

BELECTRIC: Enhanced Frequency Control Capability



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28/03/2018



BELECTRIC

centrica Flextricity



Orsted

SIEMENS Gamesa
RENEWABLE ENERGY

Company profile

- Yearly total revenue of **550M EUR**
- **84 MW / 95 MWh** energy storage systems installed or under construction
- **Over 120 patents** registered since 2001
- **Technology leader** in utility-scale solar power business

12+

YEARS OF
EXPERIENCE

500+

CONSTRUCTION
WORKERS
WORLDWIDE

1500+
MWp

WORLDWIDE INSTALLED
SOLAR POWER



Agenda

**Project
Background**



Progress and Tests



Moving Forward



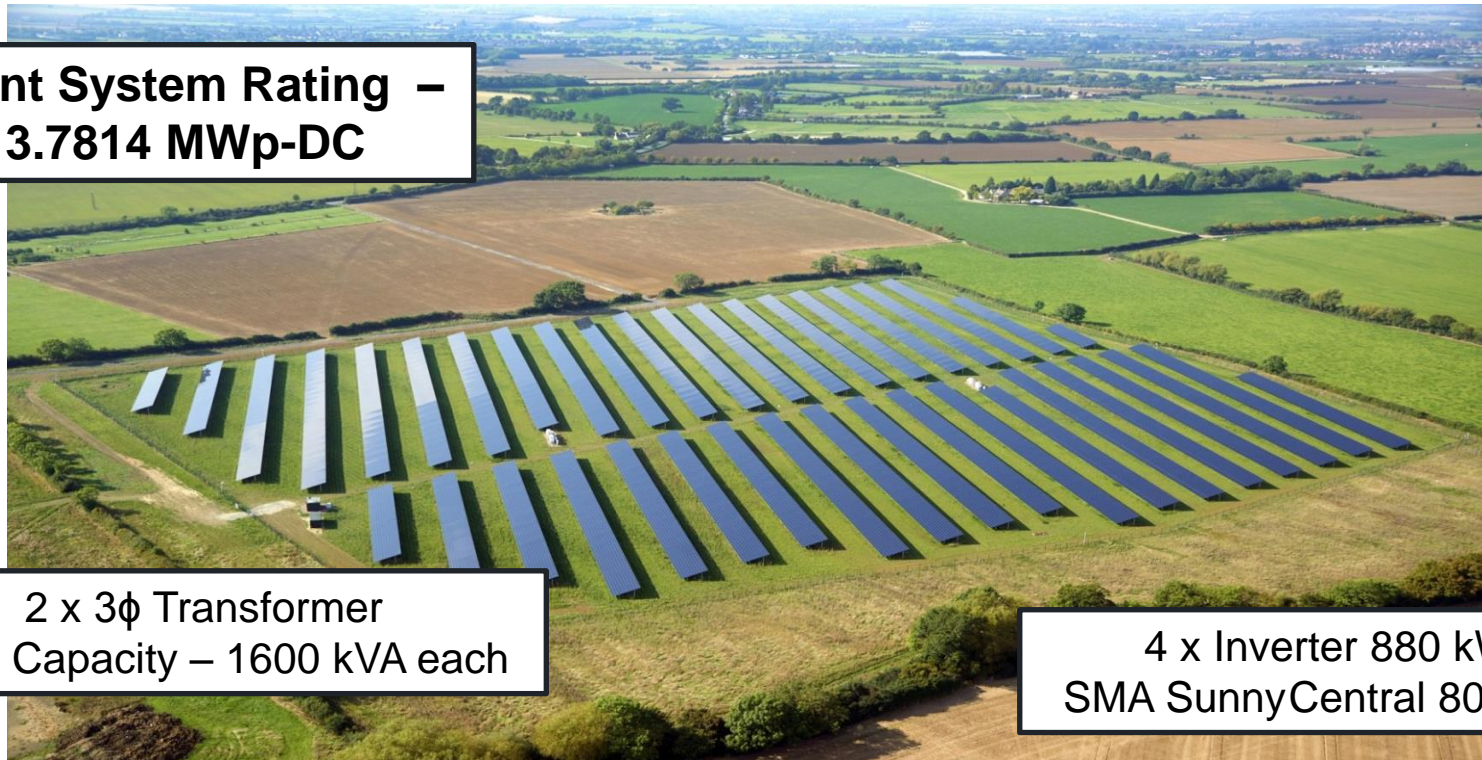
Project Background

- Role of BELECTRIC
- Hardware overview
- Communication system



Rainbows solar PV farm in Willersey, England

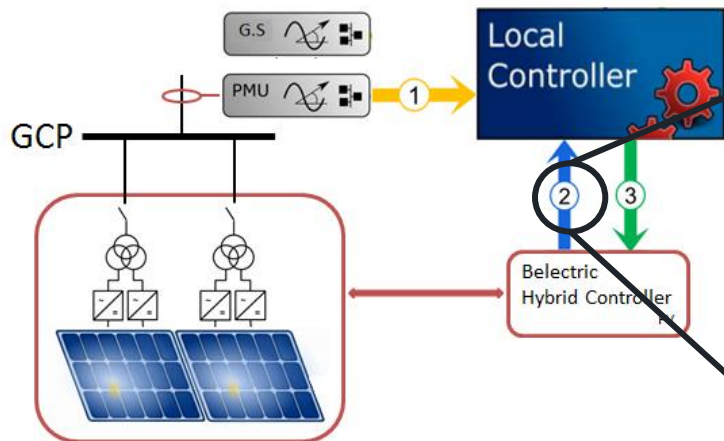
**Plant System Rating –
3.7814 MWp-DC**



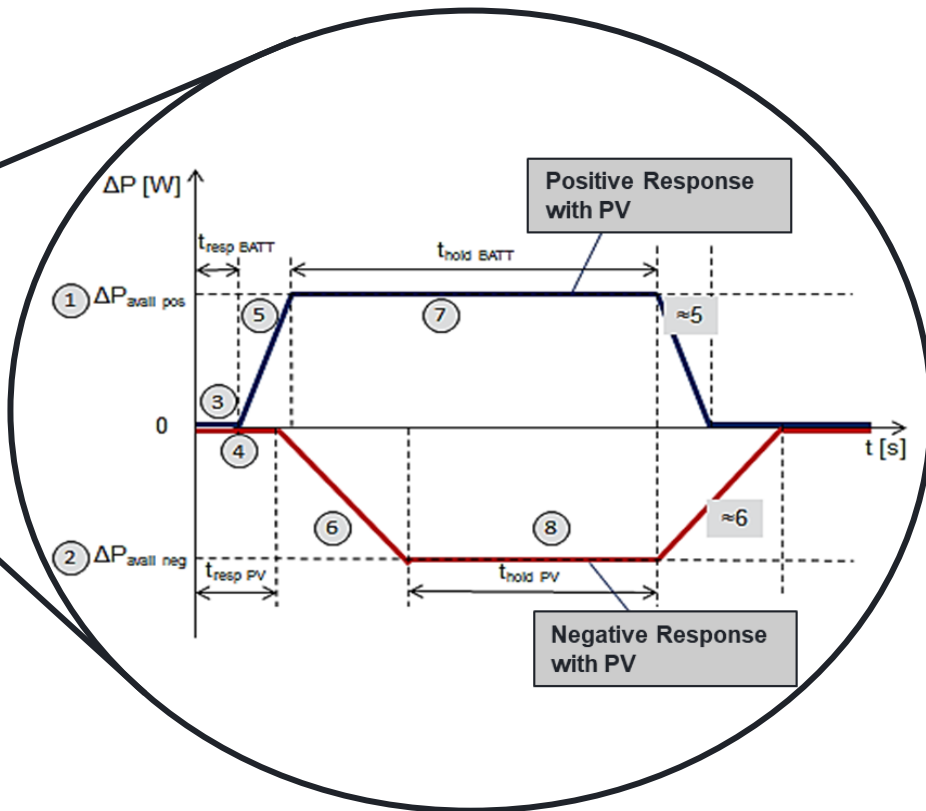
**2 x 3 ϕ Transformer
Nom. Capacity – 1600 kVA each**

**4 x Inverter 880 kW_{AC}
SMA SunnyCentral 800CP XT**

System communication overview

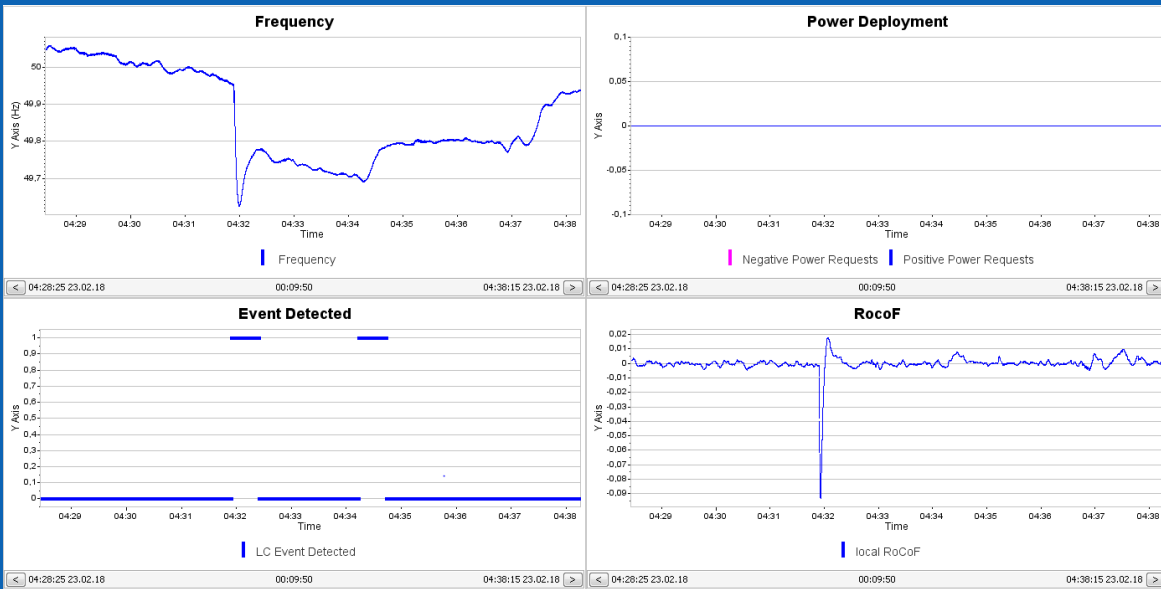


- ➡ 1 IEEE C37.118 (PMU Portal)
- ➡ 2 IEC 61850 GOOSE (MMS)
- ➡ 3 IEC 61850 GOOSE
- ↔ Modbus TCP/IP

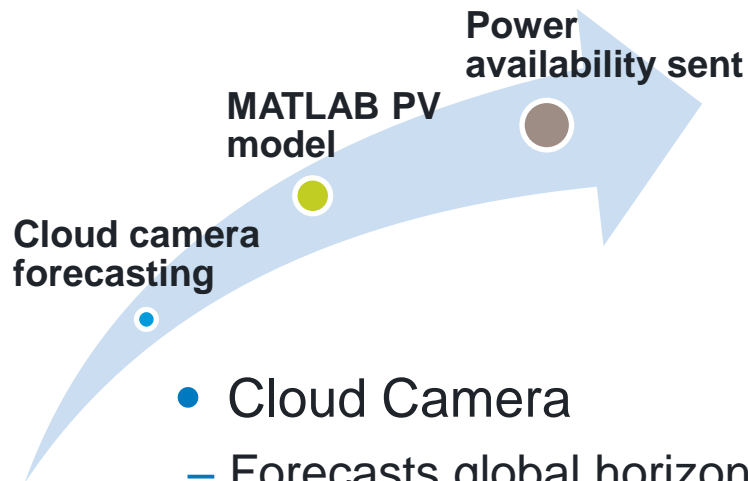


Progress and Tests

- Forecasting
- Tests & Trials
- Key Learnings

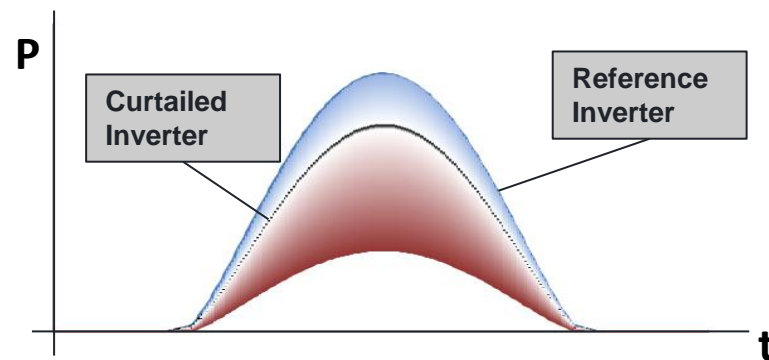


Forecasting: Hold time and curtailment reference



- Cloud Camera
 - Forecasts global horizontal irradiance data for the next 15 minutes
- Findings
 - Inconsistent and low accuracy
 - Probabilistic forecasting

- MATLAB PV Plant Model
 - Calculates power production by Rainbows during a solar irradiance
- Findings
 - Model accuracy: Underestimating ✓
 - PV Model slows communication
 - Revised forecasting system



Photovoltaic stand alone tests

Precursor

- Inverter control
- Lookup table test
- Curtailment test

Open Loop Test

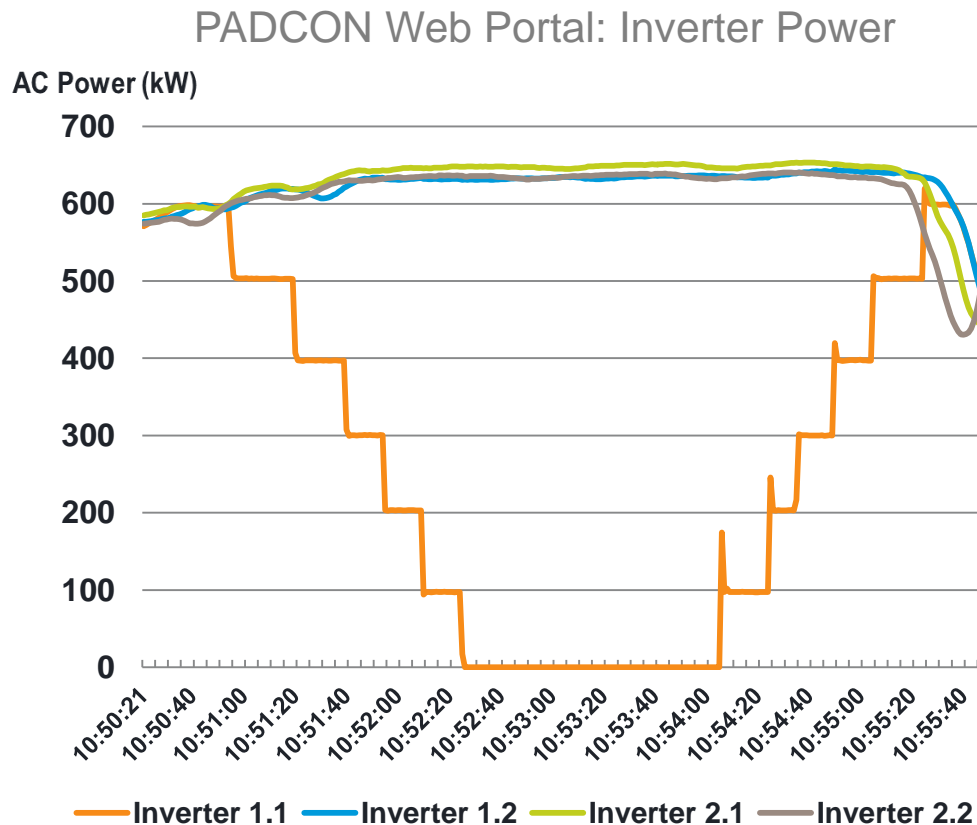
- Frequency event: simulated
- Frequency event: non simulated

Hardware in Loop Test

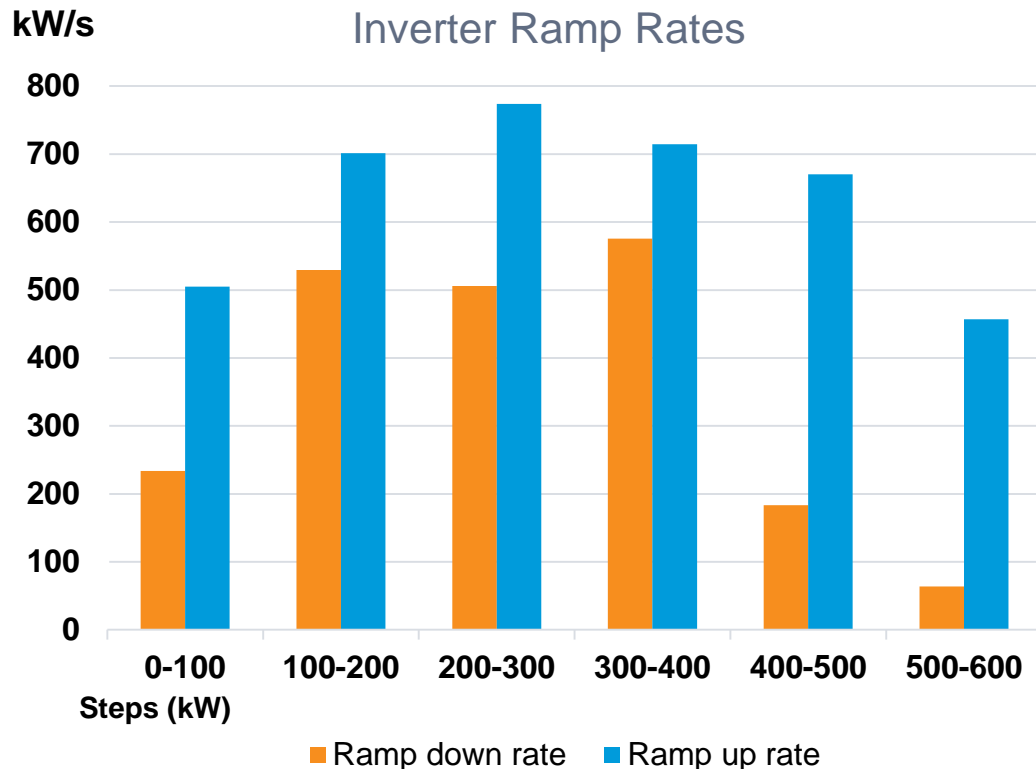
- Frequency event: simulated
- Frequency event: non simulated

Precursor test lookup table

- Purpose
 - Investigate inverter behaviour
 - Find ramp up/down rates
- Only inverter 1.1 participated
 - 100 kW working point step – changes (hard curtailed)
- Test conducted during high and constant irradiance ($\sim 750 \text{ W/m}^2$)
- Data measurement via Phasor Point Measurement Unit (PMU)



Precursor test lookup table: Results

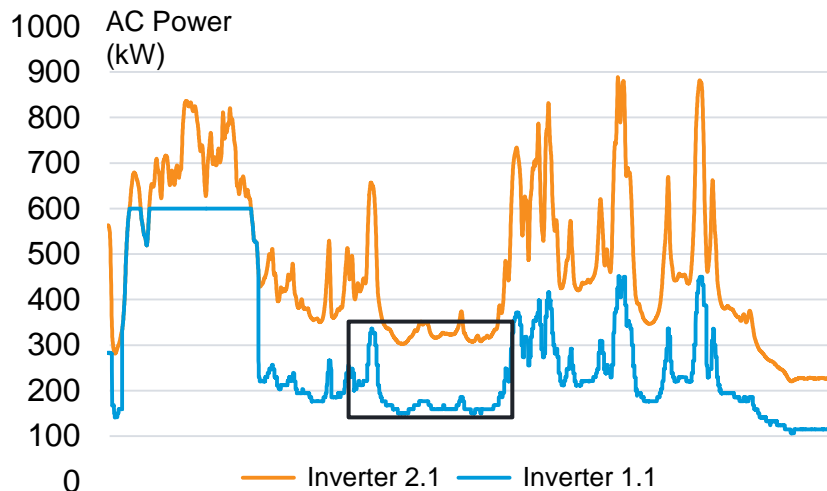


- Ramp rate did change with working point
 - Ramp down slower than ramp up
- Further testing necessary
 - Expect similar behavior with different inverters
 - Investigate variables impacting behavior

Precursor test curtailment

- Purpose
 - To provide positive power response (50%) and negative power response (50%) during an event
 - Hard curtailment vs soft curtailment
 - Have Rainbows still behave like a PV plant
- Results
 - Positive/negative power response ✓
 - Minimum ± 8.8 kW working point change limit

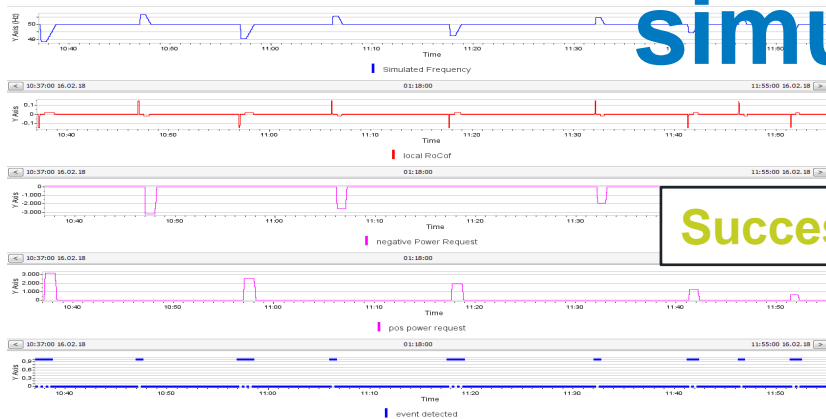
PADCON Web Portal: Soft Curtailment



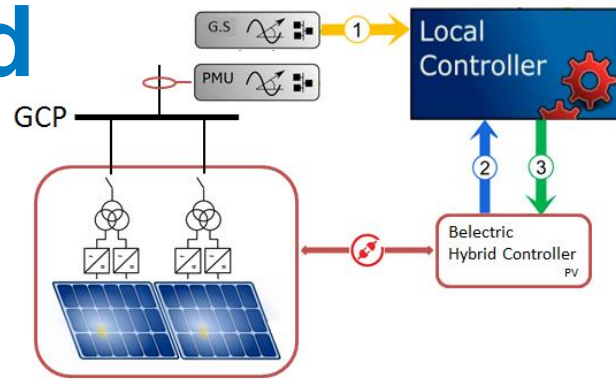
Continuous Soft Curtailment

Open loop test – simulated & real

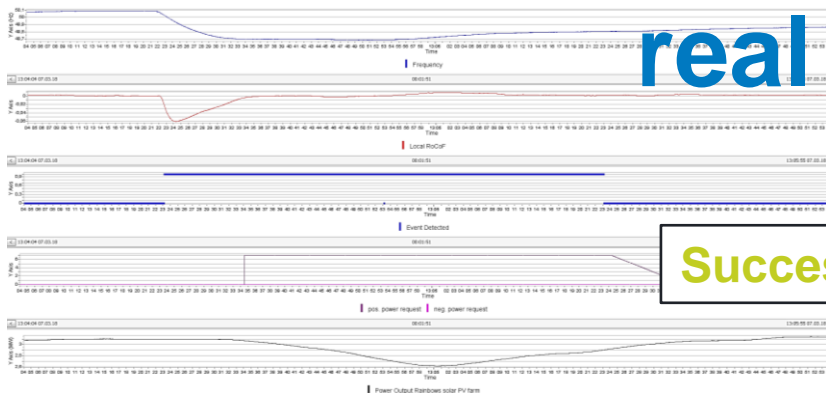
simulated



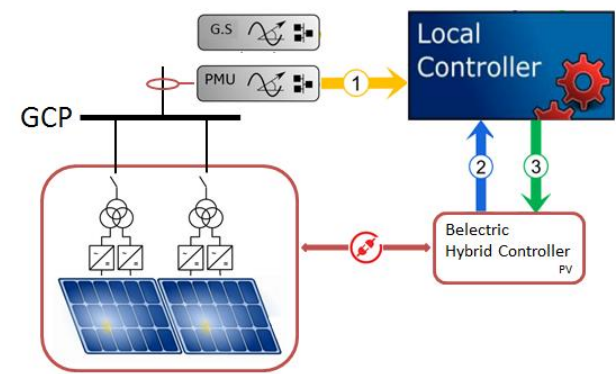
Successful ✓



real

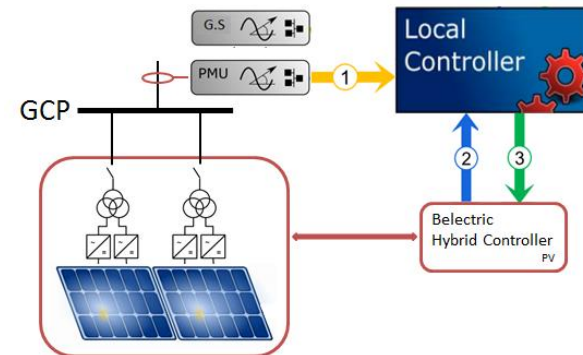
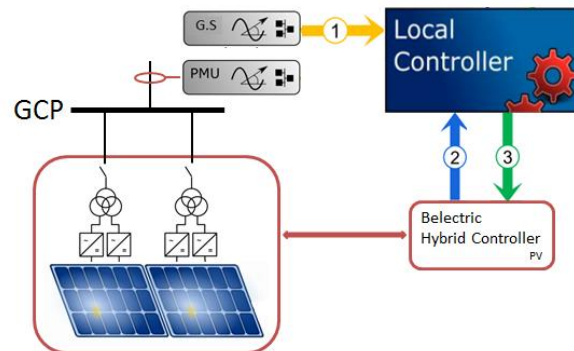


Successful ✓



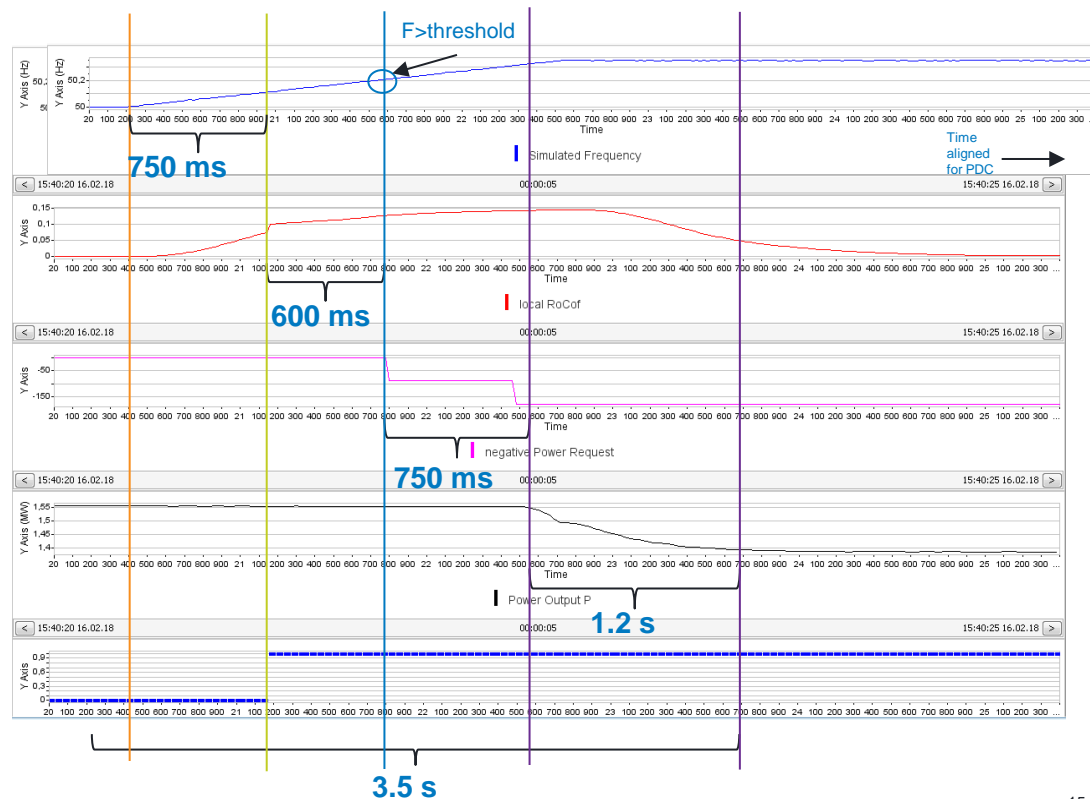
Hardware in the loop test

- Purpose
 - To investigate the system hardware and real time power response of the inverters during a frequency event
- Test subdivision
 - **Grid Simulator**: actual resource availability with simulated frequency events
 - **PMU**: actual resource availability with real frequency events



HiL test simulated frequency event

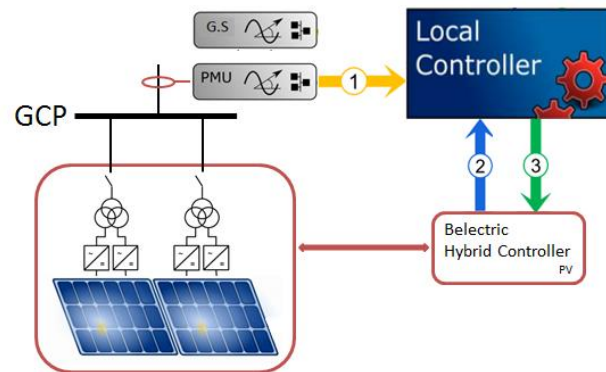
- Test Procedure
 - Inverter 1.1's actual resource availability sent to the GE local controller
- Simulated frequency event of 50.35 Hz
 - Hardware reacted to negative power request sent by GE local controller ✓
 - Inverter 1.1 AC power curtailed
 - Provide negative power response through PV



HiL test real frequency event

- Test Procedure
 - First Test Period: No curtailment
 - Second Test Period: Inverter 1.1 soft curtailed to 50%

- Testing on-going
 - Events are rare and must coincide with PV power availability



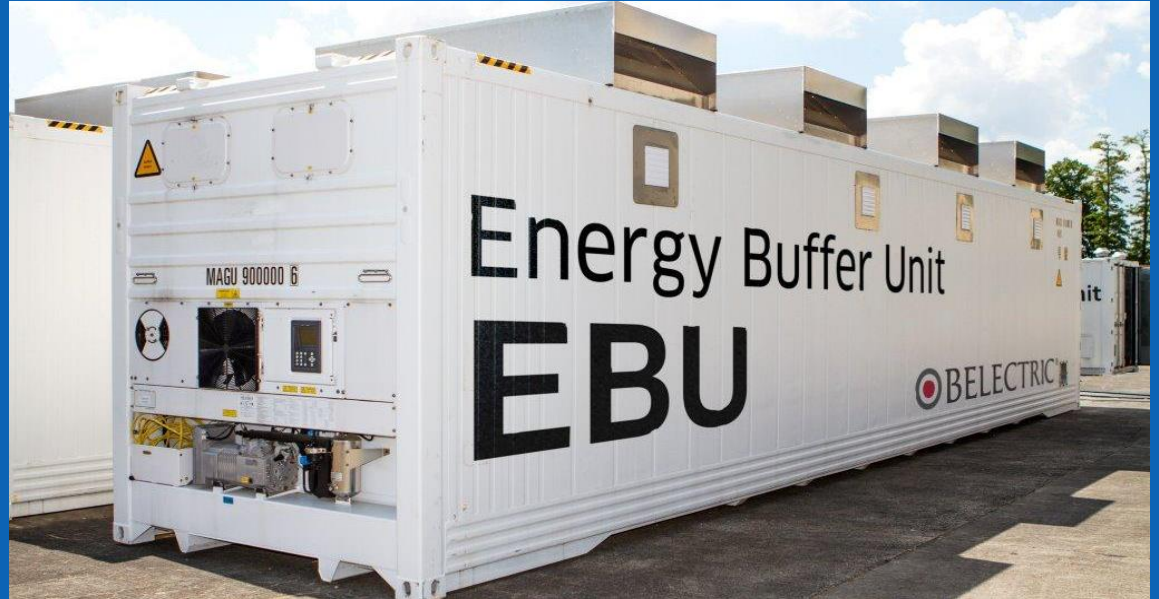
Name	Value
locRsrcState	
.resourceType	2
.Availability	TRUE
.posAvailablePower	296.725
.negAvailablePower	890.175
.posPowerResponseTime	500
.negPowerResponseTime	500
.powerRampUpRate	8000
.powerRampDownRate	8000
.posPowerMaxDuration	900
.negPowerMaxDuration	900

Key learnings so far

- PV systems can be integrated into the EFCC scheme
- PV power availability forecasting
- Communication traffic highly effects communication rate and inverter response time
- Adjustment to data point table - sent and received
- PV inverter ramp rates are asymmetric
- Inverter power response has ± 8.8 kW power response resolution
- Importance of time synchronisation
- Importance of curtailment as under-frequency events are more common

Moving Forward

- Future Work
- Hybrid system
- Schedule

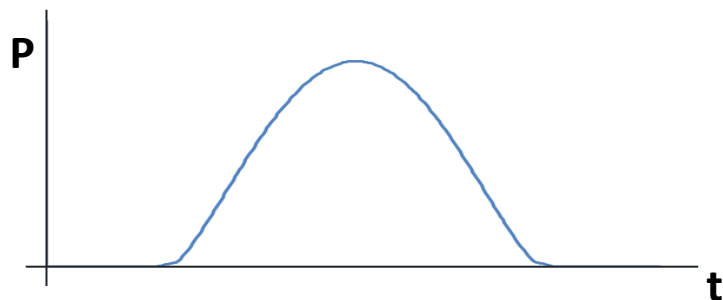


Future work

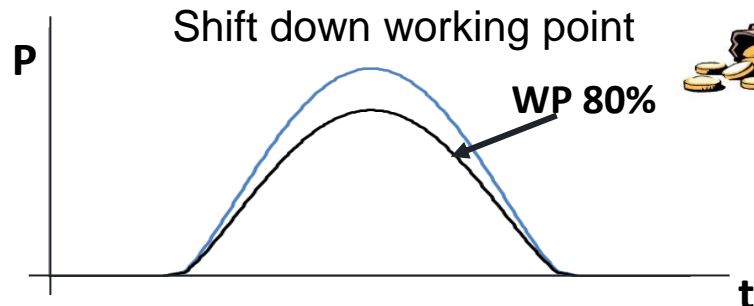
- PV stand alone
 - Investigate consistent ramp rates for PV inverters by i.e. changing current and voltage instead of power percentage set point
 - Investigate response time accuracy and consistency
- Battery stand alone solution
- PV + Battery hybrid system solution
 - Quicker response time with battery support
 - Greater system power availability

Hybrid system for EFCC

PV stand alone - frequency response



No frequency response

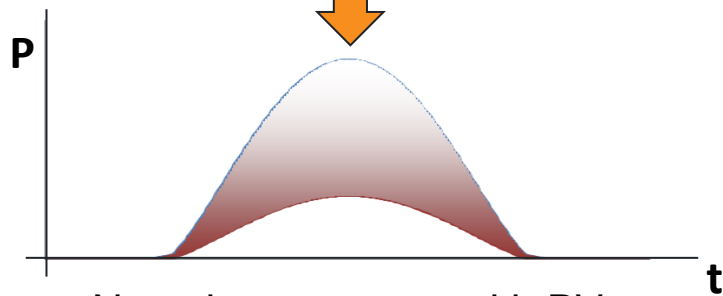


Shift down working point

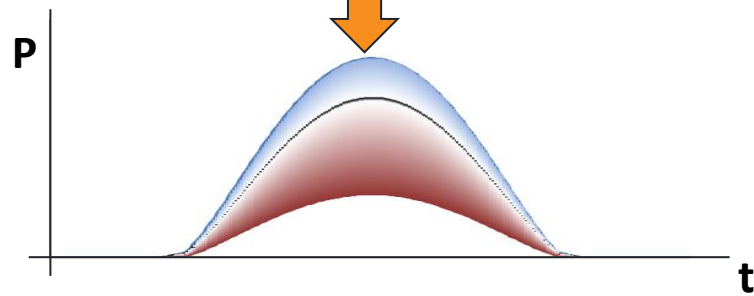
WP 80%



Positive response possible



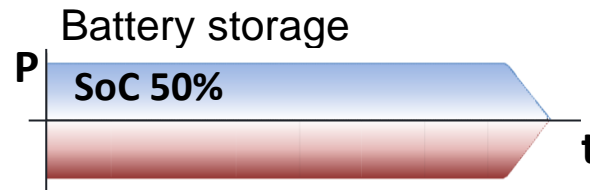
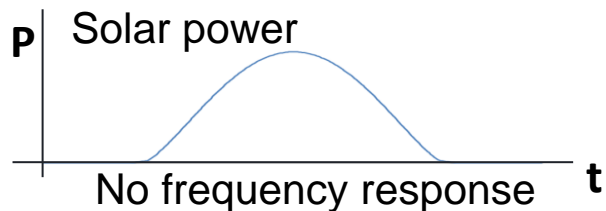
Negative response with PV



Positive and negative response

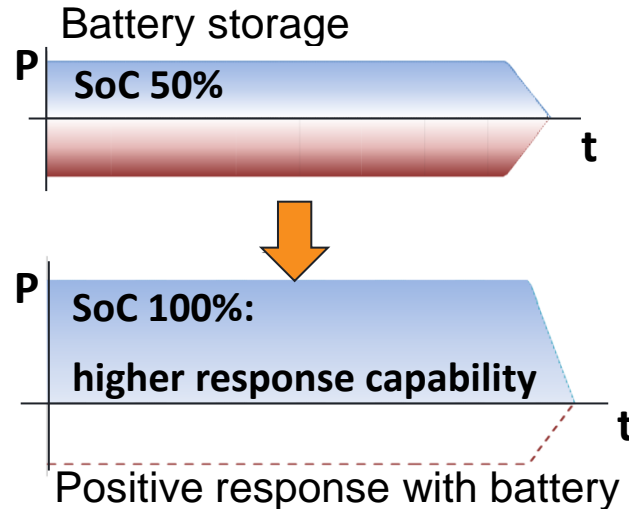
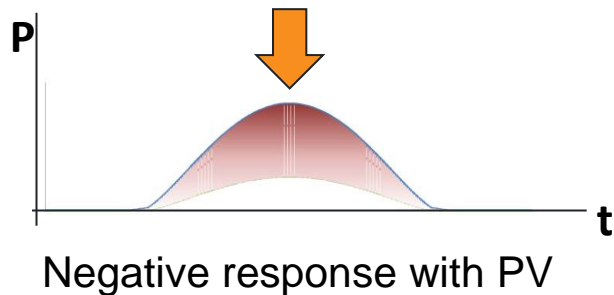
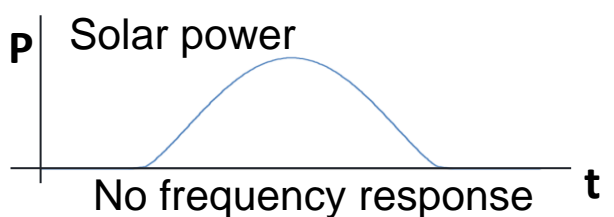
Hybrid system for EFCC

Combined PV + battery frequency response:



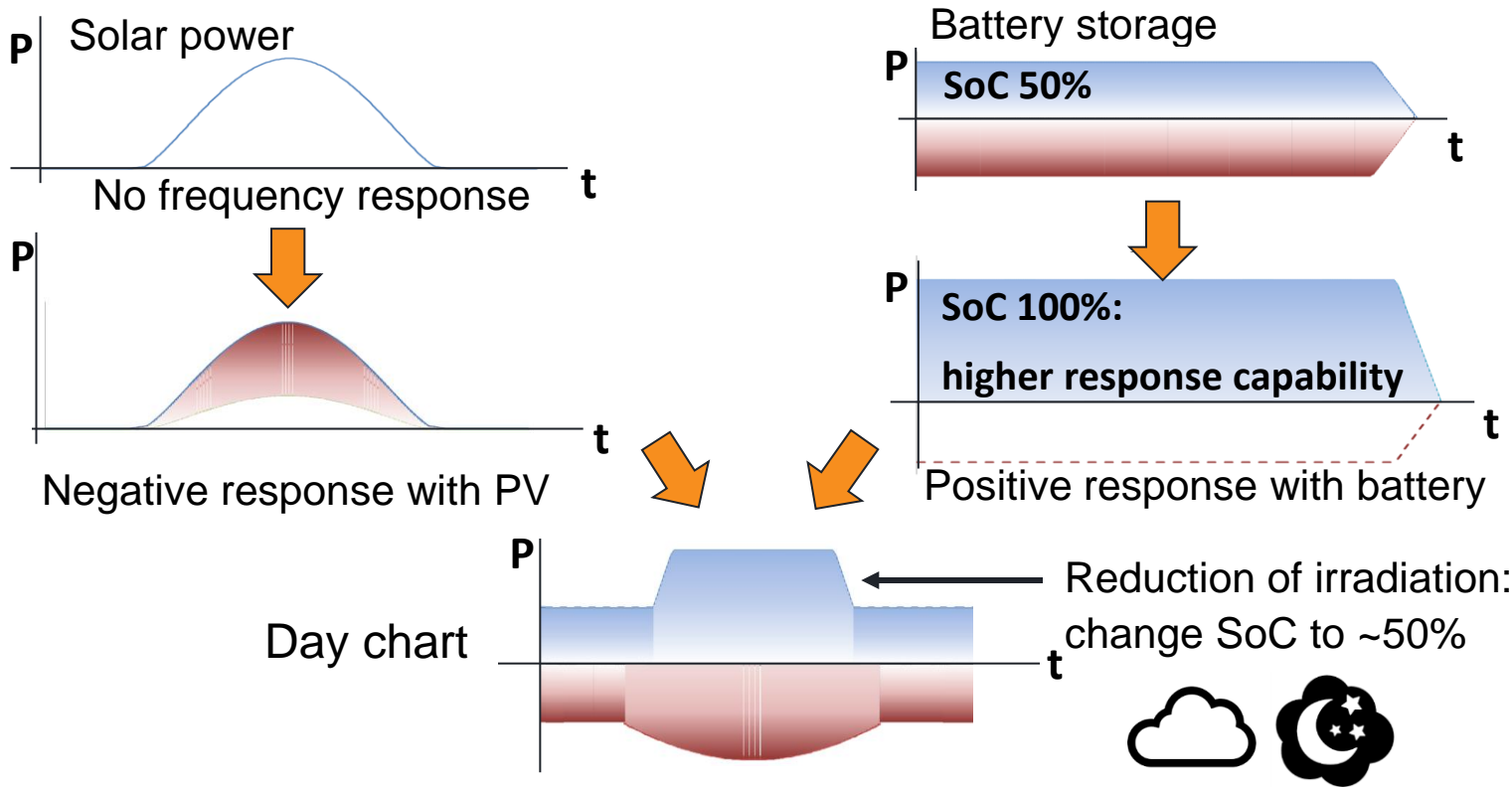
Hybrid system for EFCC

Combined PV + battery frequency response:



Hybrid system for EFCC

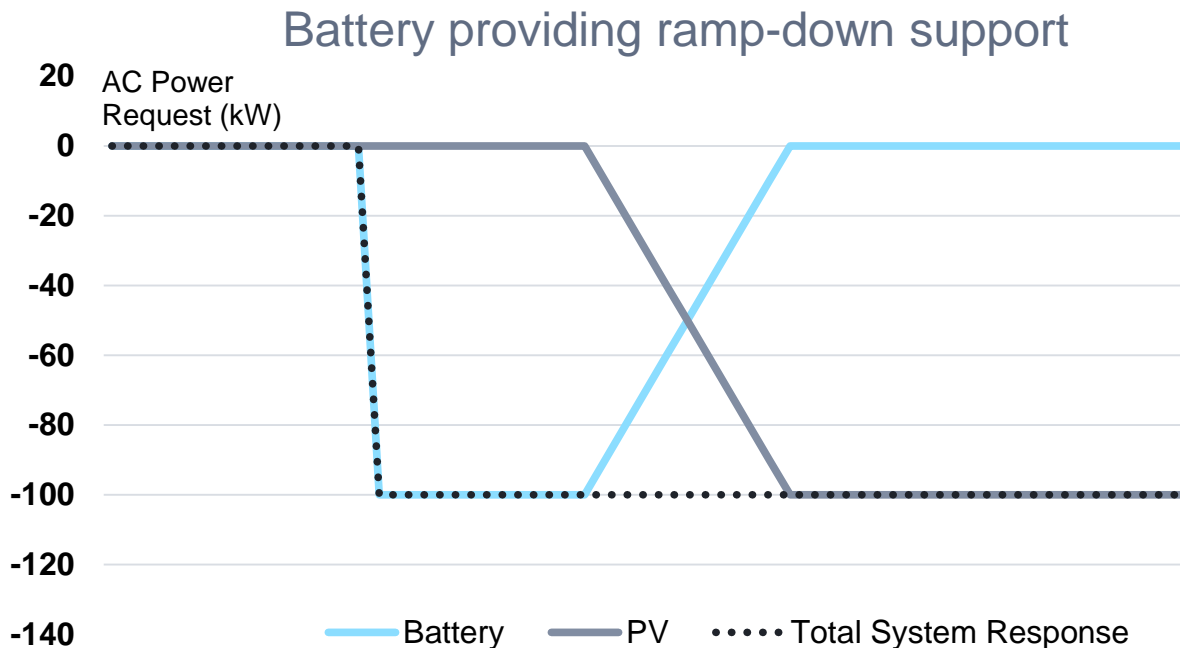
Combined PV + battery frequency response:



Hybrid system solution complexity

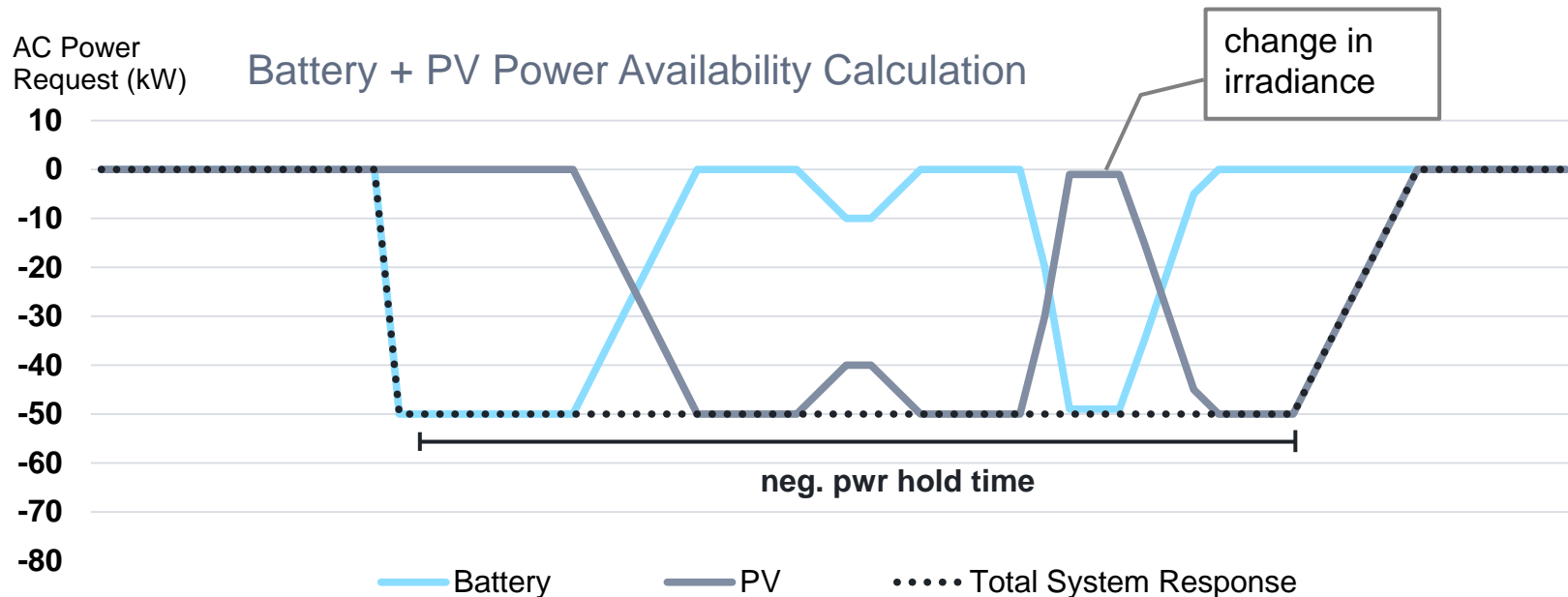
- Deciding on how resources work together
- Example: Optimising battery ramp down support vs. battery positive power availability

- Pro: faster negative power response
- Con: less battery power availability for positive response

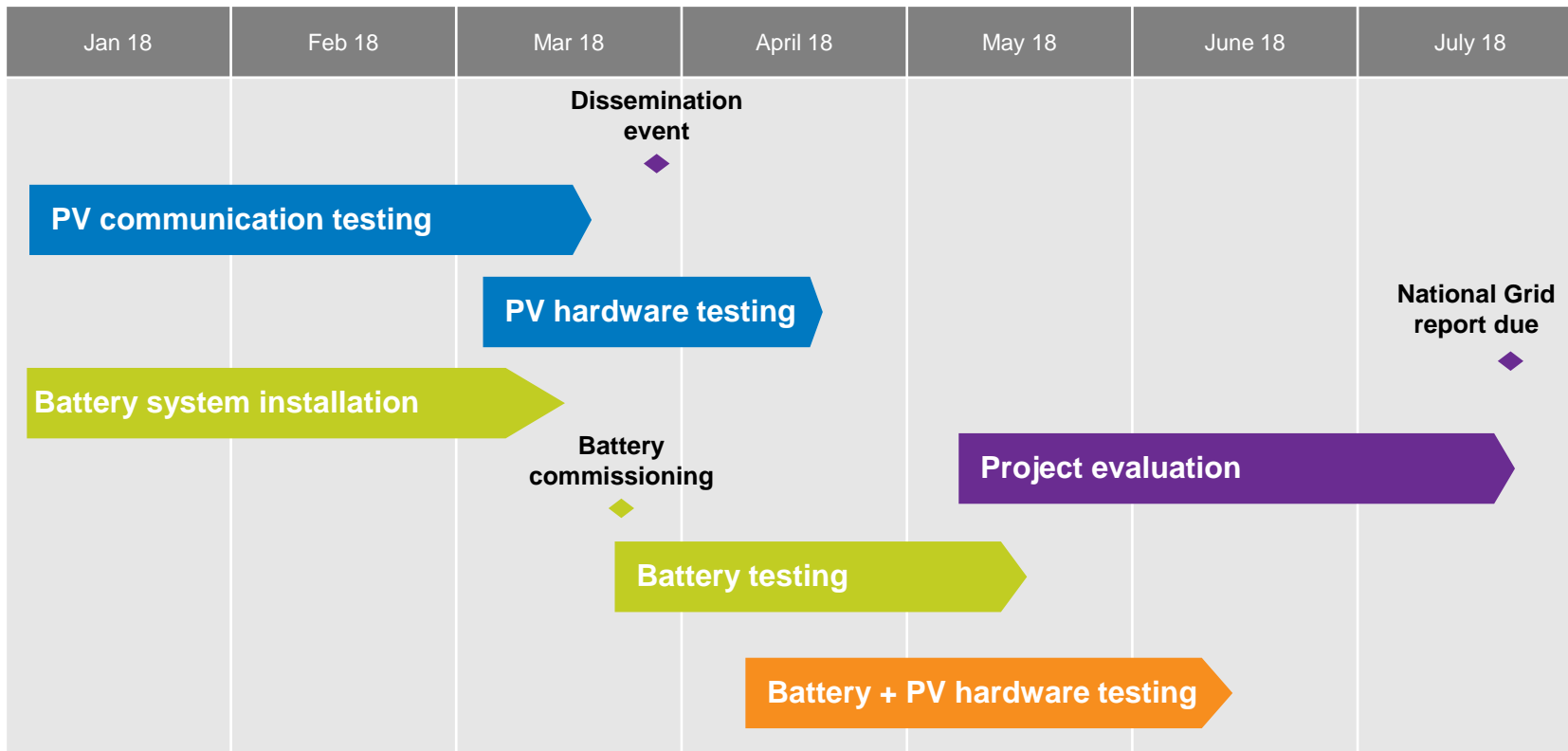


Hybrid system solution complexity

- Example: Calculation of PV + battery power availability hold time
 - Accounting for PV forecasting
 - Order in which the resources respond



Moving forward



nationalgrid



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Flexitricity



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