of DRES entering the system more than 2.5 MW of conventional reserves will be decommissioned. The rest of 0.5 MW or less will appear as reduction of the power of conventional base load units.

KPI 3: The relative increase in DRES with EASY-RES is higher than with conventional approach.

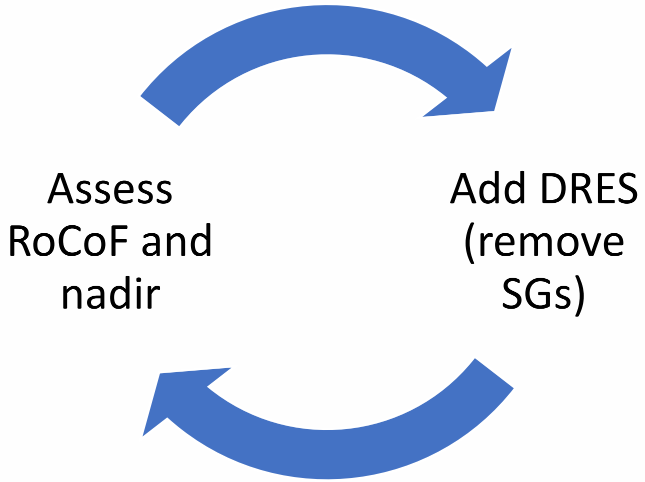
KPI 5: The additional DRES penetration, due to developed functionality, does not violate existing fault-protection means in MV and LV (symmetrical and non-symmetrical).

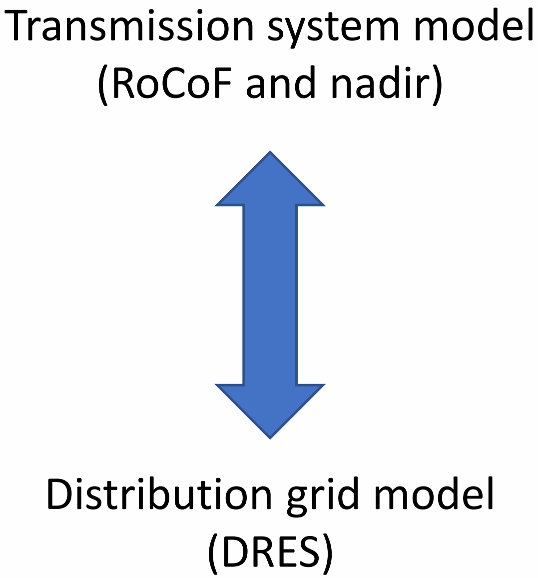
KPI 4.4: $THDv \leq 8\ \%$

Indicators of inertial response

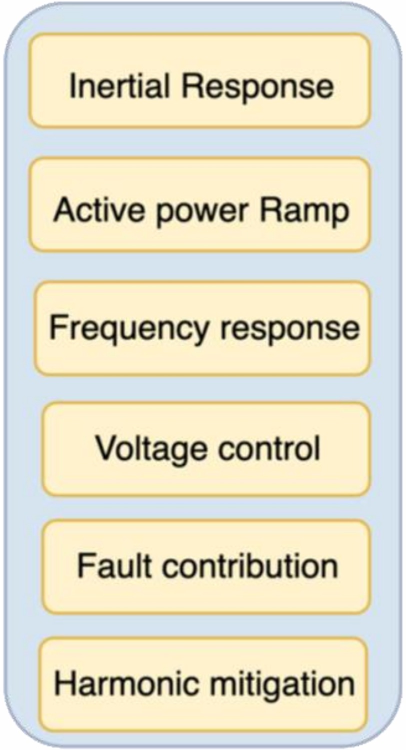


Quantifying inertial response





Indicator – DRES quantity – cost

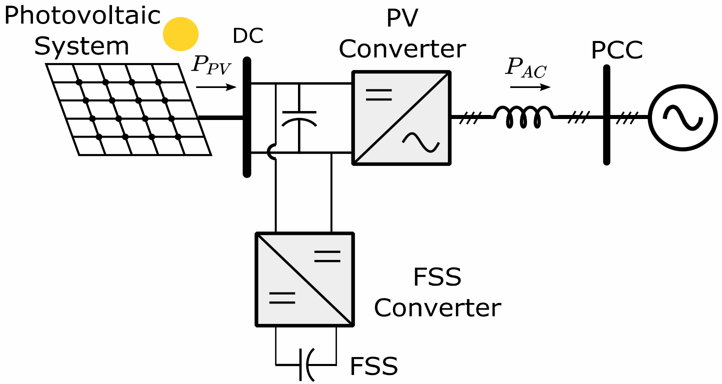


Testing of ancillary services

- Standardized procedures for testing of DRES
- Rapid prototyping and mass-production
- Taking research ideas from TRL 3 to TRL 5

- ISGAN (International Smart Grid Action Network)
- IEC TR 61850-90-7 and IEC 61850-7-420

Testing requirements



- Inertial Response
- Active power Ramp
- Frequency response
- Voltage control
- Fault contribution
- Harmonic mitigation

<u>Testing requirements:</u>

- functional testing: individual ancillary service provision
- functional testing: joint operation of several ancillary service controllers
- unit testing: single DRES operation
- system testing: multiple DRES units

Testing methodologies

Control hardware in the loop CHIL

- Suitable for control board/algorithm tests
- Automated tests with no power hardware

Power hardware in the loop PHIL

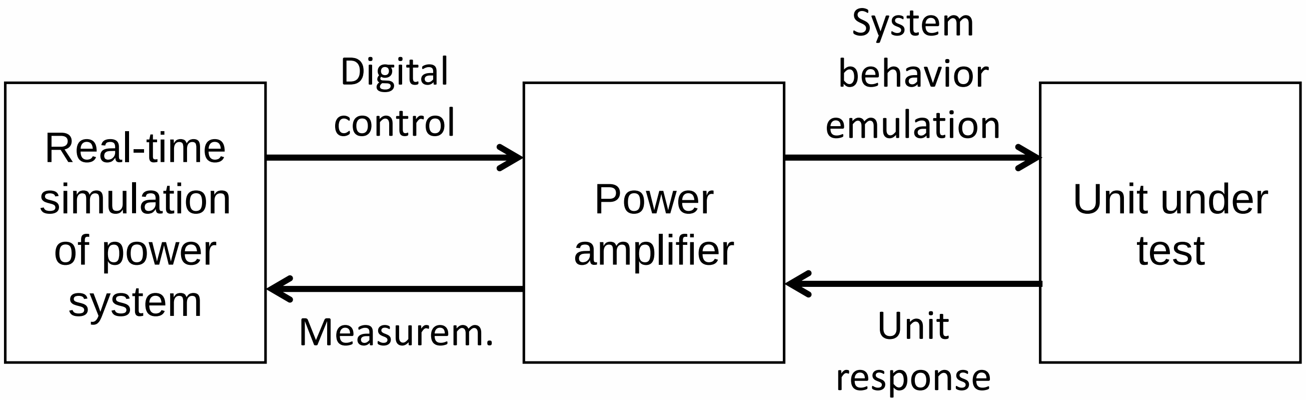
- Suitable for testing of power hardware units
- Functional unit tests

Scaled-down pilot test sites

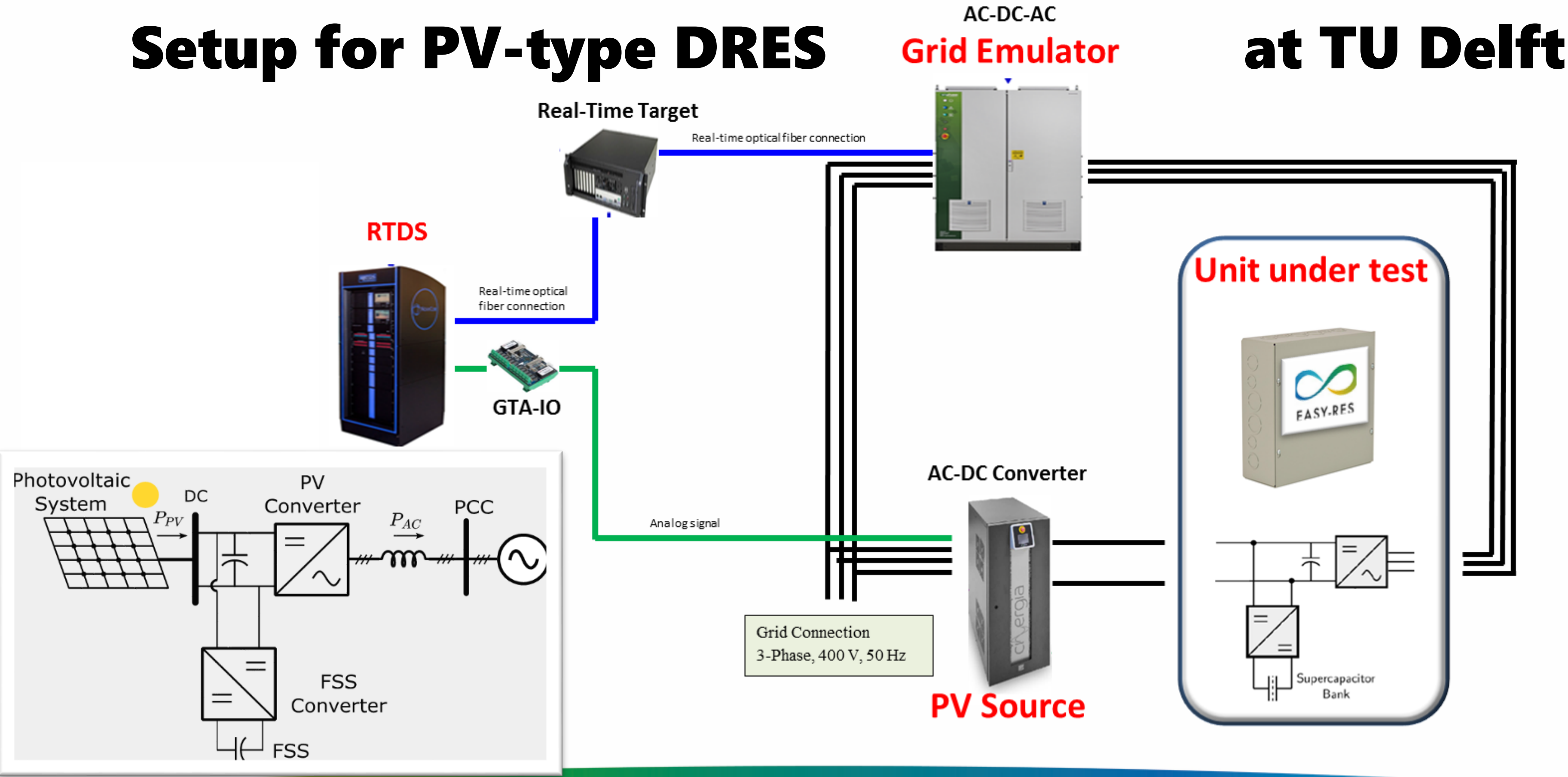
- Suitable for testing of interaction/aggregation of power hardware units
- Multiple units under test

PHIL testing characteristics

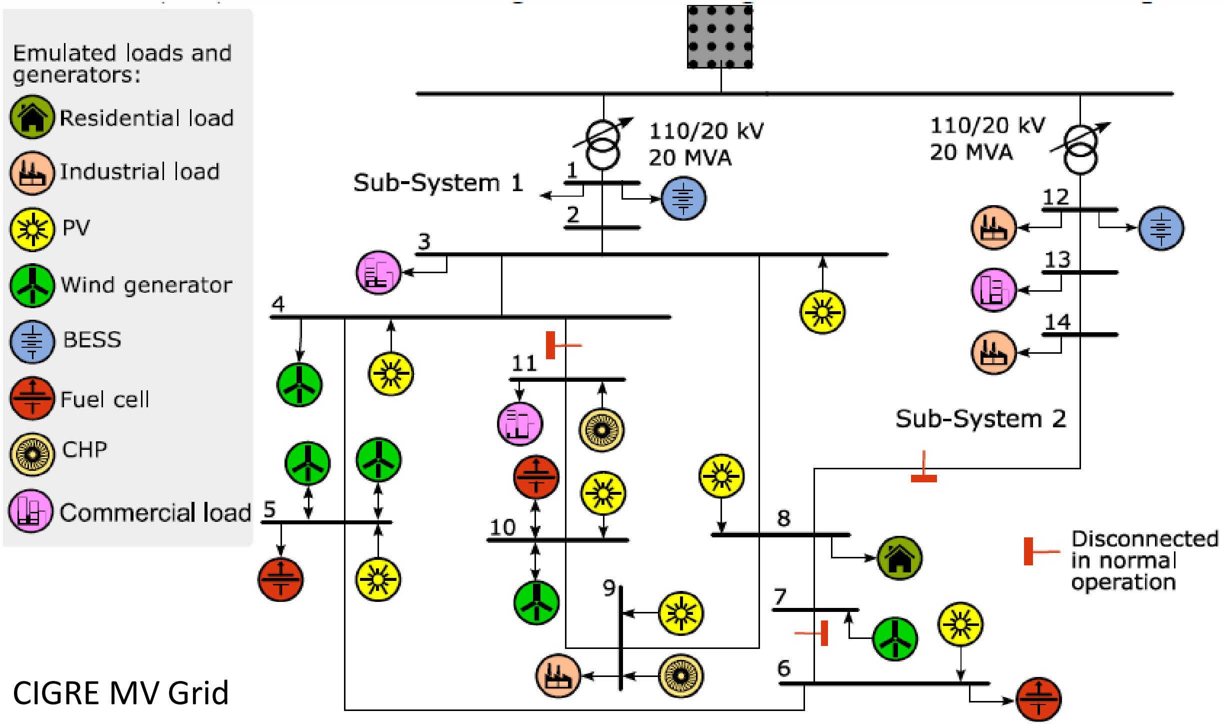
- Time delay introduced by real-time experimental system
- Dynamic behavior of the power amplifier
- Choice of interface algorithm
- Measurement equipment used (I/O, transducers)



Setup for PV-type DRES at TU Delft



Scaled-down pilot test site of University of Seville



CIGRE MV Grid

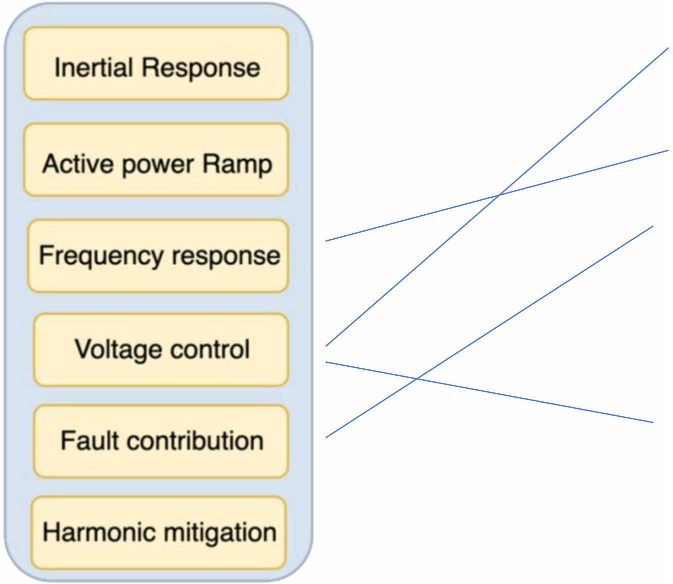
J. M. Maza-Ortega et al., "A Multi-Platform Lab for Teaching and Research in Active Distribution Networks," in IEEE Transactions on Power Systems, vol. 32, no. 6, pp. 4861-4870, Nov. 2017, doi: 10.1109/TPWRS.2017.2681182.

Managing DER behavior

- Modes: pre-established groups of settings that can enable autonomous DER behavior in response to local conditions
- Schedules: a type of mode, where the key input is a time sequence and behavior instructions for each time interval, to be executed autonomously
- Curves and tables: provide settings or actions to take based on the value of an input (temperature, etc.)
- Response times: how soon an inverter action is initiated after the command is received
- Rate of response: how quickly the desired inverter output is reached
- Timeout: how long the change from default setting or mode is in effect if a command to the contrary is not received
- Hierarchy: e.g., system protection and reliability functions take precedence over economic dispatch

J. Johnson, S. Gonzalez, M. E. Ralph, A. Ellis, R. Broderick, “Test Protocols for Advanced Inverter Interoperability Functions”, SAND2013-9880, November 2013

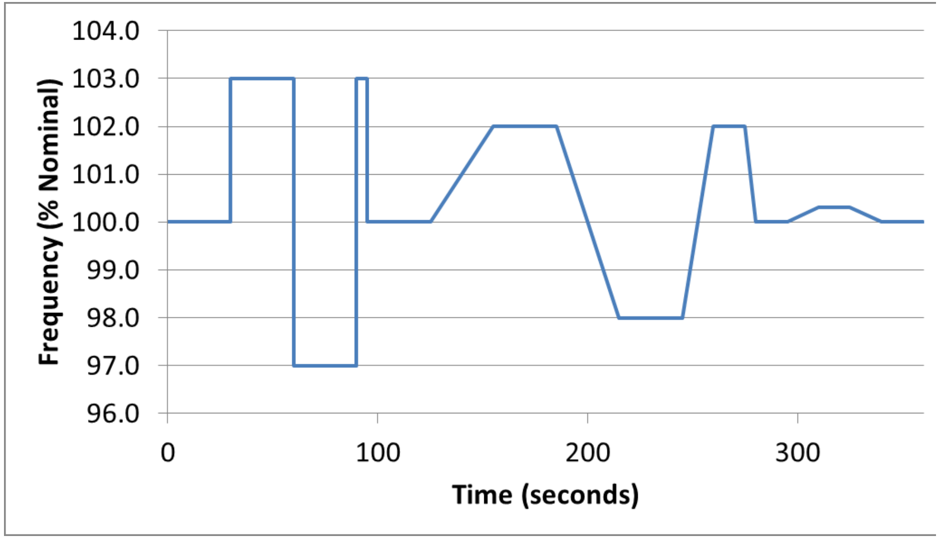
Testing procedures of IEC TR 61850-90-7

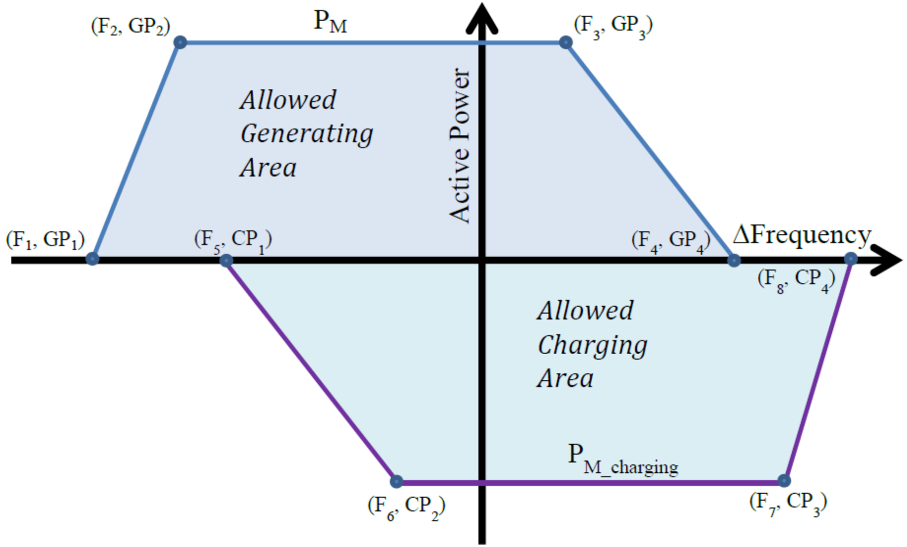


Modes	Functions
Immediate Control	INV1: grid connect/disconnect
	INV2: adjust max. generation level up/down
	INV3: adjust power factor
	INV4: request active power
	INV5: Pricing signal (charge/disch.)
Volt-Var Management	VV1: Available Var support, no P impact
	VV2: Max. Var support based on Wmax
	VV3: Static Power Converter
	VV4: Passive Mode (No Var support)
Frequency Related	FW21: High freq. reduces P
	FW22: Limiting generation with f
Dynamic Reactive Current Support	TV31: Support during abnormally high or low voltage
Low-high voltage ride-through	"Must disconnect" (MD) "Must remain connected" (MRC)
Watt triggered	WP41: Watt power factor
	WP42: Alternative watt power factor
Volt-watt management	VW51: Volt-Watt management (generation)
	VW52: Volt-Watt management (charging)
Non-power parameters	TMP: temperature
	PS: pricing signal
Setting and Reporting	DS91: Modify DER settings (power conv.)
	DS92: Log alarms and events
	DS93: Selecting status points
	DS94: Time synchronization requirements

J. Johnson, S. Gonzalez, M. E. Ralph, A. Ellis, R. Broderick, "Test Protocols for Advanced Inverter Interoperability Functions", SAND2013-9880, November 2013

Frequency related





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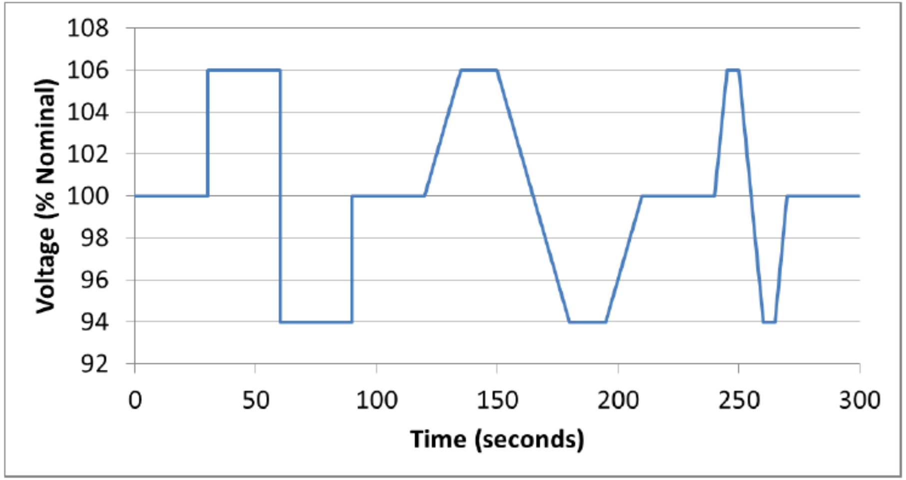
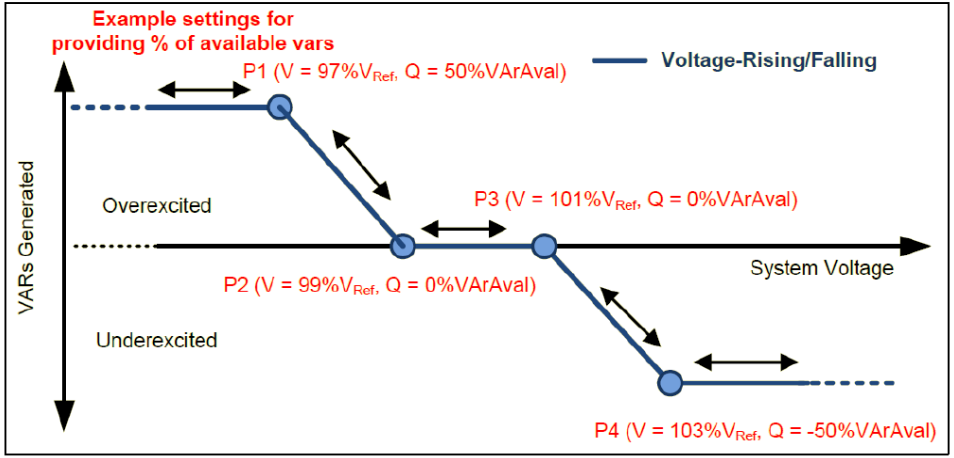
Volt-Var management





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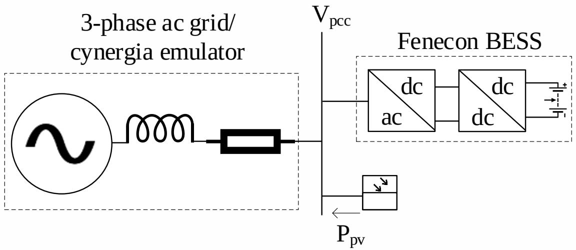
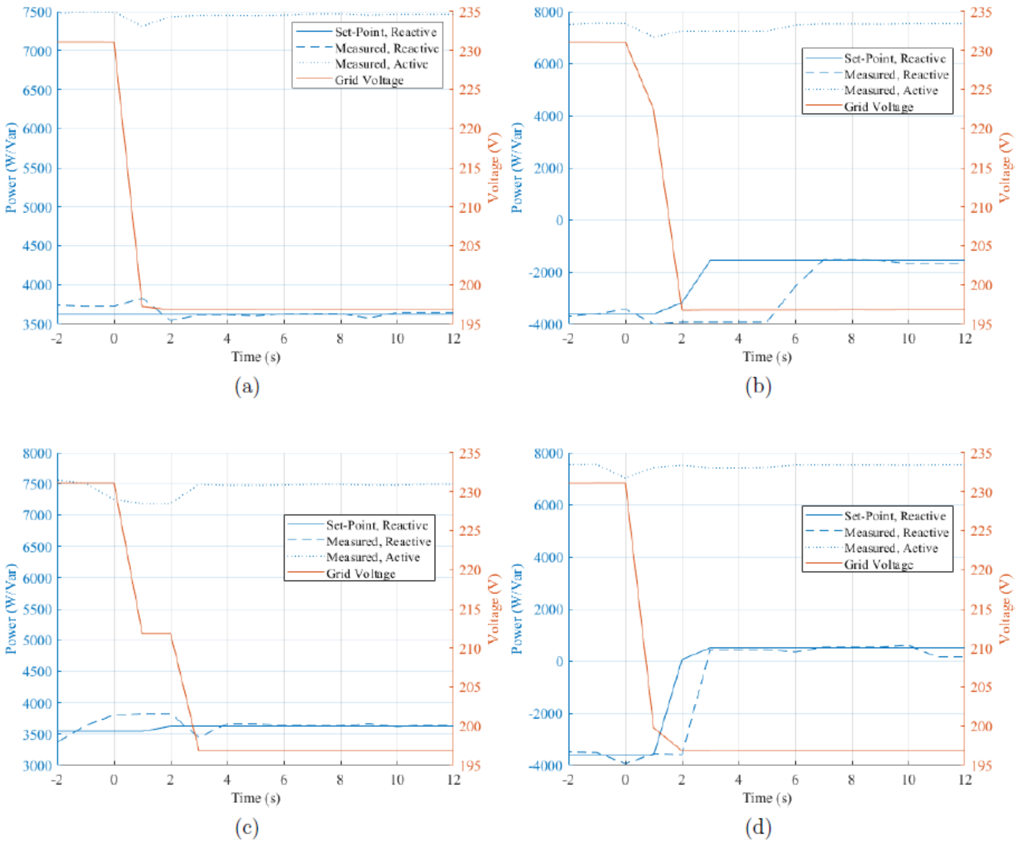
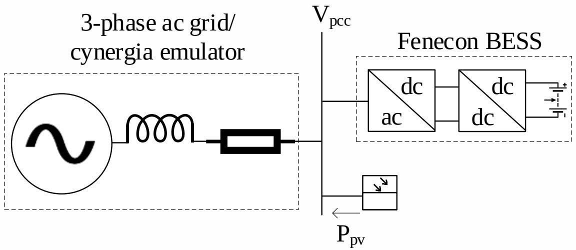
Volt-Var by BESS

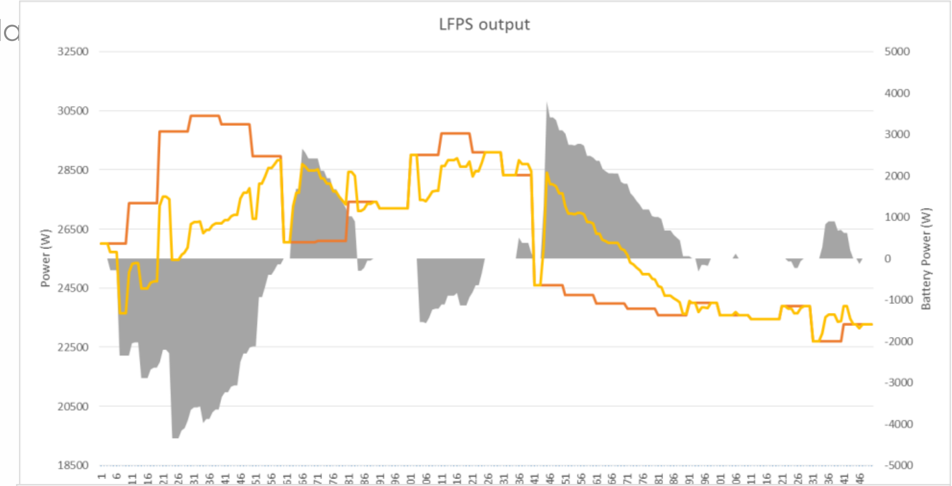


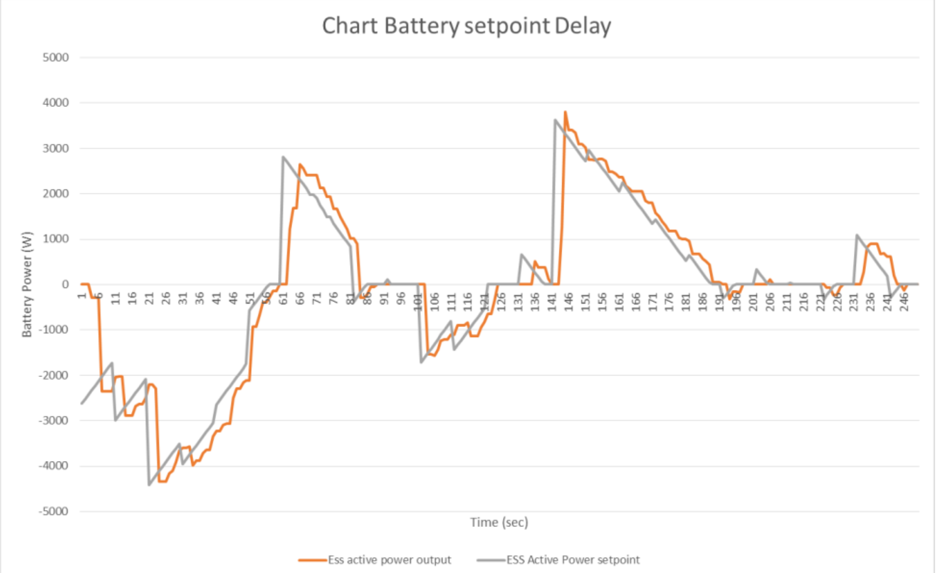


Active: ± 2.5, ± 5, ± 7.5 kW
Reactive: lead/lag 0,9, 0.8 and 0.7 power factor
Voltage drop 1 p.u to 0.85 p.u

Low-frequency Power Smoothing (LFPS) by BESS







- LFPS: absorb active power deviations of RES lasting longer than several seconds and being greater than a certain power value

- Ramp rate test specs

Thank you!

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