The Enhanced Frequency Control Capability (EFCC) Network Innovation Competition Project

Technical Capability Update: Wind, Solar and Battery

5th February 2019

11:30 – 12:30

Thank you for joining our webinar.

You are on mute and will remain muted.

Email questions to **box.EFCC@nationalgrid.com** or use the **chat** function on Webex.

How can EFCC resolve the system operability challenges?

Reduction in system inertia, making system frequency more volatile

- System inertia is the aggregated inertia of all rotating machines that are coupled to the system
- Frequency is more volatile when system inertia is low

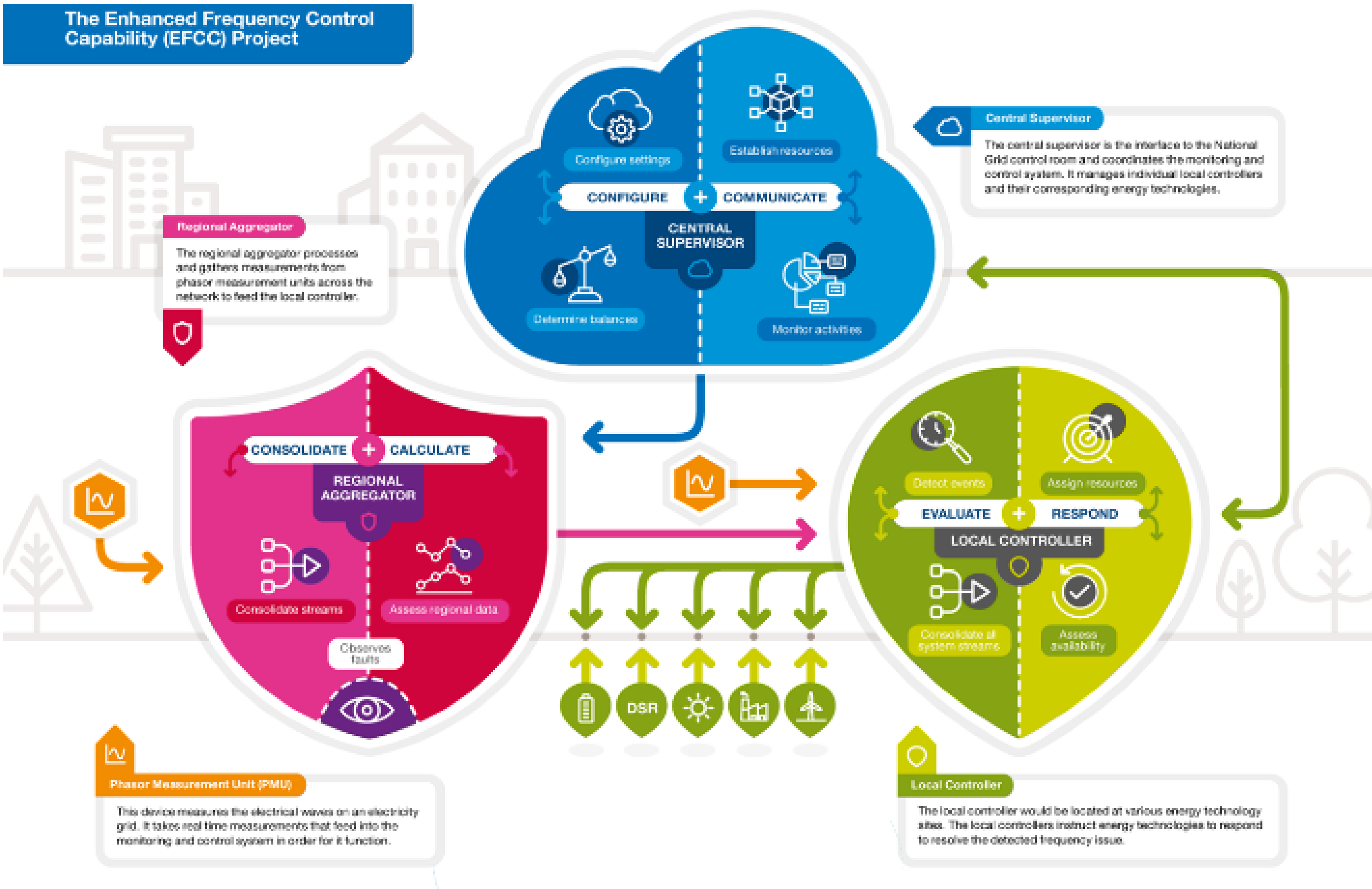
Rate of Change of Frequency (RoCoF) is increasing, faster response capability is required

- RoCoF depends on the total amount of energy stored in the rotating masses which are synchronised to the system
- Reducing system inertia requires faster delivery of response

Regional vs National Frequency: frequency differs across the system immediately after an event

- Requires proportional response to frequency events

The MCS detects and verifies frequency events, providing a targeted, proportional response



EFCC – the future of frequency control

MSC Testing

- Frequency event caused by the system load increment/decrement in the low system inertia conditions can be successfully detected
- Event detection and resource allocation modules respond within the designed time
- Wide-area based RoCoF calculation and loss of generation estimation are accurate.
- Size of data buffering window directly determines EFCC's capability to handle degraded communication performance
- Increasing buffering window can mitigate the risk of losing packets, but can compromise the response speed

DSR Flexitricity

- Developed and tested three new demand response services – Static RoCoF, Spinning Inertia and Dynamic RoCoF.
- Demonstrated that both Static RoCoF and Dynamic RoCoF can both detect and respond to EFCC Scheme signals for real events on the transmission network with appropriate setting of the control system. Delivery within the target 0.5 seconds is also achievable.
- Spinning Inertia provided by small generators is not effective if it is conducted purely on a passive basis – a roll-out of this service would require active RoCoF response in a manner similar to Dynamic RoCoF

CCGT Centrica

- Demonstrated that a CCGT can respond more quickly to rapidly falling network frequency by responding to RoCoF instead of deviation in frequency from a set point (normally 50.0 Hz).
- Determined that a new type of frequency response from large thermal plant is achievable and that a conventional primary response delivered at 10 seconds could be delivered approximately 3 seconds quicker and can be sustained for as long as dictated by network requirements.

Next Steps

Publication of Closing Down Report

Finalisation of cost benefit analysis including sensitivities

Installation of MCS on the system – testing communications network

Continue to share findings and learnings with the industry

System studies for demonstrating the capability of inertia response (IR) from windfarms

Dr Qiteng Hong

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Overview of presentation

- Objectives of the work
- Characteristics of the windfarm inertial response - data from Siemens Gamesa Renewable Energy (SGRE)
- Configuration of the network and windfarm IR models
- Case studies for Wind IR
  - Impact of windfarm capacity
  - Conservative and mean profiles
  - Impact of activation time
  - Impact of IR locations
- Conclusions



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Objectives of the work

- Investigation of the capability of windfarms in providing inertial response (IR)
- Demonstration of how wind IR can enhance frequency control in future power systems with low inertia
- Investigation of impact of different wind IR characteristics (delay, capacity, location, etc.)
- Factors to be considered for integrating wind IR for frequency response



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Wind IR profiles provided by SGRE

SGRE D7 wind turbines

10s duration profiles

- Conservative profiles
- Mean profiles

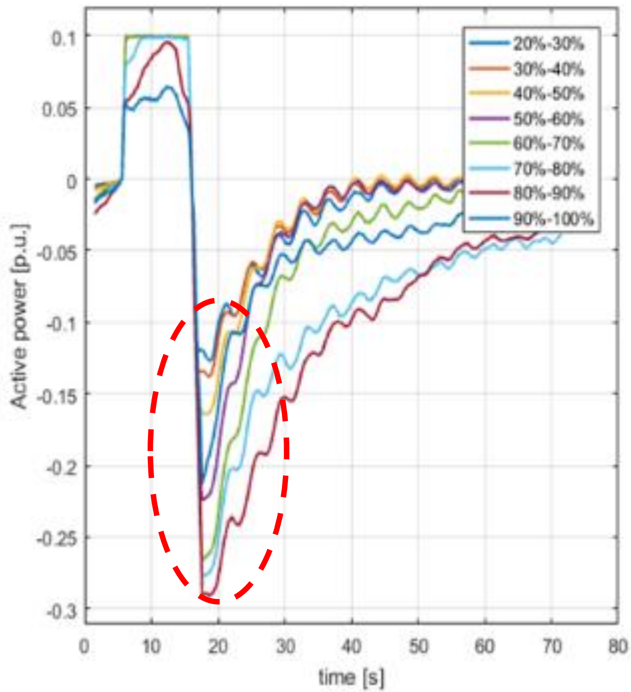
5s duration profiles with slow ramp (SR) down rate

- Conservative profiles
- Mean profiles

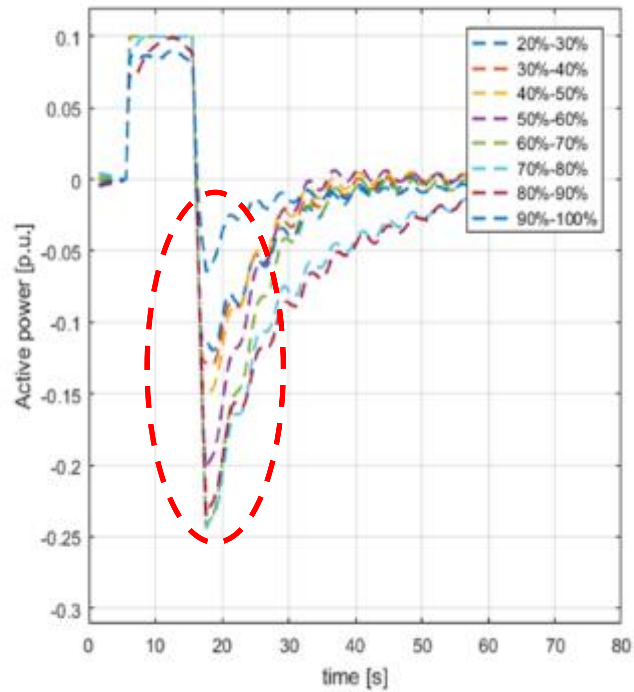
Each of these data sets containing profiles for loading conditions for 20%-100%

Wind IR profiles provided by SGRE

10s duration profiles: conservative vs mean



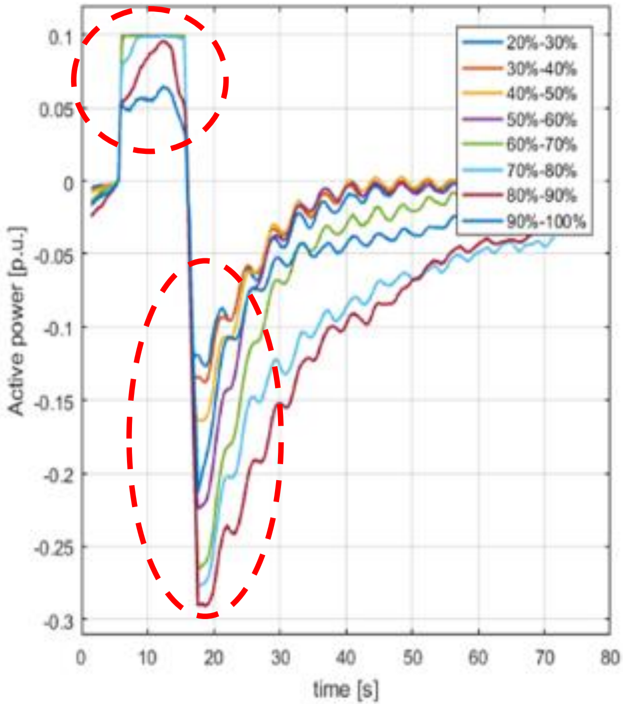
Conservative



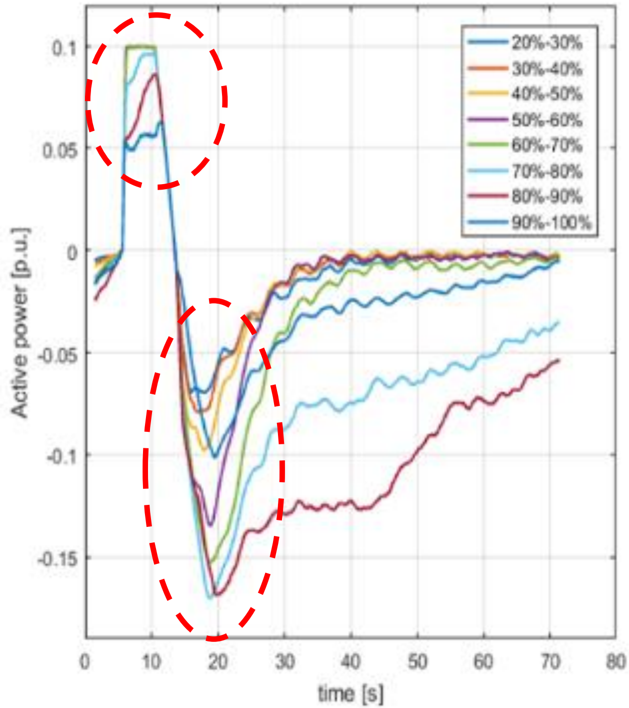
Mean

Wind IR profiles provided by SGRE

10s duration vs 5s duration with slow ramp down rate



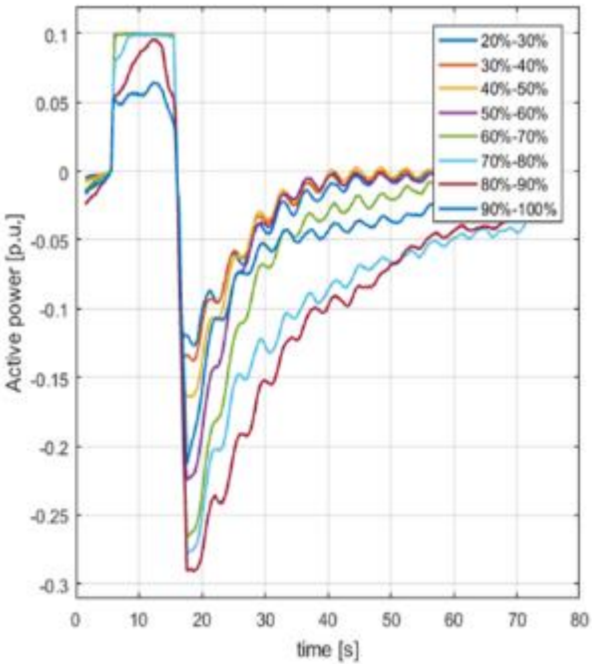
10s duration



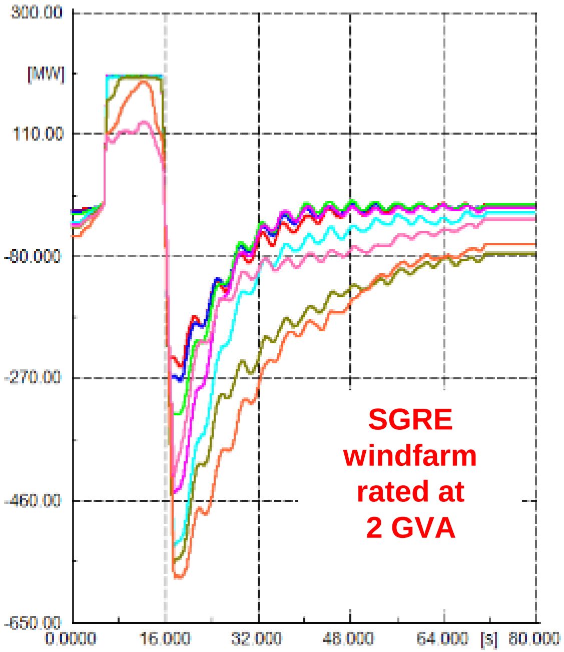
5s duration with slow ramp down rate

Wind IR profiles provided by SGRE

Original profile data in pu – converted to actual MW output via changing windfarm capacity



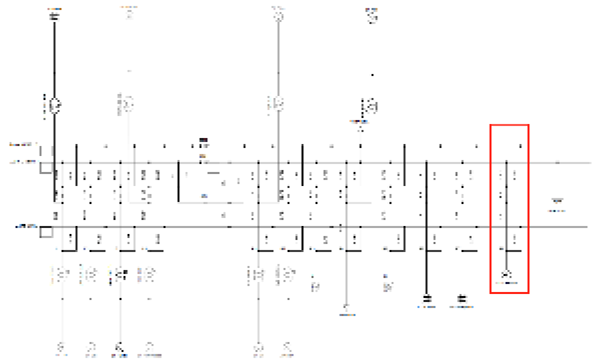
Original data (pu)

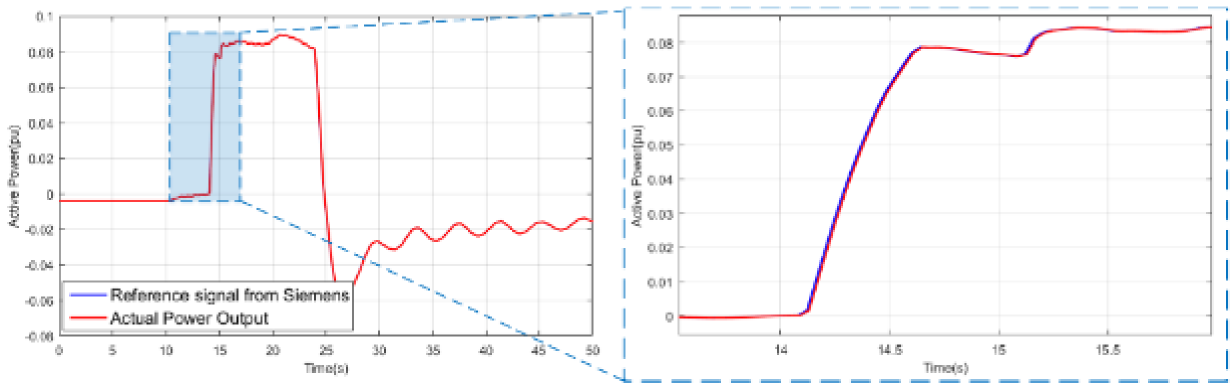


PF output (MW)

Model setups

- System inertia level – 82GVAs;
- Demand level – 25GW;
- Static gen installed in each zone to represent the SGRE windfarm - power output is configured to closely follow the IR profiles;
- Loss of generation event – 1320MW loss in Zone 01





System studies investigating impacts of capacity of windfarms

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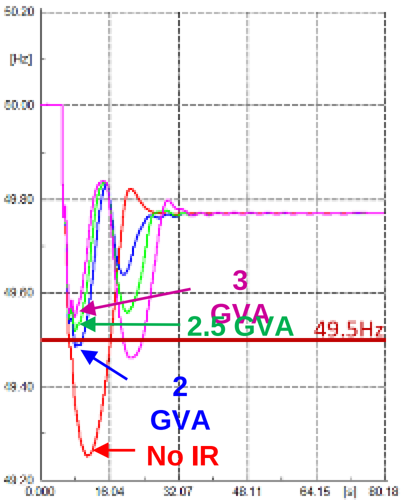
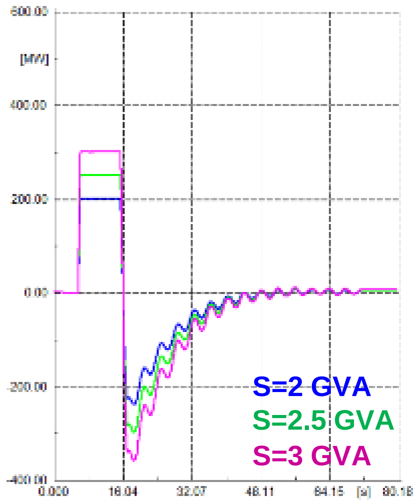
Windfarm capacity – 10s profiles

SGRE wind response (10s mean profile, 20-30% loading of rated power)





Findings:

- Fast response from wind IR:
  - Effective in containing 1st frequency dip
  - Also introduce 2nd frequency dip during recovery period
- Larger of wind IR:
  - Improved 1st frequency dip
  - More severe 2nd frequency dip
  - Capacity need careful selection
- To meet 49.5Hz limit in this case:
  - IR Rating ≥ 2GVA (for 1st drop)
  - IR Rating < 3GVA (for 2nd drop)

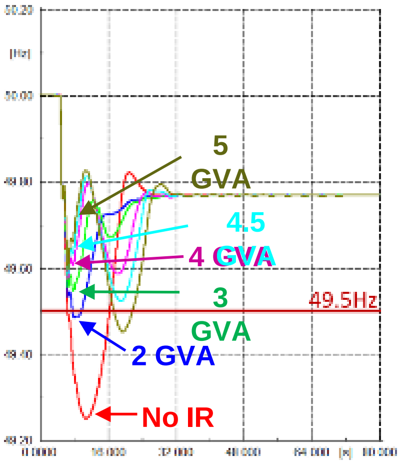
Windfarm capacity – 10s profiles

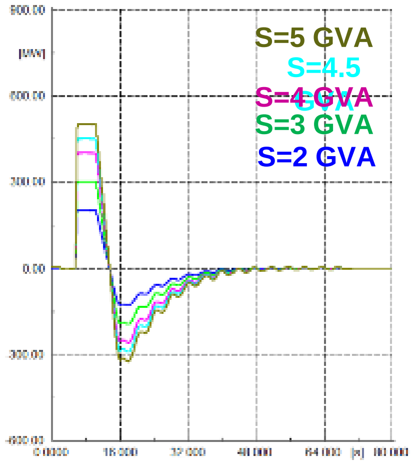
Loading (%) of rated power	Data type	Capability to achieve satisfying frequency response?	Best case	Power required from SGRE windfarm IR	
				First drop ≥ 49.5 Hz	Second drop ≥ 49.5 Hz
20%-30%	Conservative	Yes	2.5 GVA	>2GVA	<3GVA
	Mean	Yes	2.5 GVA	>2GVA	<3GVA
30%-40%	Conservative	Yes	2.5 GVA	>2GVA	<2.5GVA
	Mean	Yes	2.5 GVA	>2GVA	<3GVA
40%-50%	Conservative	Yes	2 GVA	>2GVA	<2.5GVA
	Mean	Yes	2-2.5GVA	>2GVA	<2.5GVA
50%-60%	Conservative	No	-	>2GVA	<2GVA
	Mean	No	-	>2GVA	<2GVA
60%-70%	Conservative	No	-	>2GVA	<2GVA
	Mean	No	-	>2GVA	<2GVA

- Loading below 50% are the most beneficial cases
- When loading is above 50%, not possible to stay within the required operational range, i.e. 49.5Hz
- 1^{s} drop - > around 2GVA windfarm providing IR; 2^{nd} drop – less than 2~3GVA.

Windfarm capacity – 5s+ Slow-Ramp-down (SR) profiles

SGRE wind response (5s mean profile, 20-30% loading of rated power)





Findings:

- Shorter IR duration does not appear to compromise the frequency support performance
- Slow-ramp-down power after IR shows significant advantages in containing 2nd frequency dip
- In this example, to meet 49.5Hz limit in this case:
  - IR Rating ≥ 2GVA (for 1st drop)
  - IR Rating < 4.5GVA (for 2nd drop)

Windfarm capacity – 5s + Slow-Ramp-down (SR) profiles

Loading (%) of rated power	Data type	Capability to achieve satisfying frequency response?	Best case	Power required from SGRE windfarm IR	
				First drop ≥ 49.5 Hz	Second drop ≥ 49.5 Hz
20%-30%	Conservative	Yes	4 GVA	>2GVA	<4.5GVA
	Mean	Yes	4.5 GVA	>2GVA	<5GVA
30%-40%	Conservative	Yes	4 GVA	>2GVA	<4.5GVA
	Mean	Yes	4 GVA	>2GVA	<4.5GVA
40%-50%	Conservative	Yes	3.5 GVA	>2GVA	<4GVA
	Mean	Yes	4 GVA	>2GVA	<4.5GVA
50%-60%	Conservative	Yes	2.5 GVA	>2GVA	<3GVA
	Mean	Yes	3.5 GVA	>2GVA	<3.5GVA
60%-70%	Conservative	Yes	2.5 GVA	>2GVA	<3GVA
	Mean	Yes	3 GVA	>2GVA	<3.5GVA
70%-80%	Conservative	Yes	2.5 GVA	>2.5GVA	<3GVA
	Mean	Yes	3 GVA	>2GVA	<3.5GVA
80%-90%	Conservative	Yes	2.5 GVA	>2.5GVA	<3GVA
	Mean	Yes	3.5 GVA	>2GVA	<4GVA
90%-100%	Conservative	Yes	4 GVA	>2.5GVA	<4.5GVA
	Mean	Yes	9 GVA	>2GVA	<9.5GVA

- Significantly improved capability for frequency support;
- 1^{s} drop - > around 2GVA windfarm providing IR; 2nd dip – less than around 3~5GVA

System studies investigating impact of conservative and mean profiles

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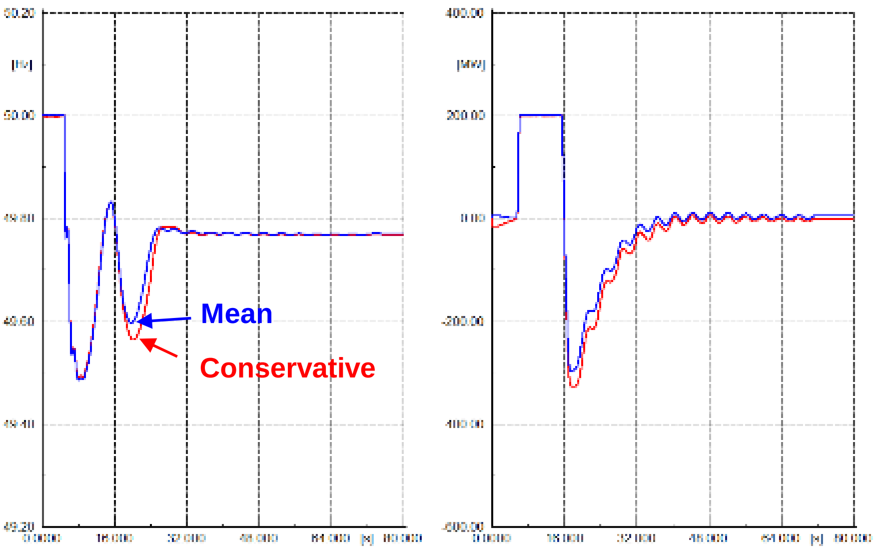
Conservative and mean profiles

10s duration profile data:



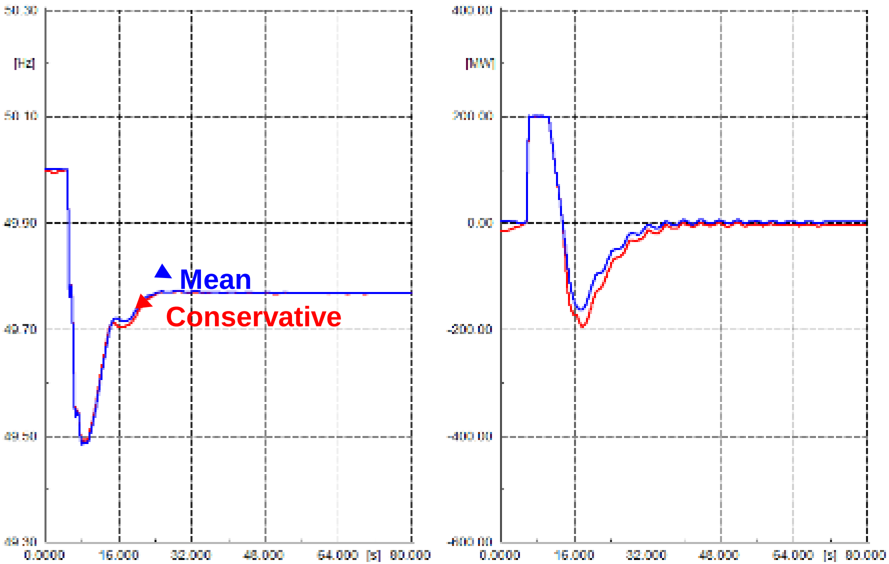
SGRE wind response (10s conservative profile, 40-50% loading of rated power, 2GVA)

Findings:

- Generally, profiles with *mean values show better performance* than the ones with conservative values, in terms of the second frequency dip.
- Time of the second frequency drop could vary which could introduce challenges to coordinate with other sources of frequency support.

Conservative and mean profiles

5s duration profile data with slow ramp down rate:



SGRE wind response (5s conservative profile, 40-50% loading of rated power, 2GVA)

Findings

- Generally, profiles with *mean values show better performance* than the ones with conservative values, in terms of the second frequency dip.
- Time of the second frequency drop could vary which could introduce challenges to coordinate with other sources of frequency support.

System studies investigating impact of activation time

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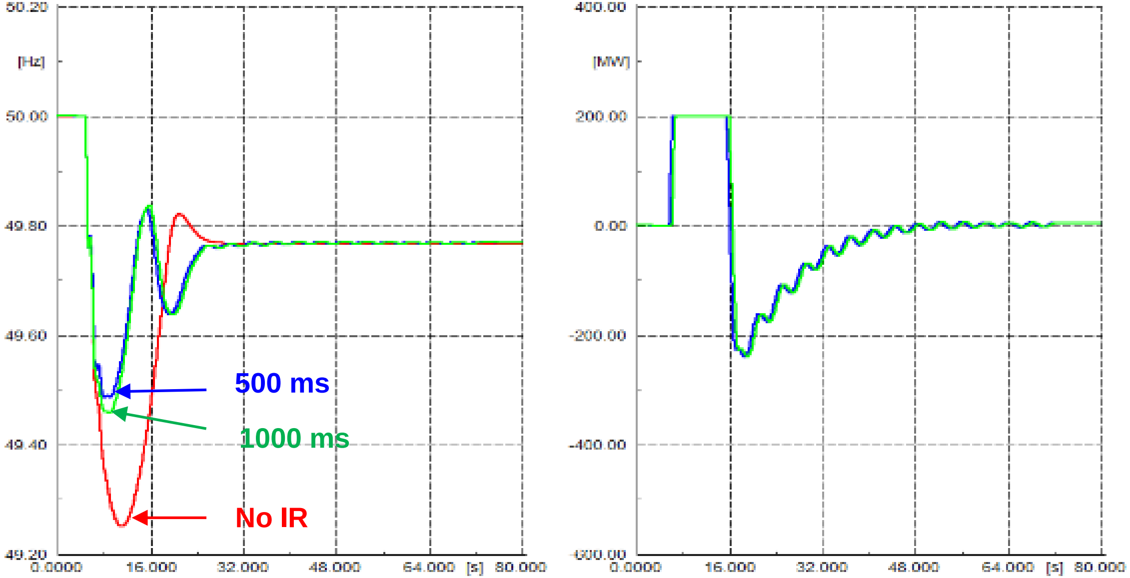
Activation time – 10s profiles

Findings

- Longer delay in IR, **less support for the 1st dip** while **no obvious difference in 2nd dip**
- Impact on first dip is not significant with delay range at 0.5s to 1s

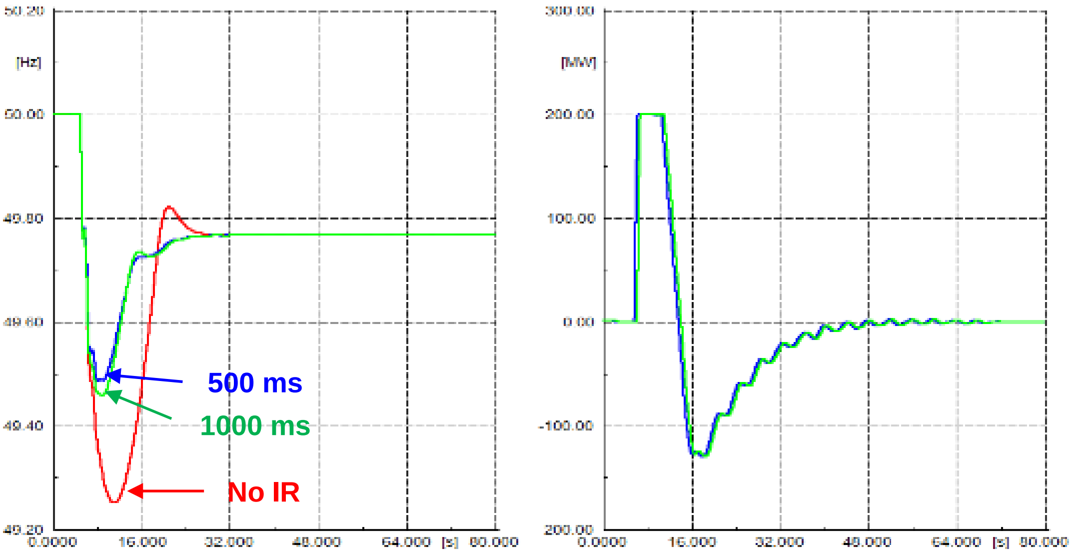


SGRE wind response (10s mean profile, 20-30% loading of rated power, 2 GVA)

Activation time - 5s + Slow-Ramp-down (SR) profiles

Findings:

- Longer delay in IR, **less support for the 1st dip** while **no obvious difference in 2nd dip**
- Impact on first dip is not significant with delay range at 0.5s to 1s

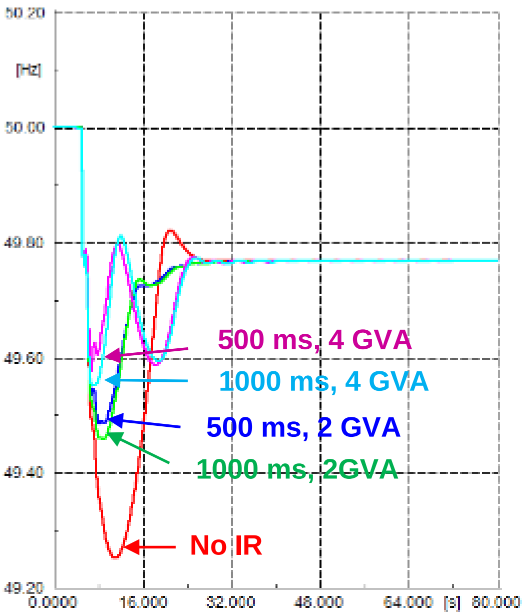


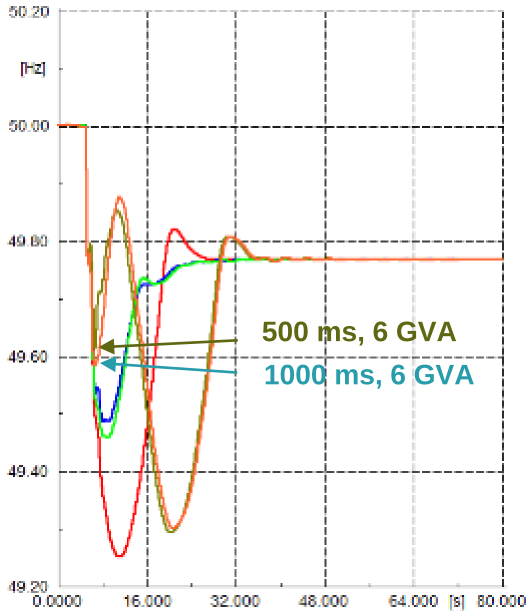
SGRE wind response (5s mean profile, 20-30% loading of rated power, 2GVA)

Activation time - 5s + Slow-Ramp-down (SR) profiles

Findings:

- For the same capacity of windfarm, impact of different activation time is limited
- Windfarm with different capacities have larger impact on frequency control effectiveness





SGRE wind response (5s mean profile, 20-30% loading)

System studies investigating impacts of location of wind IR

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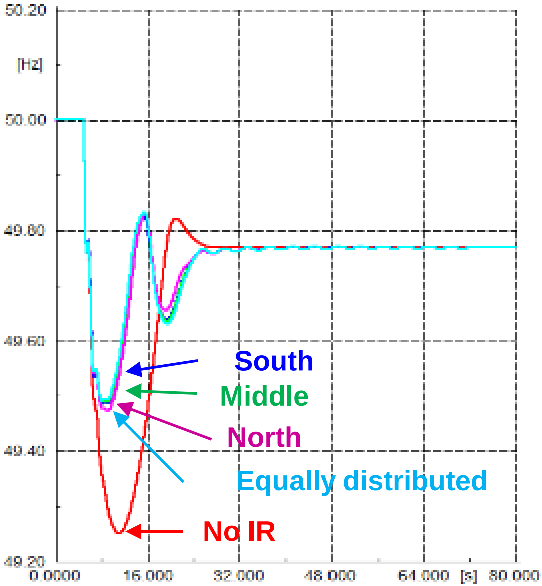
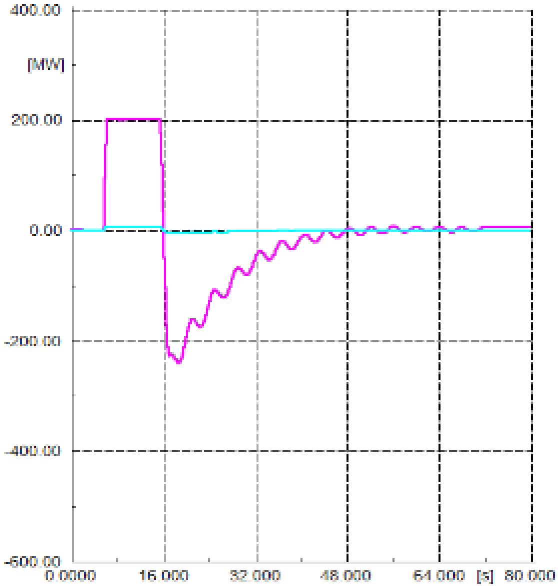
IR Location – 10s profiles

Findings:
- No significant differences on frequency nadir
- Slightly difference when IR response located in north (Scotland) while event at the south



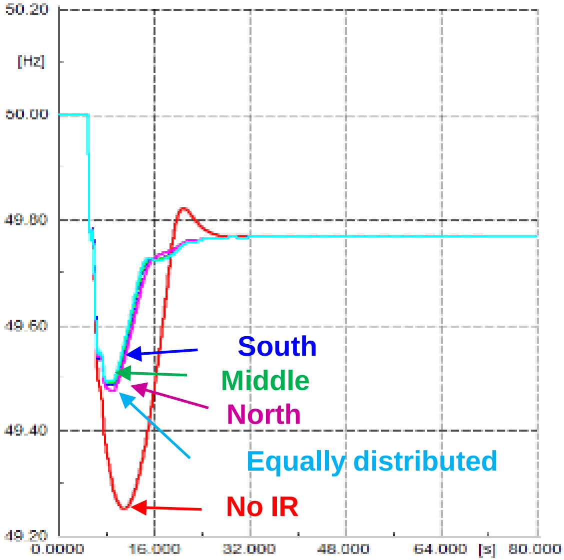


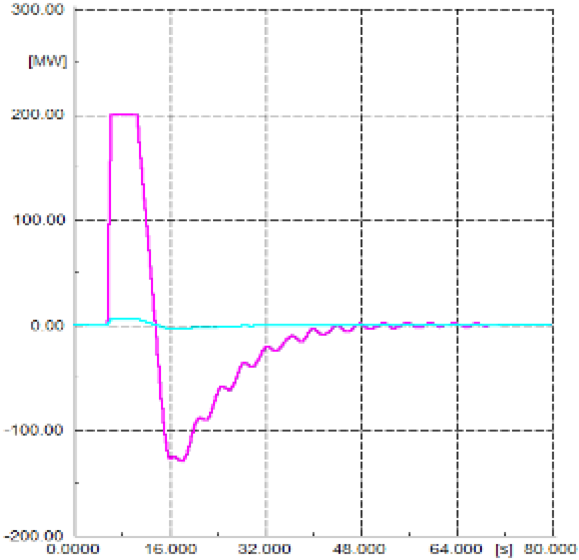
SGRE wind response (10s mean profile, 20-30% loading of rated power, 2GVA)

IR Location - 5s + SR profiles

Findings:

- No significant differences on frequency nadir
- Slightly difference when IR response located in north (Scotland) while event at the south





SGRE wind response (5s mean profile, 20-30% loading of rated power, 2GVA)

Conclusions

- Wind IR has shown great potential in enhancing frequency control – however the 2^{nd} frequency dip needs to be considered.
- With larger windfarm capacity, the 1^{st} frequency dip can be significantly improved, while its capacity has to be carefully chosen to keep the 2^{nd} frequency drop above the required 49.5Hz limit.
- The 2^{nd} frequency dip can be significantly improved by
    - ramping down slowly of the windfarm output after the IR
    - careful selection of suitable capability of wind farms in providing IR.
- The occurrence of the frequency 2^{nd} dip varies with profile data type/ratings/loading levels so close coordination with other resources is needed.
- Location on the network and activation time of the windfarm IR does not appear to have a significant impact on frequency nadir

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Powering the Future

Dr Tim Müller

Belectric

nationalgridESO

The role of **BELECTRIC** in **EFCC**

BELECTRIC realises control scheme for RoCoF based fast frequency response with solar PV and battery resources

EFCC will provide additional functionality to the current balancing services

- Achieves 100% active power < 1 second (target 500 ms)
- RoCoF triggered
- Regional
- Technology agnostic
- Fast comms network
- Coordinated response

EFCC Power Resource: Solar PV System

3.7 MWp

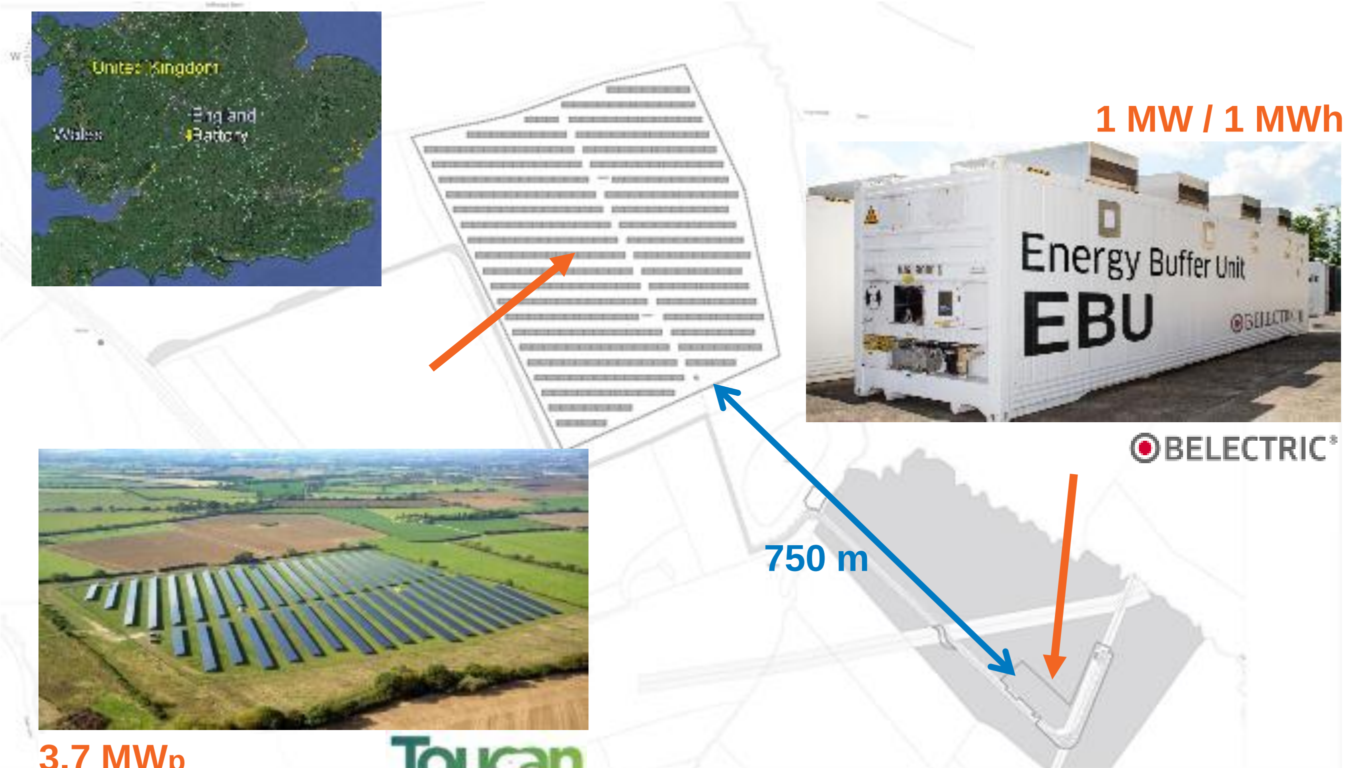
Toucan energy

EFCC Power Resource: Battery System

1 MW / 1 MWh

BELECTRIC®

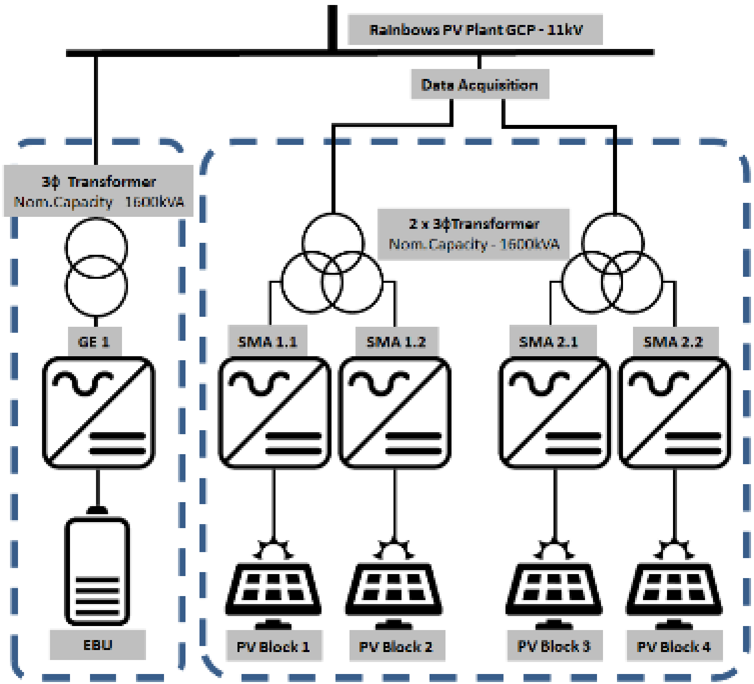
EFCC Power Resource: PV+Battery Hybrid System



Toucan energy

EFCC Power Resource: PV+Battery Hybrid System

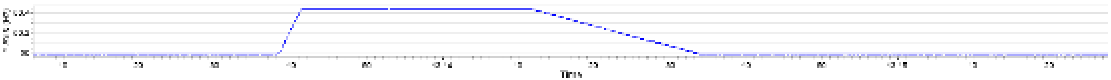
- Hybrid system provides increased overall system availablity.
- Frequency response provision throughout day/night.
- Enhanced overall system performance due to faster battery response times.
- No PV inverter curtailment neccessary in hybrid system.



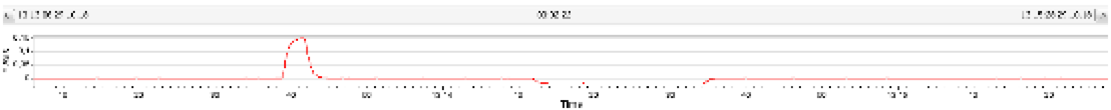
SMA – Sunny Central 800CP XT
GE – GE Prosolar Converter

Improvements – Since EFCC dissemination event 2018

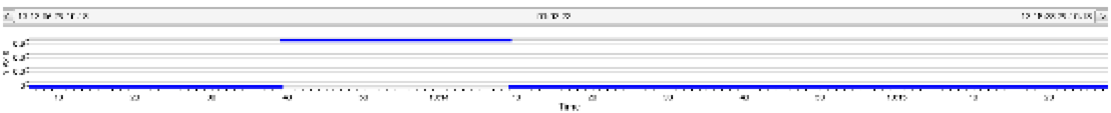
– **Current**: EFCC PV Stand Alone test and trials (Oct 2018)



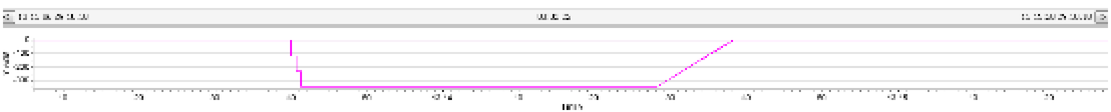
Frequency



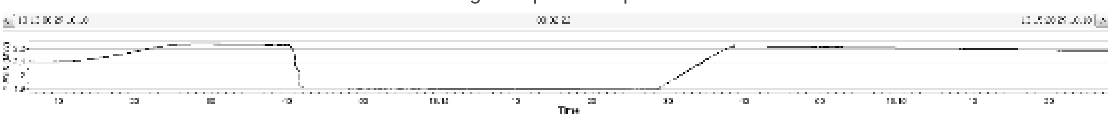
Local RoCoF



Event Detection



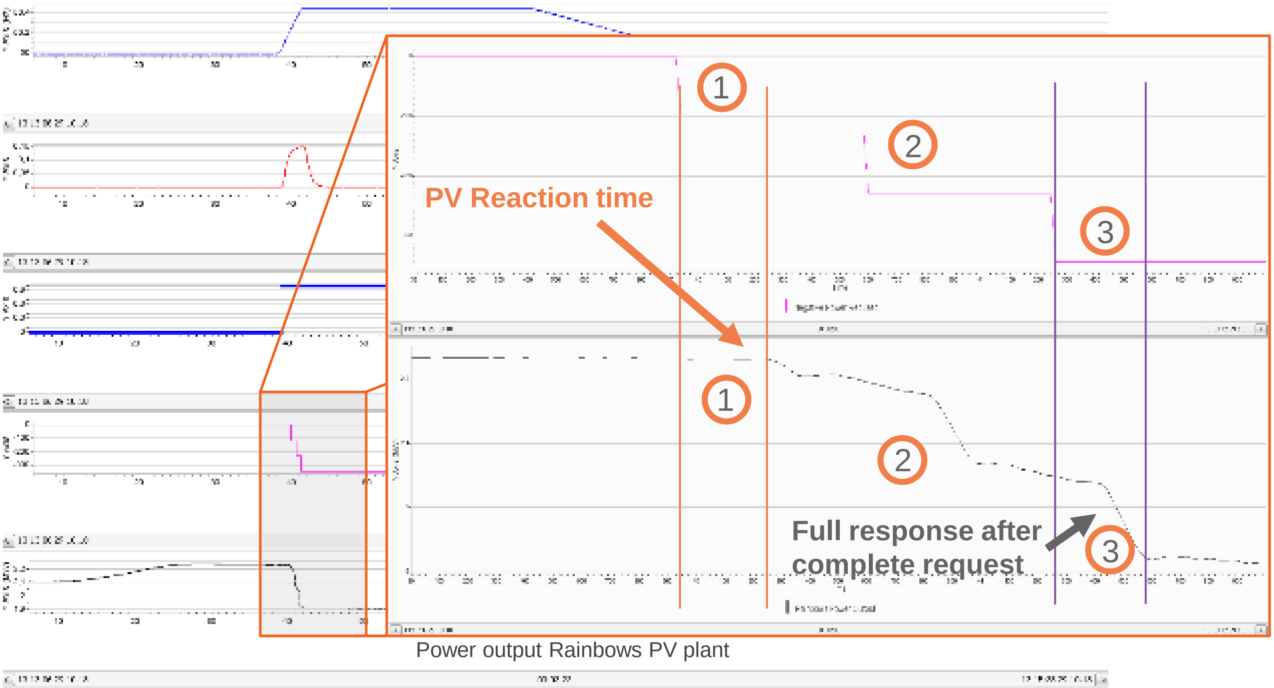
Negative power request



Power output Rainbows PV plant

Improvements – Since EFCC dissemination event 2018

- **Current**: EFCC PV Stand Alone test and trials (Oct 2018)



Power output Rainbows PV plant

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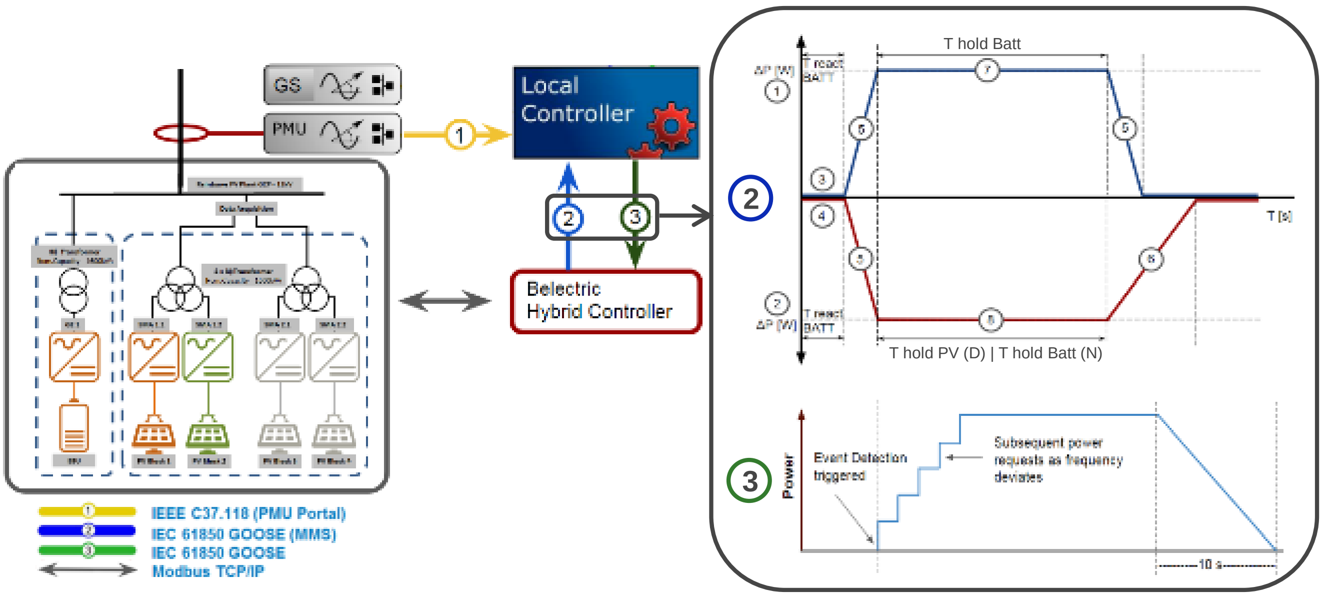
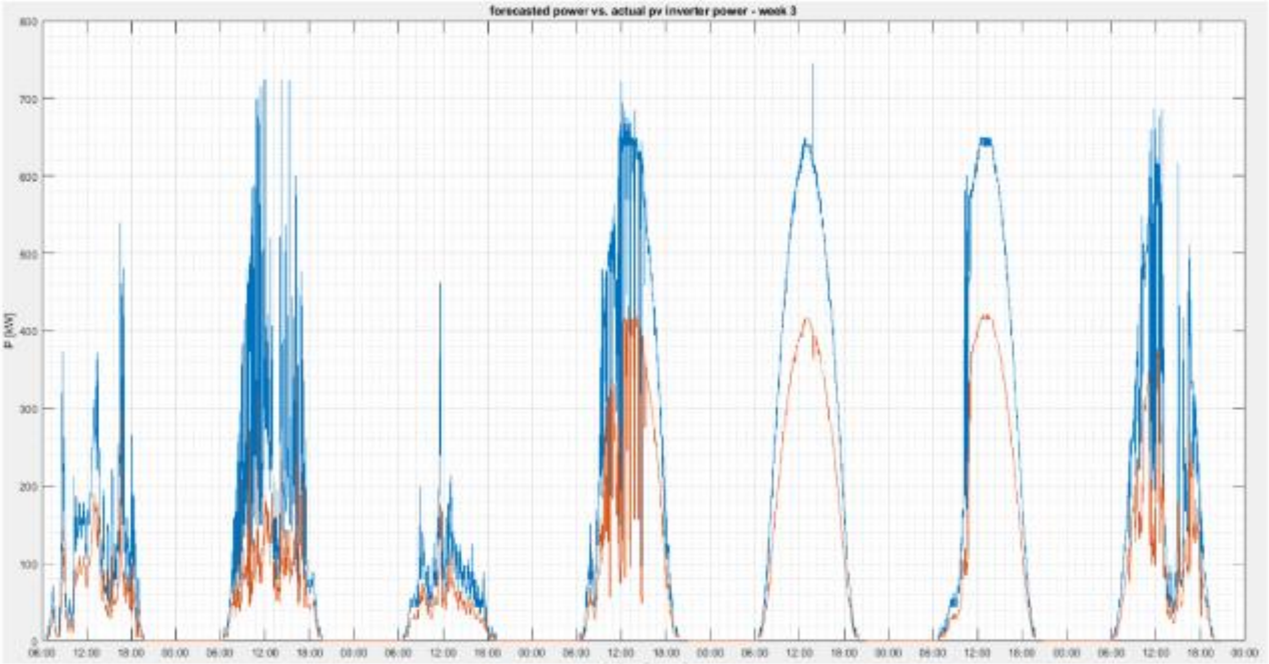
PV- Battery Hybrid System Communication overview



1 : Positive power available (kW)
2 : Negative power available (kW)
3 : EBU Reaction time (ms)
4 : EBU Reaction time (ms)
5 : EBU Ramp down rate(kW/s)
6 : EBU Ramp down rate(kW/s)
7 : T hold Batt
8 : T hold PV(D) | T hold Batt(N)

Solar PV - Forecasting Analysis

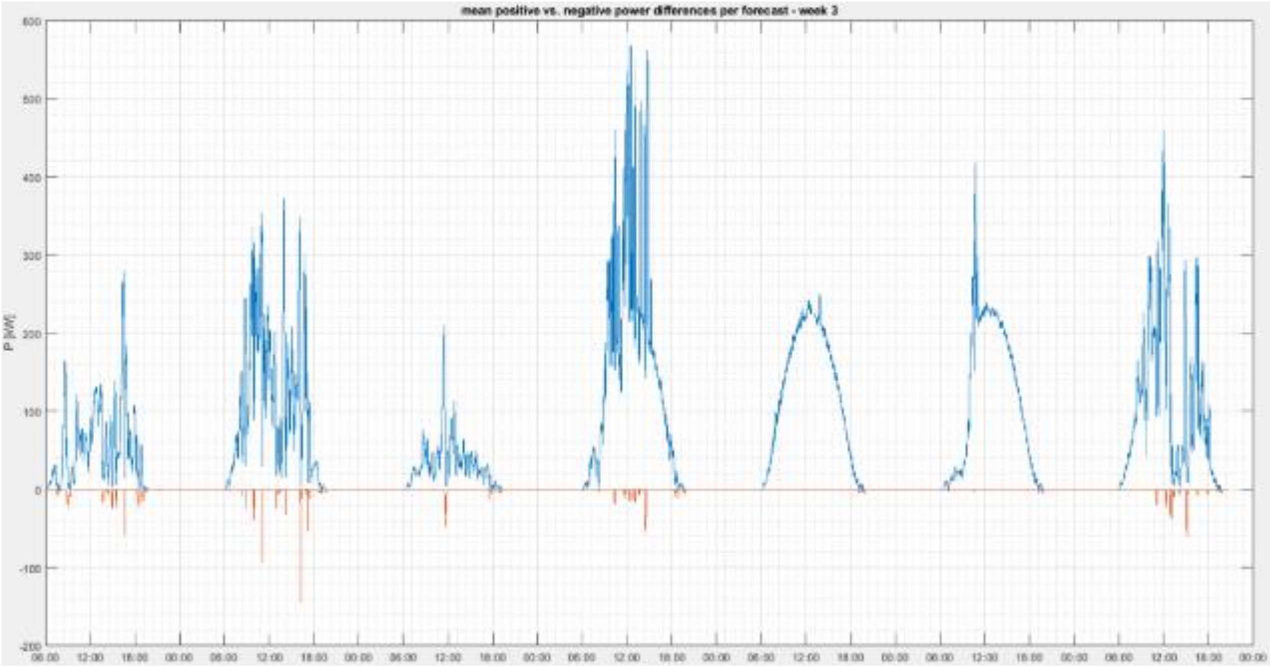
PV Balancing Power – Forecasting accuracy



Forecasted power output [kW]
Real power output [kW]

Solar PV - Forecasting Analysis

PV Balancing Power – Forecasting positive and negative error margins



Mean negative power differences [kW]
Mean positive power differences [kW]

EFCC Hybrid System Control Strategy

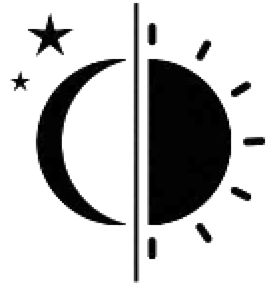
NIGHT

Under frequency event

Positive response: Energy Buffer Unit

Over frequency event

Negative response: Energy Buffer Unit



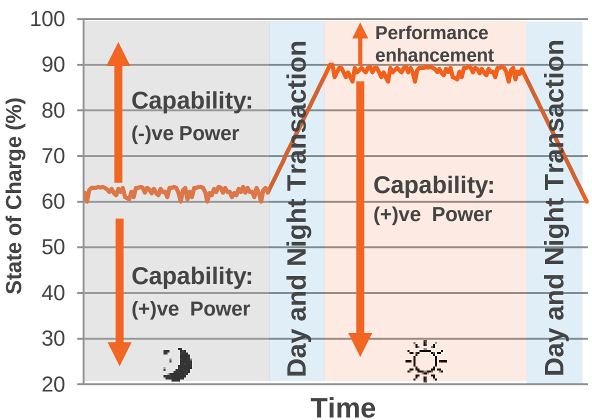
DAY

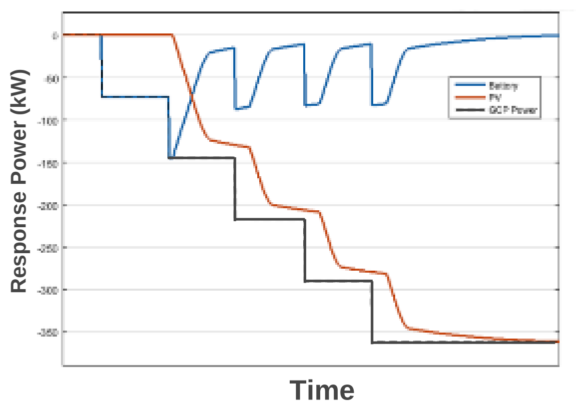
Under frequency event

Positive response: Energy Buffer Unit

Over frequency event

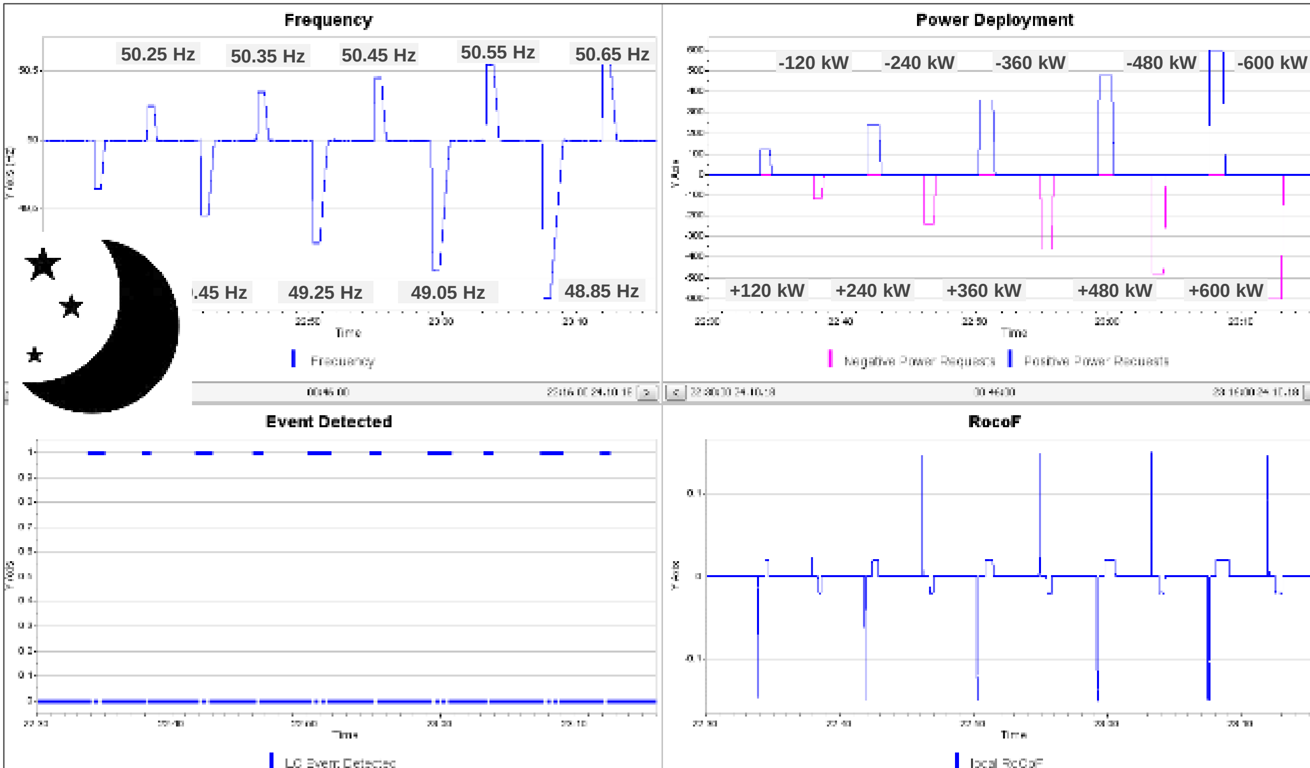
Negative response: Energy Buffer Unit & PV





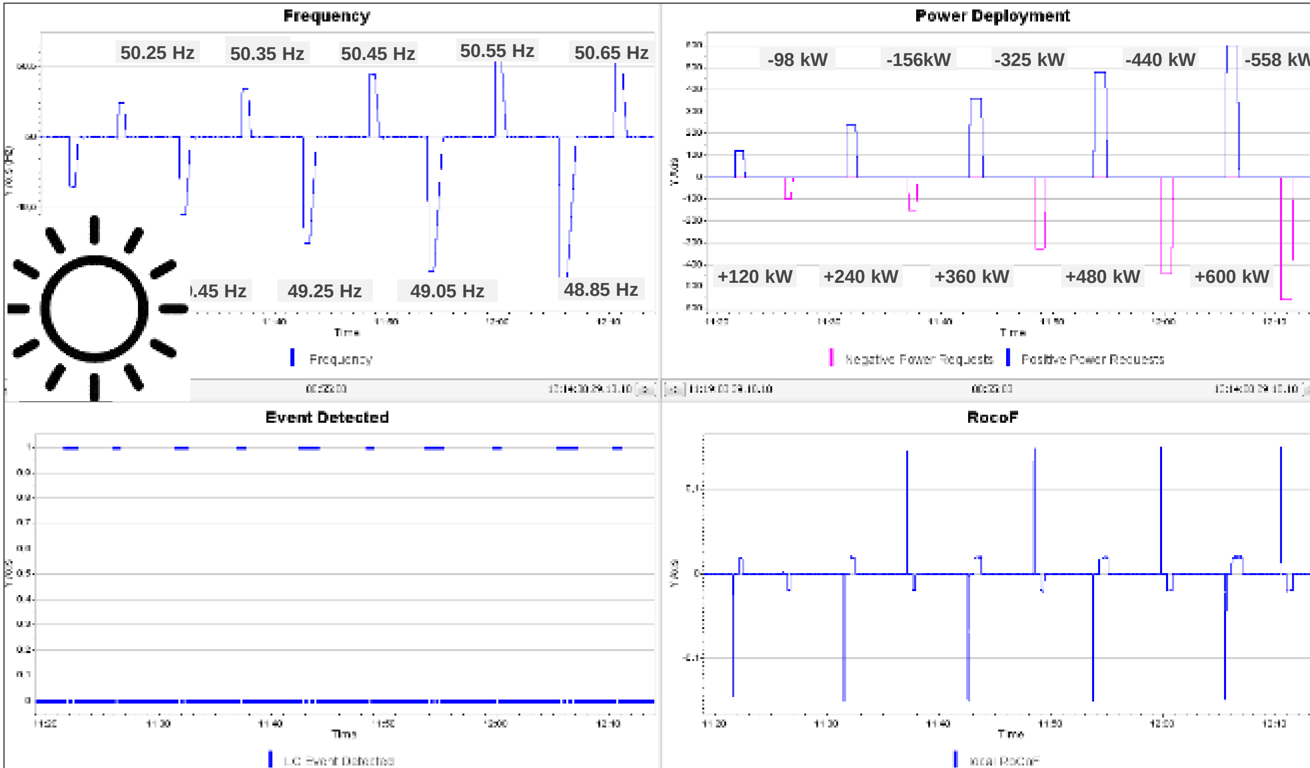
PV-Battery Hybrid System – Open Loop Test

Night : PV Unavailable – EBU provides power availability: + 600 kW / - 600 kW



PV-Battery Hybrid System – Open Loop Test

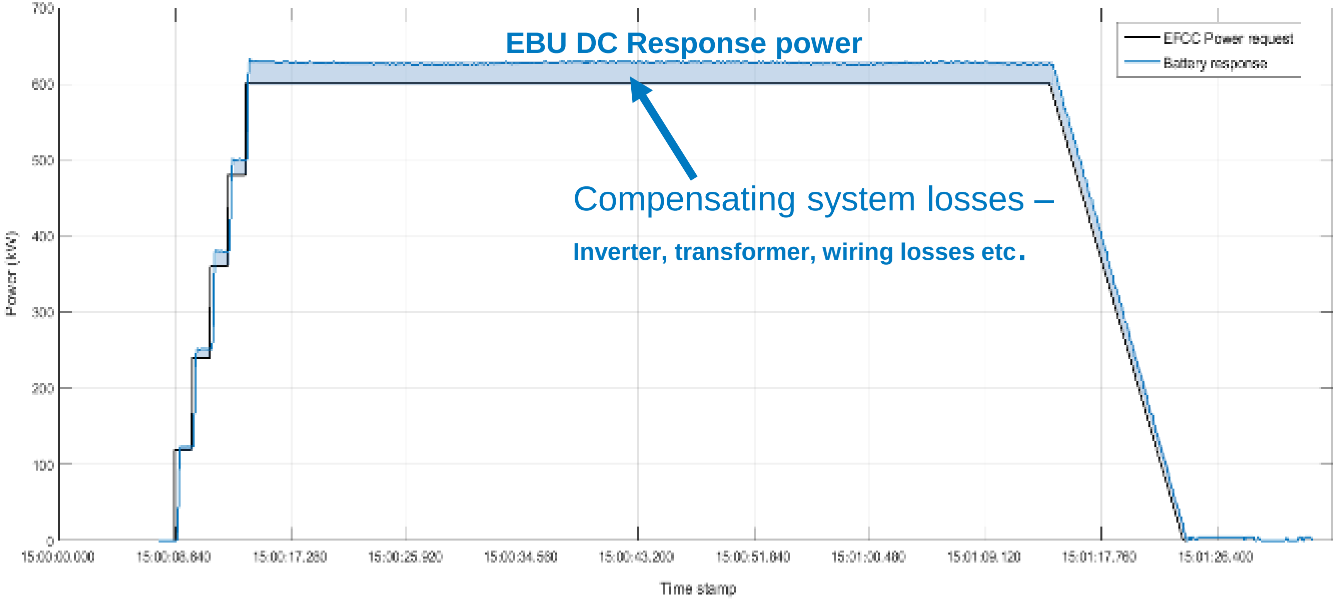
Day : PV Available – Power availability: + 600 kW (EBU) / - 558 kW (PV Inv 1.1)



PV-Battery Hybrid System – Hardware in Loop Test

Under frequency event during **DAY** and at **NIGHT**

EBU response for exemplary frequency event | Frequency nadir: 48.85 Hz



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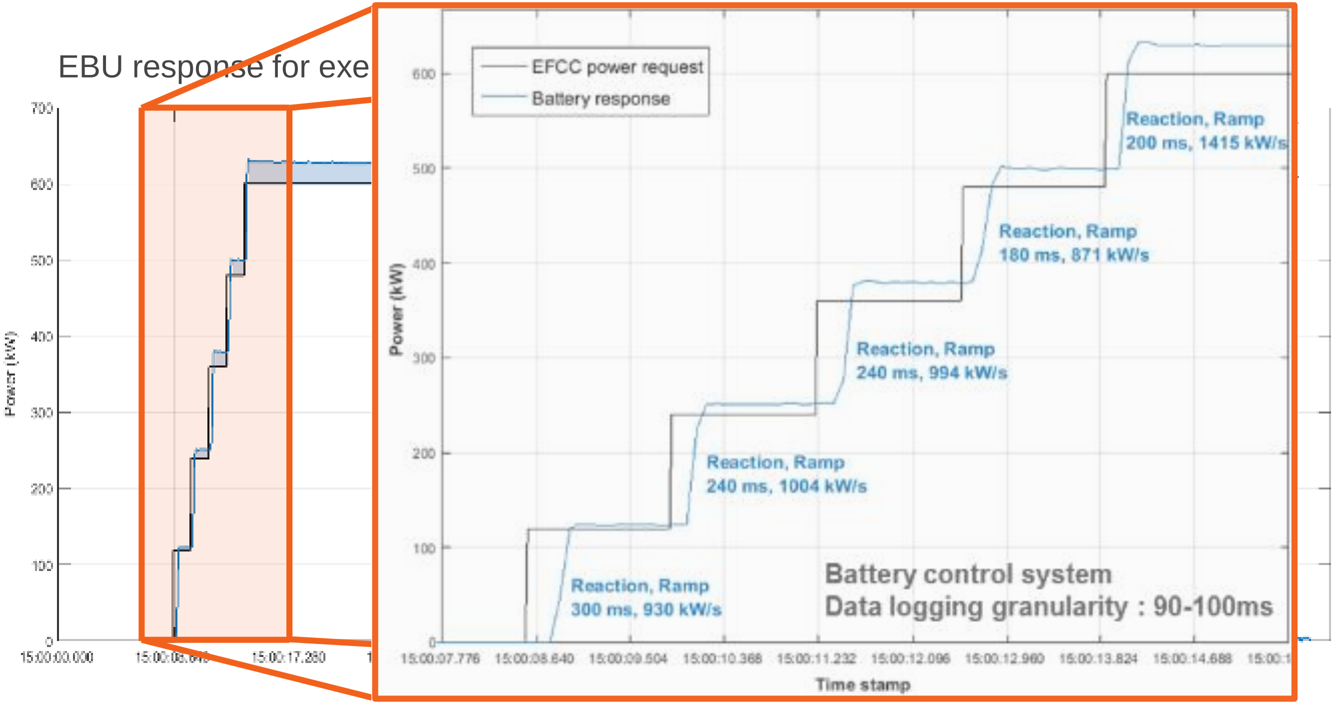
PV-Battery Hybrid System – Hardware in Loop Test

Under frequency event during **DAY** and at **NIGHT**

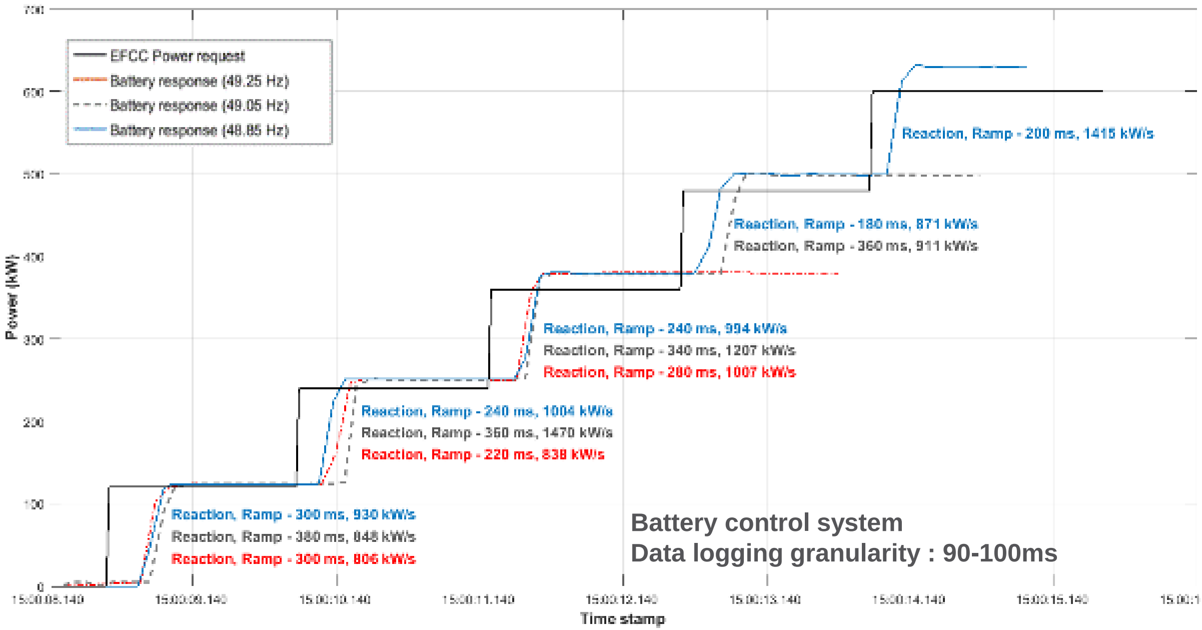
EBU response for exe



PV-Battery Hybrid System – Hardware in Loop Test

Under frequency event during the **DAY** and at **NIGHT**

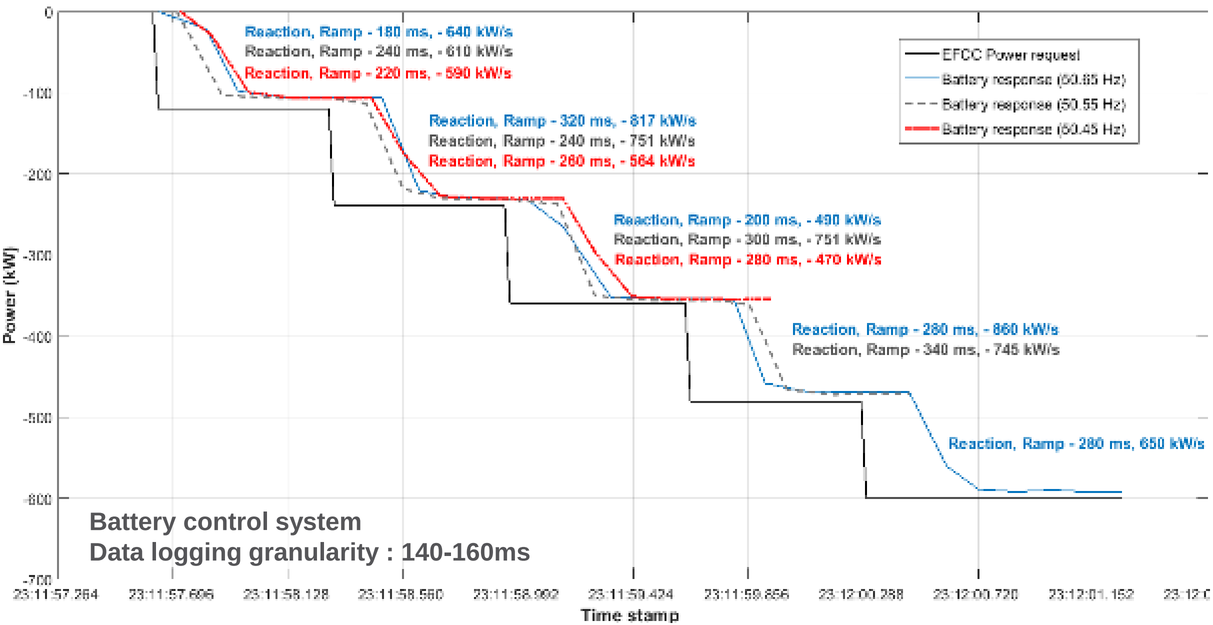
EBU response for frequency event | Under frequency (49.25 Hz, 49.05 Hz, 48.85 Hz)



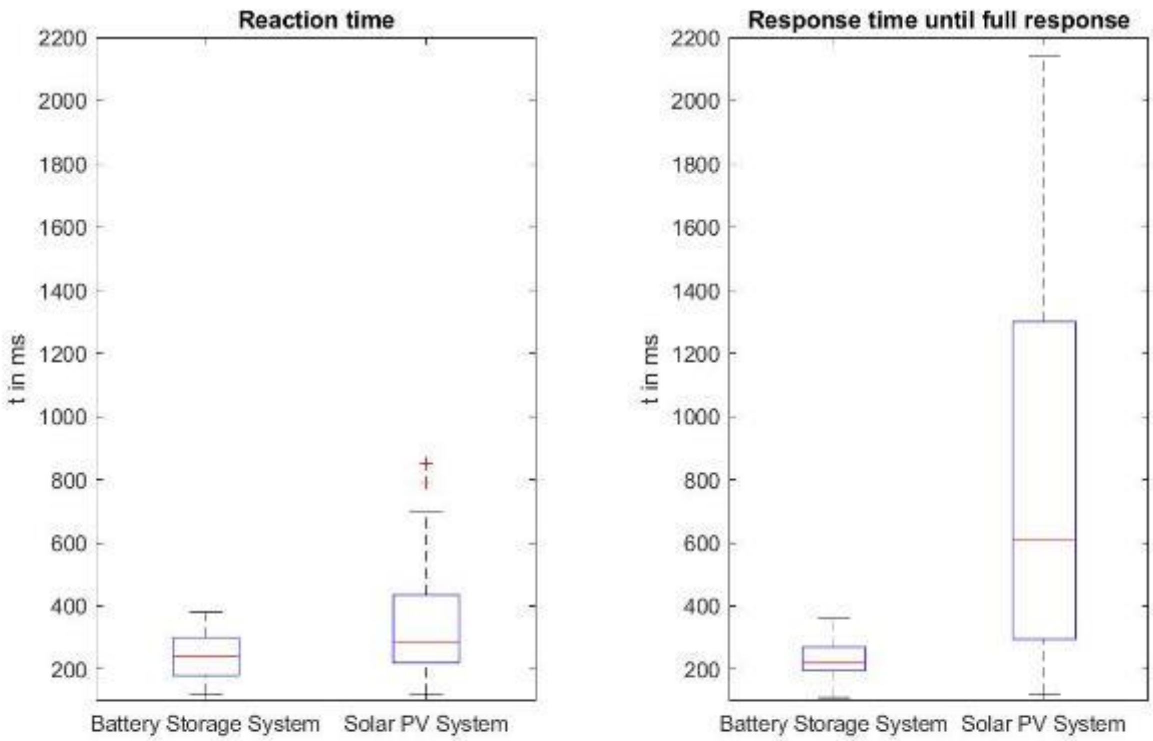
PV-Battery Hybrid System – Hardware in Loop Test

Over frequency event during the **NIGHT**

EBU response for exemplary event | Over frequency (50.45 Hz, 50.55 Hz, 50.65 Hz)



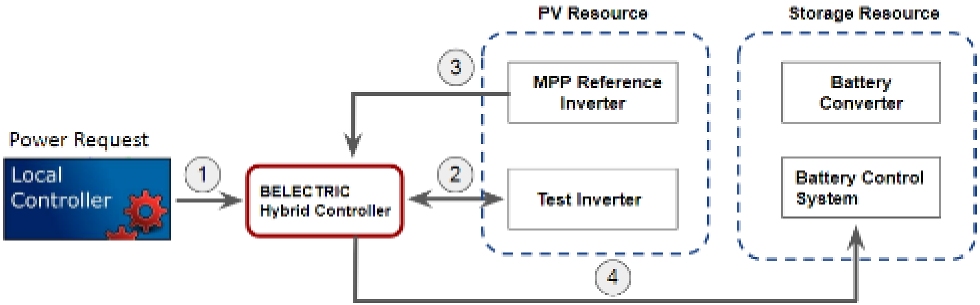
PV-Battery Hybrid System – Hardware in Loop Test

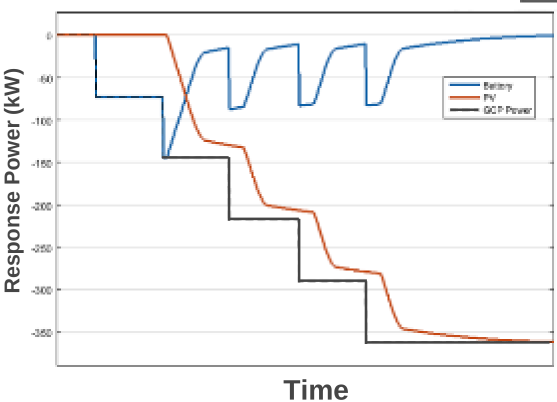


PV-Battery Hybrid System – Hardware in Loop Test

Over frequency event during the DAY

PV - EBU response for frequency event | Control Scheme





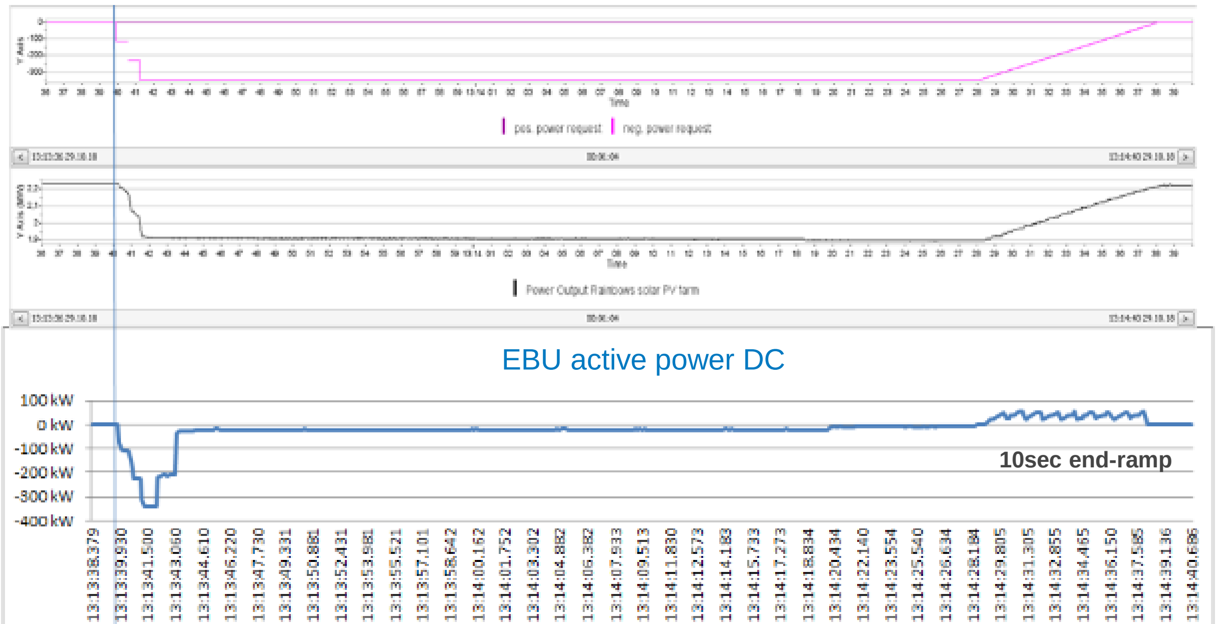
Residual power = EFCC + (Ref Inv – Test Inv)

Residual power	:	Storage resource power command
EFCC	:	Power request
Ref Inv	:	PV reference MPP power
Test Inv	:	Inverter power under EFCC test trial

PV-Battery Hybrid System – Hardware in Loop Test

Over frequency event during the **DAY**

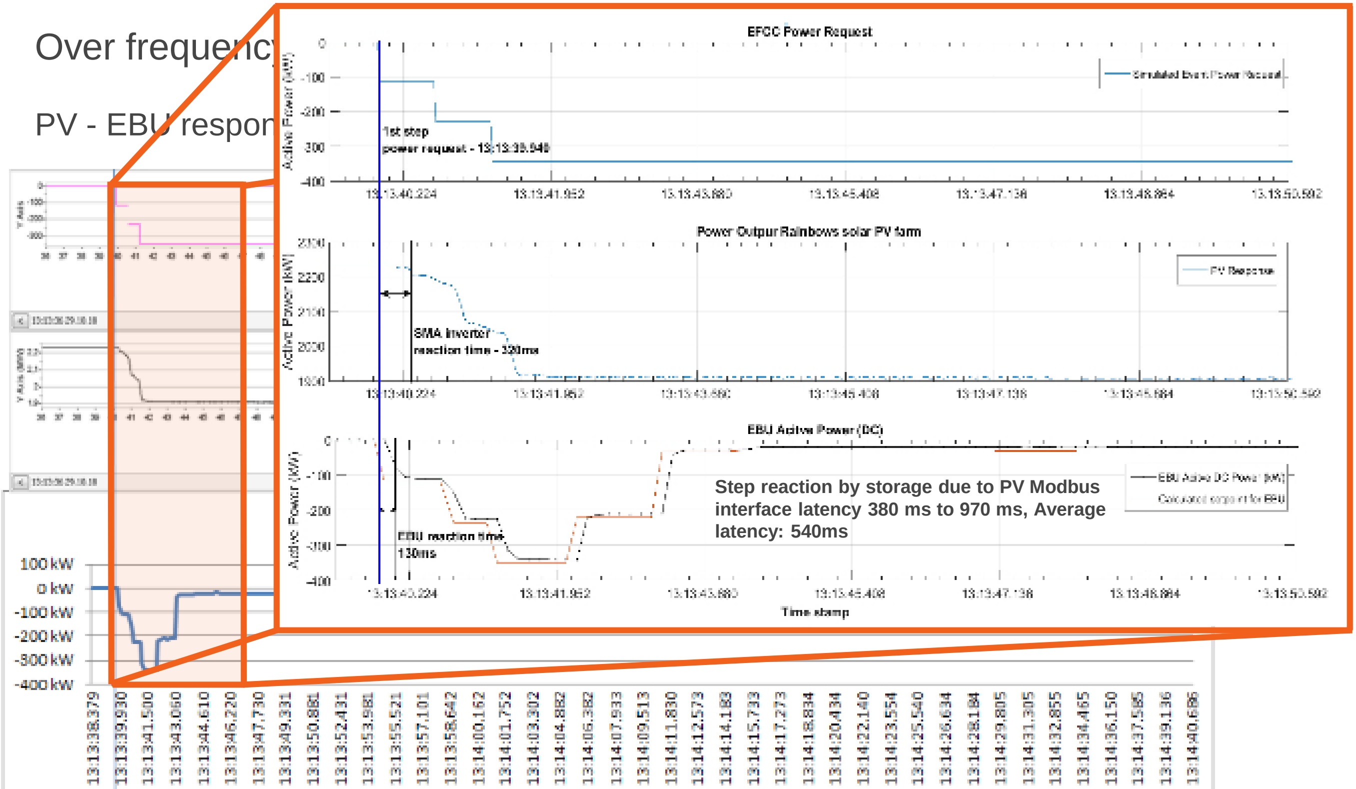
PV - EBU response for frequency event | Over frequency (50.45 Hz)



PV-Battery Hybrid System – Hardware in Loop Test

Over frequency

PV - EBU response



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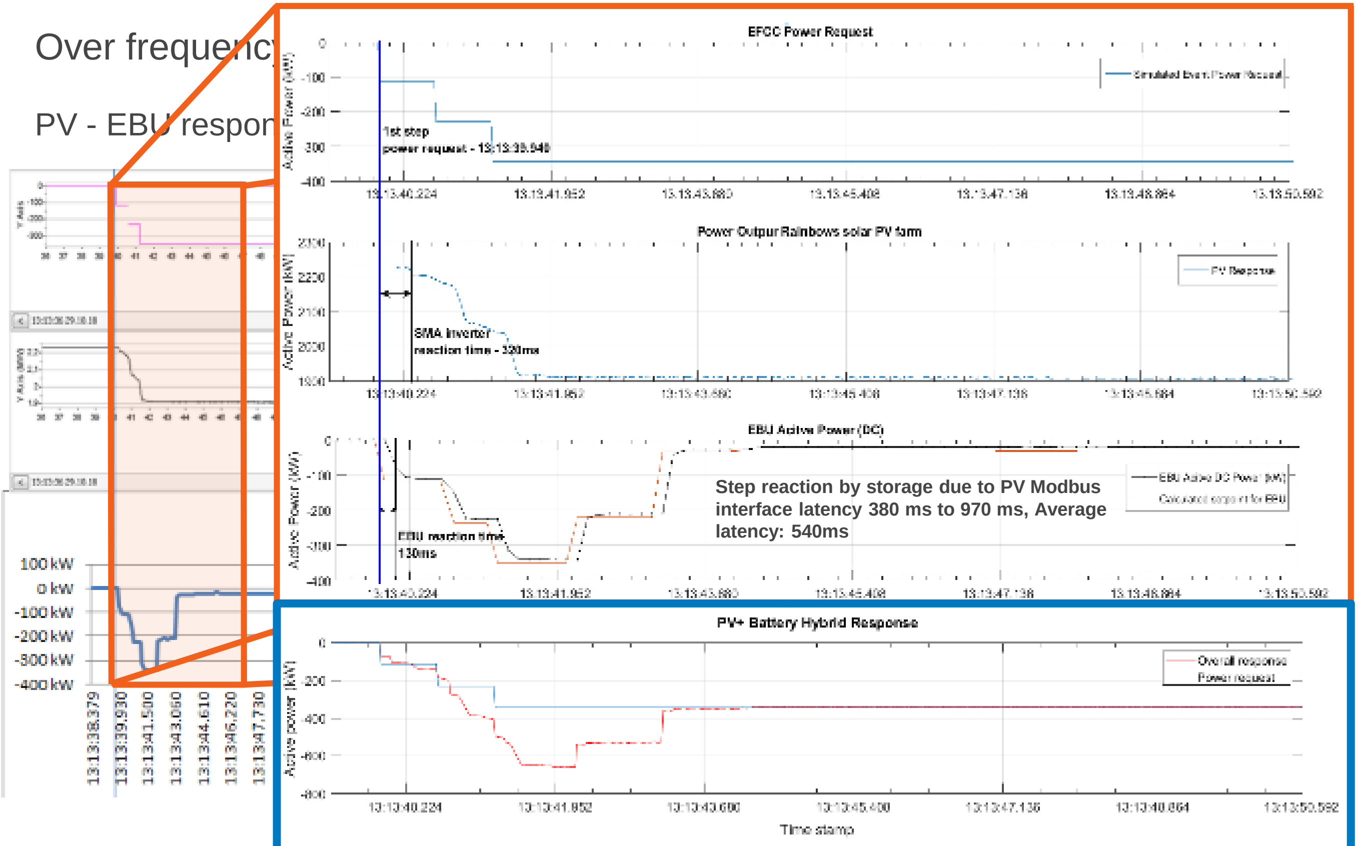
PV-Battery Hybrid System – Hardware in Loop Test

Over frequenc

PV - EBU respon



Moving Forward

- From Local Response Service to Wide Area Response Service.
- Virtual synchronous machine to provide synthetic inertia.
- Advanced measurement system to eliminate data logging limitations.
- NGET- interface – sent and received parameters can be further optimised for hybrid systems.

Key Learning

- Solar PV+Battery Hybrid systems can be integrated into the EFCC scheme and create additional value, faster overall response and increase the overall system availability.
- Battery systems can support large scale solar PV systems in the provision of system services on TSO level, where the battery may provide the fast reaction part of the response and the night time availability.
- Solar PV inverter internal MODBUS interface updates along with communication traffic on MODBUS connection between control and inverter highly affect the overall response time on PV side.
- Communications topology inside PV solar farms were never meant to be fast → good network design with fast switches, and bridges necessary.
- Retrofitting a PV power plant network to provide frequency response is possible.

Questions

Email questions to:
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