Domestic Energy Storage Workshop

12th September 2017

Our objectives

- Share our plans and experience and seek your views on:
  - current domestic storage solutions
  - emerging and innovative solutions
  - getting you connected quicker/easier
- Seek your views on topics that would benefit from similar workshop events

Your objectives

- What do you want to get out of today?
  - feedback forms
- Help us to meet your objectives
- Open discussion is encouraged
- Opportunities for private discussion during breaks and after the workshop

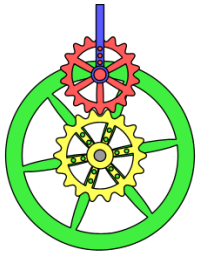
Energy Storage Overview

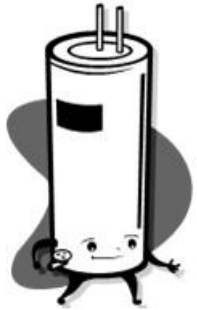
David van Kesteren

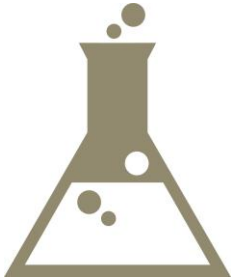
Senior Asset Management Engineer

Energy storage systems

- A system capable of repeatedly storing and releasing energy in a controlled manner
  - has an input as well as an output
- Thermal
- Gravitational
- Kinetic
- Pressure
- Chemical
- Elastic, magnetic, electrical, nuclear, sound…







Electrical energy storage systems

- A system capable of repeatedly storing and releasing energy in a controlled manner
- Requires both import and export capability (i.e. it is a load and a generator) to charge and discharge the system
  - Batteries
  - Pumped hydro
  - Flywheel
  - Compressed air

Domestic / small scale applications

- Battery storage is the developing market
- Applicable at domestic and commercial level
- Typically used to offset rooftop solar installations
  - reduces exported power at midday, by charging battery
  - reduces imported power at tea-time, by discharging battery
  - reduces annual electricity bills
  - need to consider initial capital cost and life expectancy
  - works well within an export limiting scheme
  - good for both the customer and the network operator

Large scale applications

- Battery storage is the emerging market
  - Some historical pumped hydro schemes
- Generally offering network balancing services to National Grid
  - Enhanced or firm frequency response (EFR/FFR)
  - Peak network load support (capacity auctions / STOR)
- Enquiries vary from 1MW up to 100MW
- Trend towards larger installations
- Low acceptance rates

Components of a basic storage system

Control system

Northern Powergrid connection

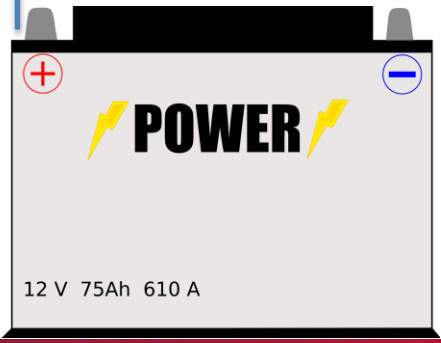
Customer consumer unit

DC/AC converter

Power limit (kW)
- size of engine

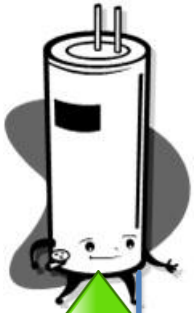
DC battery

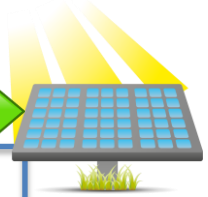
Storage capacity (kWh)
- size of tank



Components of a complex system

Controllable load (water heater)





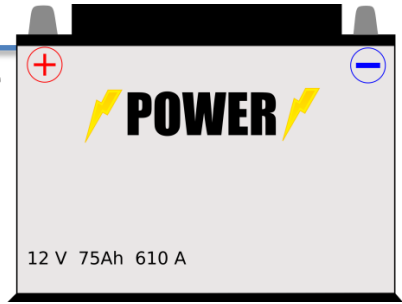
Solar panel (DC)

Control system

consumer unit

Northern Powergrid connection

Storage system



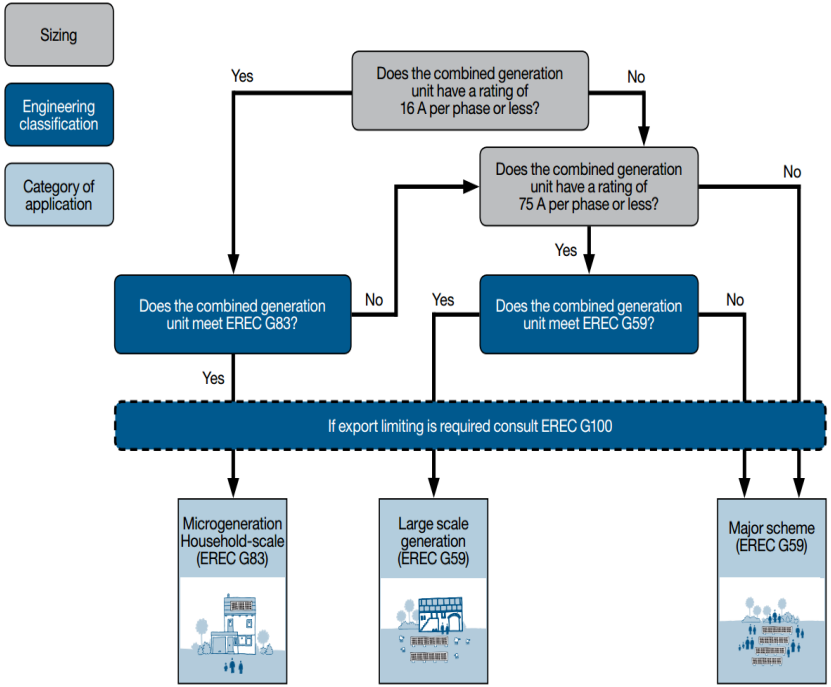
Domestic Energy Storage Sizing and Systems

Rimnesh Shah

Smart Grid Development

Sizing and engineering recommendations

- Application route and which EREC to apply under depends on the size of the connection.
- The size is the total combined capacity if adding to new or existing generation.

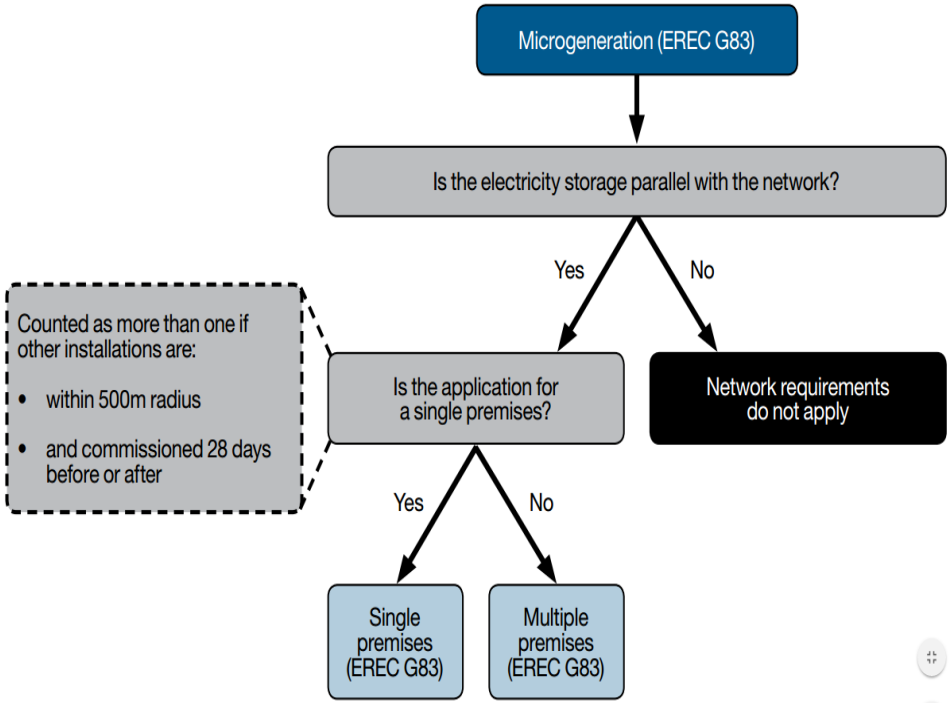


- Sizing cut-off:
  - <=16A/phase equates to upto 3.68kW for single phase and 11.04kW for three phase
  - <=75A/phase equates to upto 17kW for single phase and 50kW for three phase
- Sizing cut-off leads to EREC classifications:
  - G83
    - SSEG <= 16A/phase
    - Type tested and installed in acc with G83/2
  - G59
    - SSEG > 16A/phase
    - Type tested and installed in acc with G59/3
- Category of application:
  - Micro-generation, large scale and major scheme

http://www.energynetworks.org/assets/files/news/publications/ENA%20Electricity%20Storage%20Guide.PDF

G83's and multiple premises

- If the electricity storage falls under G83 than further checks required to confirm network parallel operation.
- As shown in the diagram if parallel operation is required than rules of EREC G83 single and multiple premises apply.
- Typical examples of non- parallel operation:
  - Storage designed to be operational for short periods of time ex: 5 minutes only
  - Islanded systems found typically in rural networks
- Witness testing not required at EREC G83 standards.

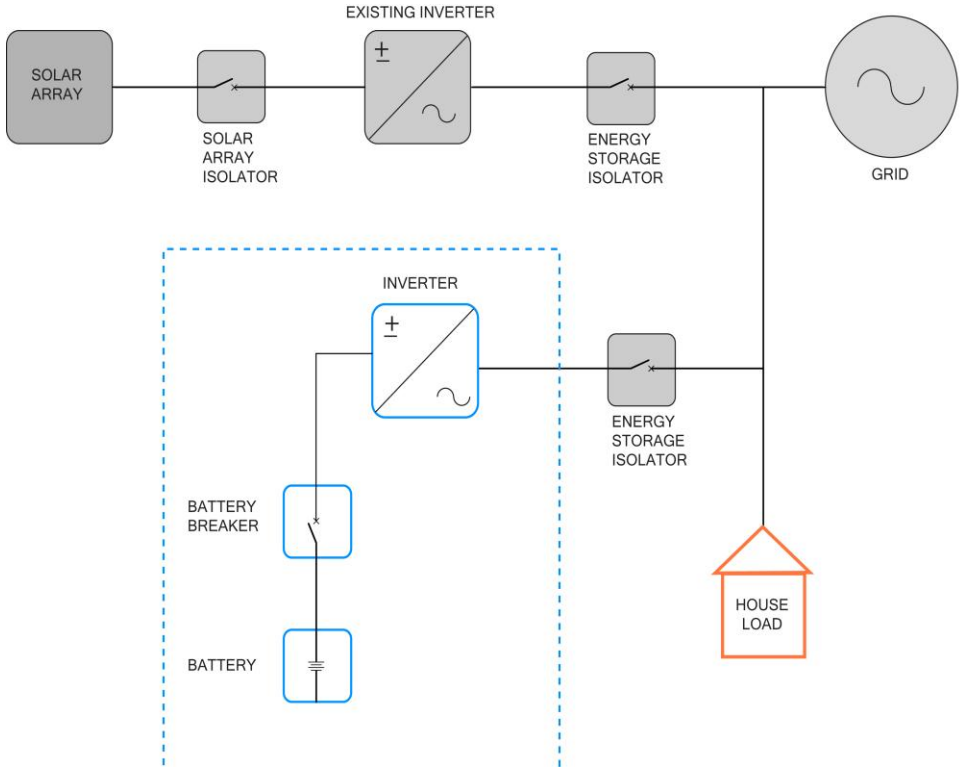


http://www.energynetworks.org/assets/files/news/publications/ENA%20Electricity%20Storage%20Guide.PDF

Notifications vs. Applications

- No central registration schemes like FITs or RHI nor any certification schemes like Microgeneration Certification Schemes (MCS) currently.
- Reliant on G83/G59 notifications/applications respectively.
- G83:
  - G83/2 Commissioning Confirmation Form along with SLD to DNO within 28days of installation
  - Multiple premises G83 requires application prior to installation
- G59:
  - Application prior to installation

AC coupled domestic energy storage system

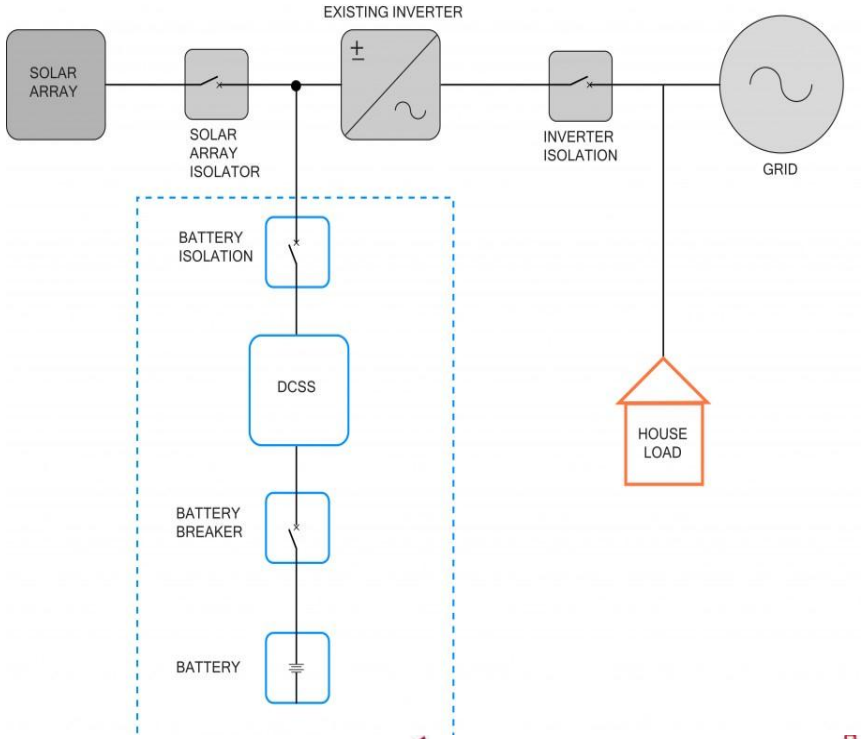


- Connected on AC side of the DG system invertor
- Solar as well as Grid chargeable
- Access to better tariffs and other grid services; hence potentially better returns
- Slightly higher costs as connection via a second separate inverter
- Easy install for new or existing systems
- G83/G59 notification/application depending on system size
- Less physical constraints

https://www.solarchoice.net.au/blog/ac-vs-dc-solar-battery-storage-explained

DC Coupled Domestic Energy Storage System

- Connected on DC side of the DG system invertor; typically between DG and inverter
- Stores power directly from the DG
- Potentially used for islanded system or as back up; but at FITs loss
- Typically cheaper as needs only one inverter and controls
- Potentially G83/G59 not needed on retrofit install unless inverter change
- New install via certified installers and to confirm compatibility to existing
- Can't benefit from smart tariffs and grid services
- More physical constraints as next to DG inverter



https://www.solarchoice.net.au/blog/ac-vs-dc-solar-battery-storage-explained

Distributed Storage & Solar Study (DS^3) Project Background

Paris Hadjiodysseos

Smart Grid Development Engineer

Two sessions!

- Project background and battery technology
- Project goals and lessons learned so far

LV generation application process (G83)

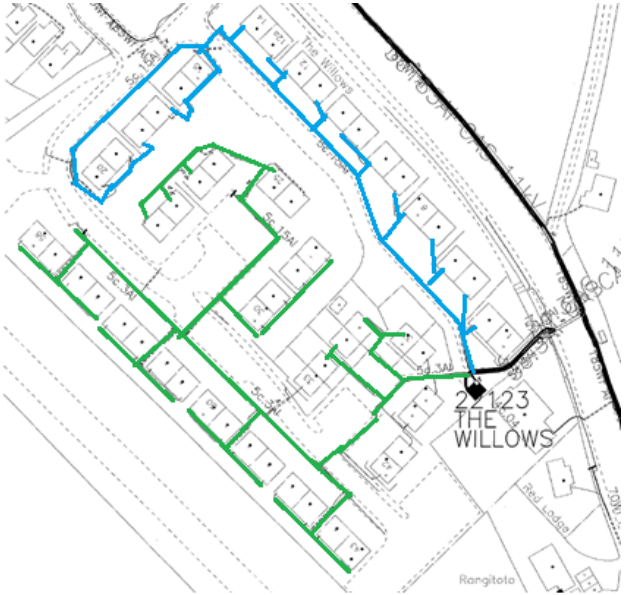
- Small-scale generation to a single premise
  - < 16A or 3.68kW per phase
  - Notify within 28days of commissioning

- Small-scale to multiple premises
  - < 16A or 3.68kW per phase
  - Apply for approval before connection

Assessment of multiple premises

- Declared Voltage limits: 230V +10/-6%
  - Load: 216V
  - Generation: 253V

- Worst case
  - Max Generation &
    Min Load



2015 – Oxspring, Barnsley

Key

- **Feeder 2** - 37 properties, 15 with PV (42% penetration)
- **Feeder 3** - 55 properties, 11 with PV (20% penetration)
- PV installed
- PV refused

- 2.7kW - 3.68kW
- Connected 27

2016 – Oxspring, Barnsley

Key

- **Feeder 2** - 37 properties, 15 with PV (42% penetration)
- **Feeder 3** - 55 properties, 11 with PV (20% penetration)
- PV installed
- PV refused

- 1x BESS in 23 properties with PV
- 2x BESS in 4 properties with PV
- 9x BESS in properties without PV

Oxspring, Barnsley

DS^3 Project

- A community energy project involving Northern Powergrid, Gen Community Ventures and Moixa.
- Part of Barnsley Council's Anti Poverty Action Plan 2015-18
- Focuses on social housing
- Reduce householders' energy costs / provide opportunity for income through grid services

What's in it for Northern Powergrid?

- Regen SW: 2030 70-80% of rooftop PV installed with storage
- Develop an understanding of the impact PV/storage combination on network design
- Understanding the network benefits (if any) of storage behind the meter
- Supportive of Barnsley Council's Anti Poverty Action Plan

What are the costs?

- £300k financial contribution:
    - Purchase & install 40x batteries
    - Substation monitoring equipment
    - Data analysis and network modelling

Innovation strategy

- Project fits within the scope of our Innovation Strategy Portfolio
- Investigates the utilisation of customer flexibility to contribute to:
  - Future proofing for LCTs
  - Provide faster, cheaper connections for customers
  - Being socially responsible organisation

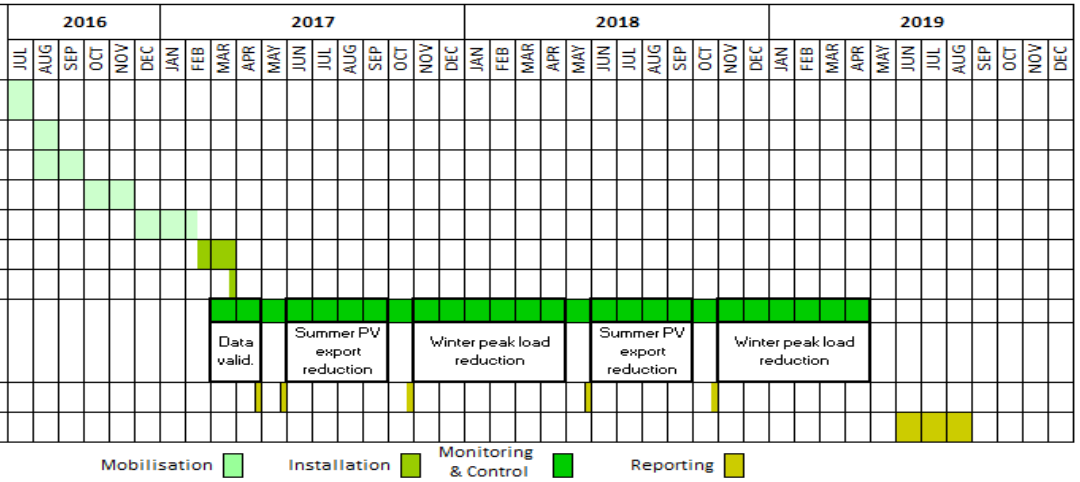
Community engagement

- Update PSR – Priority Service Register
- DC Lighting
  - Electrically dependent individual
  - Lights stay on if Power Cut
- Energy heroes
  - Fully sponsored 6 week school program
  - Improves pupils data handling and problem solving skills
  - Support communities reduce their energy costs
- Community Event
  - Meet with tenants and discuss their savings

High level project plan

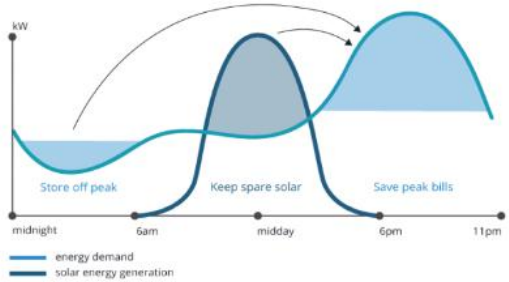
Project plan for Energise Barnsley - Distributed energy storage and services

	High-level Plan	
1	Agrement to proceed in principle / internal authorisation	July
2	Collaboration Agreement	August
3	Agree project outcomes, data requirements, plan, etc	August
4	Customer Enagement Plan / Data Protection Strategy	Oct - Nov
5	Engage stakeholders & tenants and confirm opt in	Dec - Jan
6	MASLOW Battery installation (40 properties)	Feb - Mar
7	Install Network Monitoring (1 substation)	Mar
8	Data collection & Analysis Specific Trial objectives	Apr
9	Interim reports	Various
10	Final report / dissemination event	Aug-19

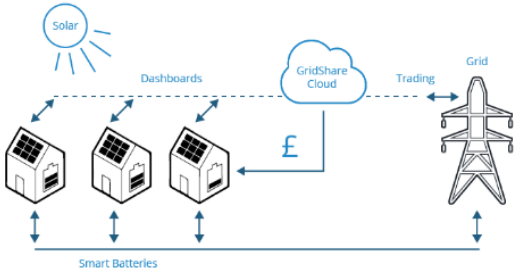


How the battery works

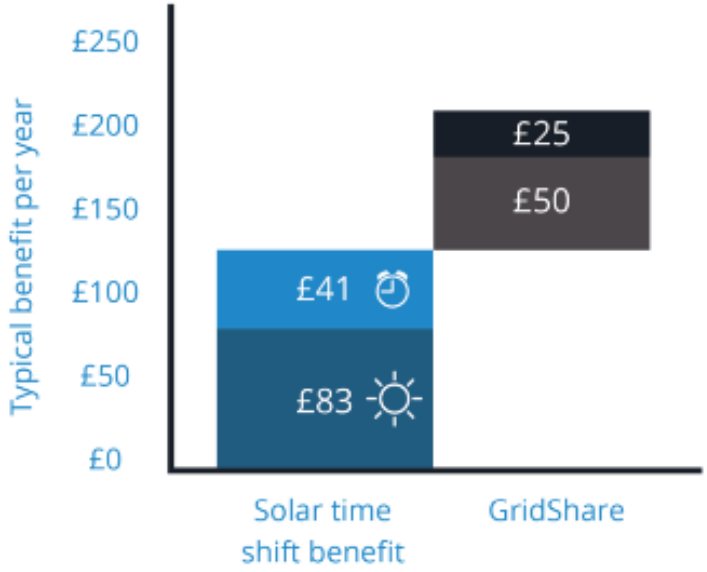
- Store excess solar energy as well as Economy 7



- Aggregate batteries to create ‘virtual power station’ & release power to the network



Financial benefit



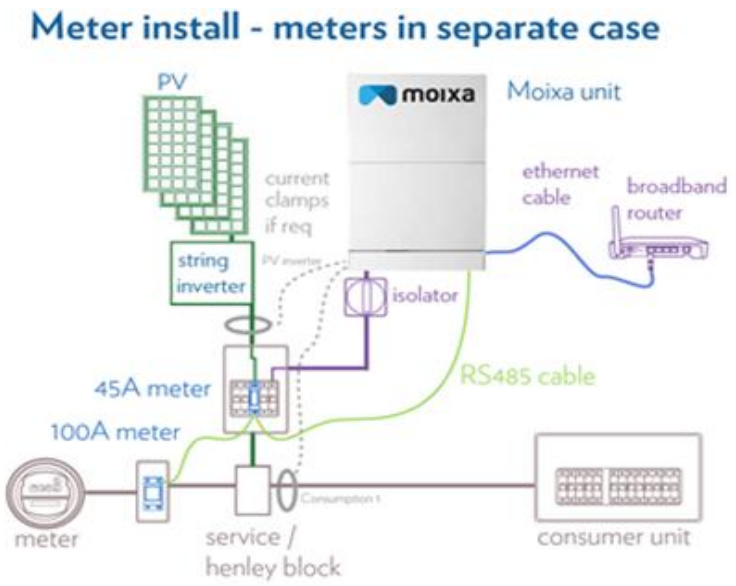
- PV
- ToU Tariff
- Grid share

Moixa smart battery

- Lithium Iron battery (LiFEP04 or LFP – Lithium ferrophosphate)
  - Balance between price and cycle life
- 10 year warranty & projected life of approx. 20 years (10,000 cycles) – dependent by charge/discharge cycles
- Battery cells are sourced from China and assembled in UK (Hastings)
- Chemistries used in EVs continue to grow they might become competitive for static storage

Moixa Factory - Hastings

Sizing the battery



- 2-3kWh Battery (up to 7hrs worth)
- 430W output inverter (per battery)
- How many bedrooms / occupants?
- PV present?
  - < 2kWp: likely 2kWh battery
  - > 2kWp: likely 3kWh battery
- E7 or ToU tariff: likely 3kWh

Thank you!

Any Questions?

Distributed Storage & Solar Study (DS^3) Project Goals and Lessons Learned

Paris Hadjiodysseos

Smart Grid Development Engineer

Potential DNO learning

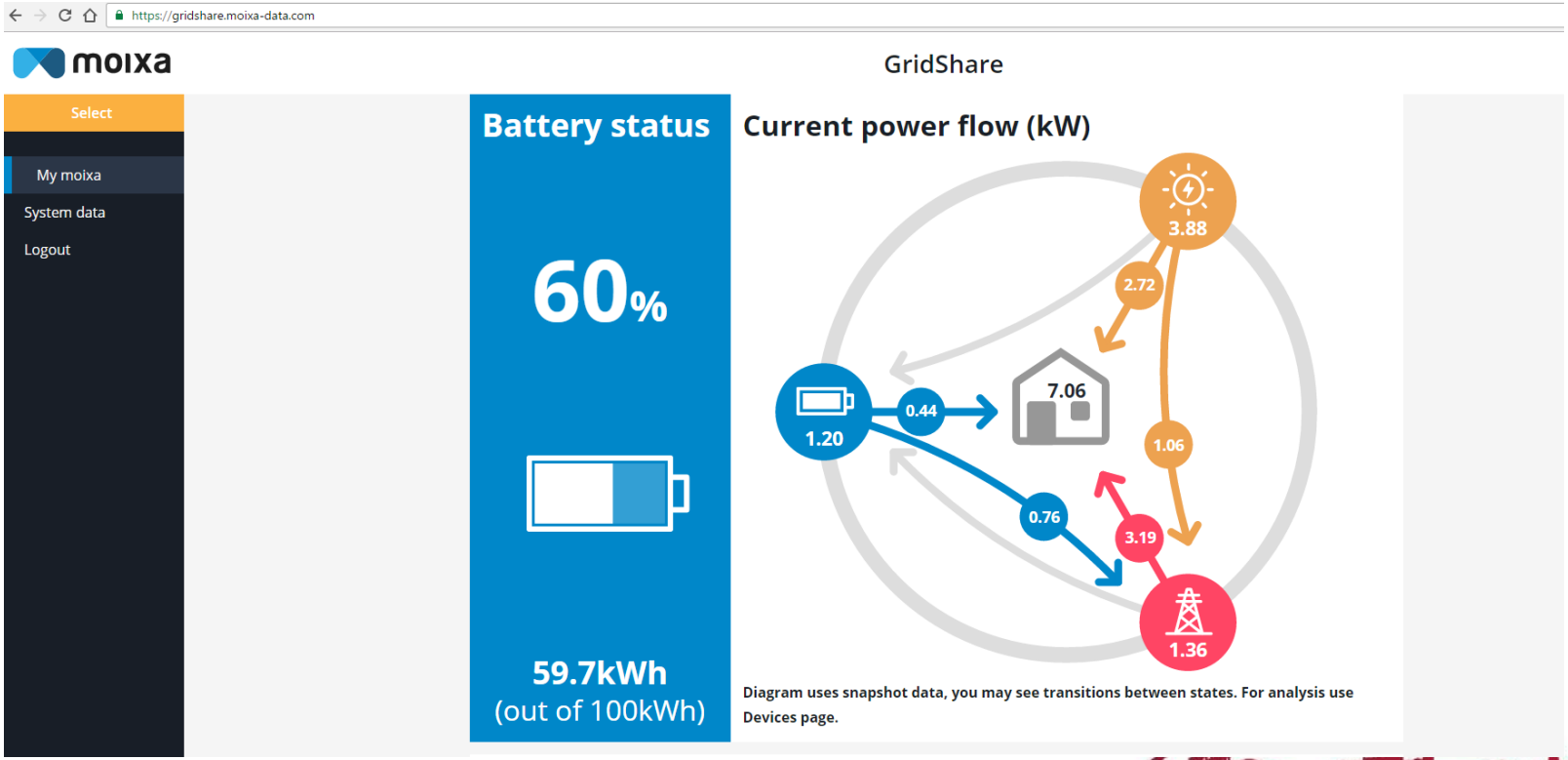
- How clusters of domestic batteries can increase capacity on the electricity network and enable more homes to install PV
- How a battery can affect the peak output of a PV installation & reduce peak load consumption
- What battery penetration is needed to make a difference to PV constraint & peak load
- Whether a de-rating factor would be appropriate for PV installations that have a battery
- Whether different design parameters would be appropriate to new housing estates with batteries
- Gaining a DNO understanding of the Moixa Cloud aggregation platform and how a DNO can interact with it to dynamically manage DNO constraints

Analysis

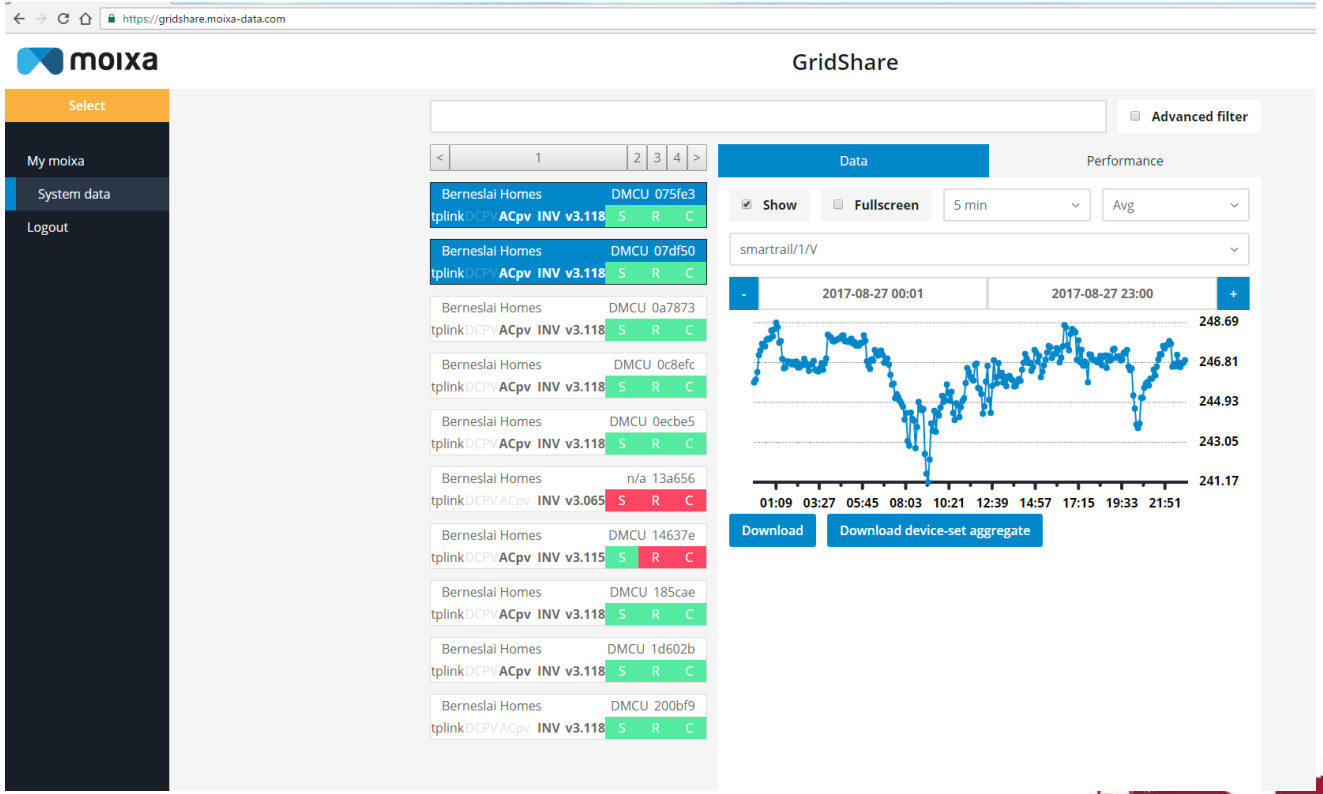
- Impact of batteries on network current flows and voltage:
  - **Trial 1:** Default algorithm to maximise the benefit of storage for tenant
  - **Trial 2:** Alter algorithm to maximise DNO benefit
- Is there any change if the batteries are providing other grid services
- How does this compare to the benefits of DNO owned storage on the network?
- Recommendations for designers:
  - Can designers accept more PV if there is aggregator controlled storage behind the meter
  - Can designers design to a lower ADMD if storage is installed in premises

Installation

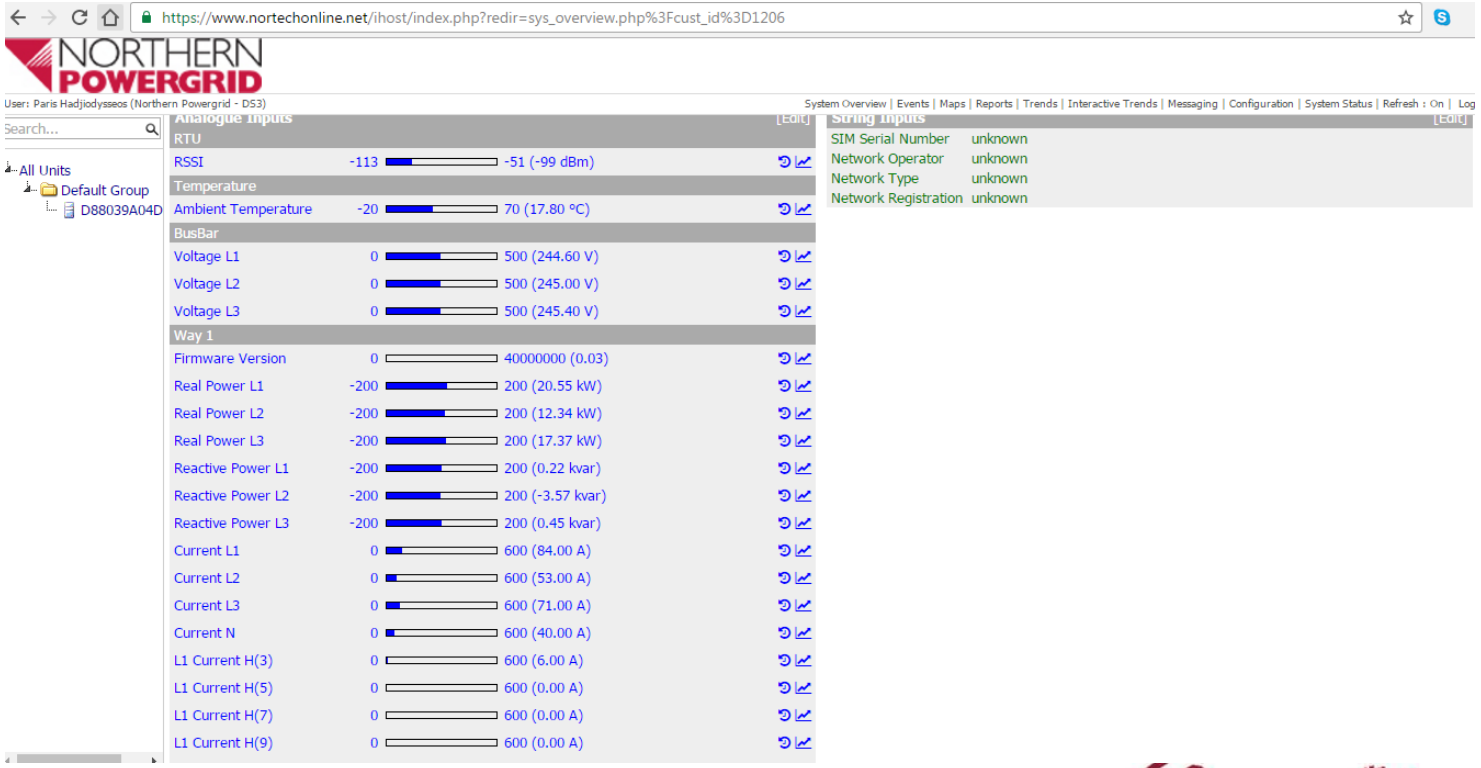
Moixa platform - overall



Moixa platform – Property view



Substation monitoring



Lessons learned – Non-technical

- Unexpected issues with accessing the properties
- Some tenants did not have broadband
- Some tenants switch off their routers
- Some tenants not tech savvy therefore not engaged with technology

Lessons learned – technical

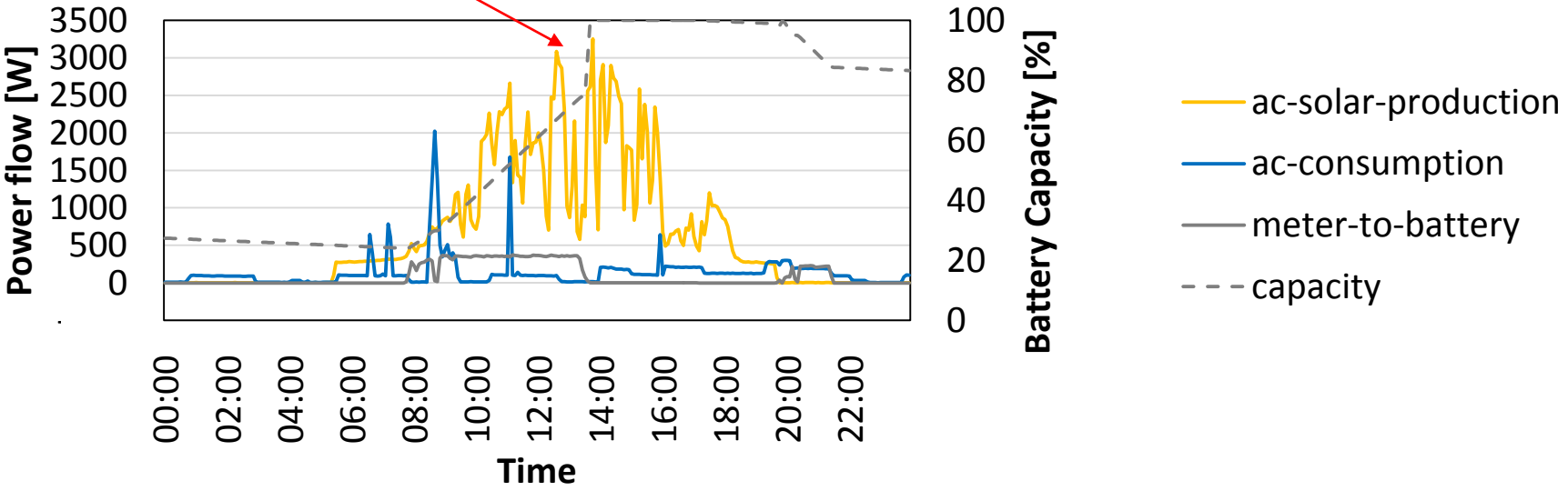
- Unstable communication link
  - Intermittent and unreliable data
  - Battery control limitation
- Reverse polarity

Data analysis

- The next slides discuss the impact of PV size
- Data from houses 65f60b & 07df50 on the 26th of August 2017

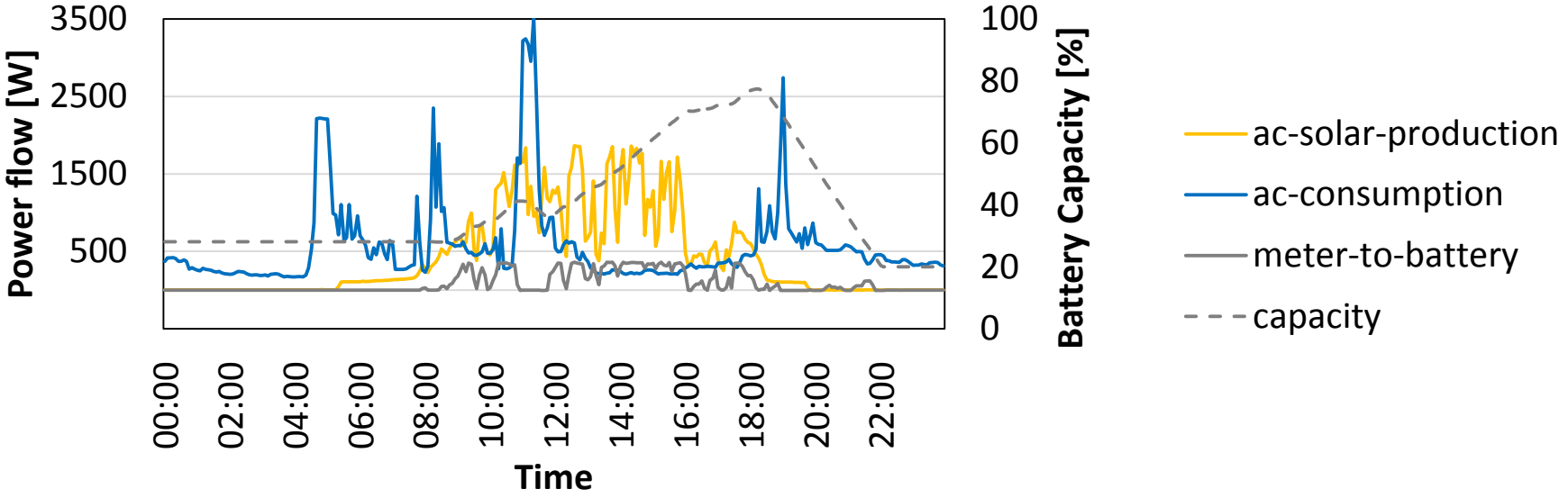
3.68kWp solar – 26/08/2017

The sudden increase in capacity is odd, but even without the issue the battery would be full before the end of the generation period.



- Despite battery capacity being low, strong solar production charges the battery quickly

2.7 kWp solar – 26/08/2017



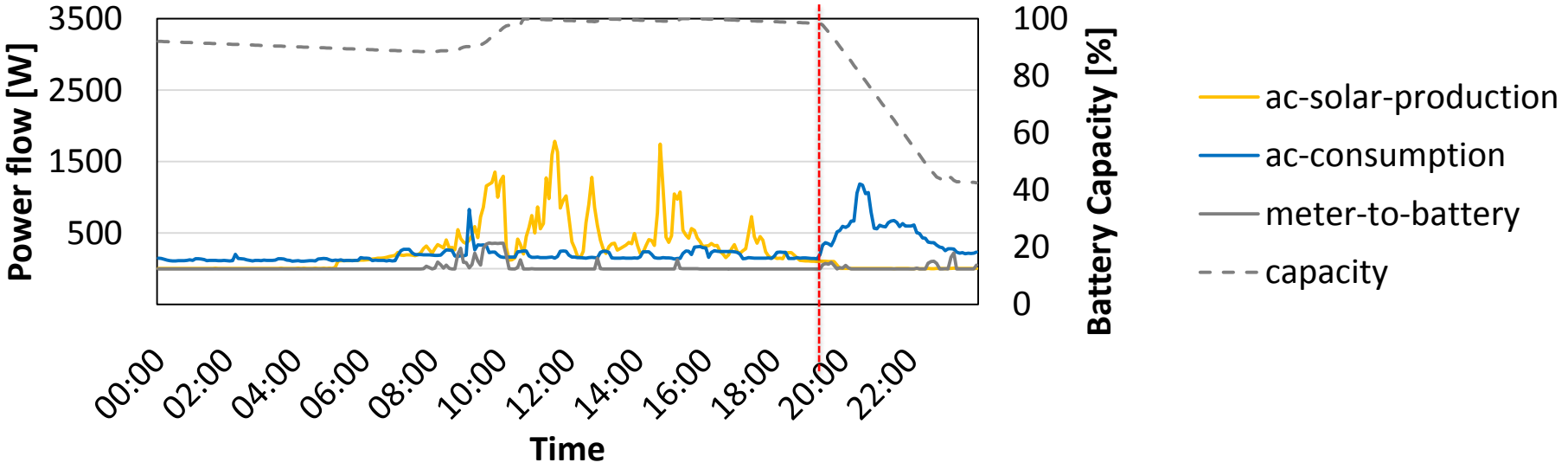
- Low battery capacity and high house consumption
- Store part of the generation over the entire period

Data Analysis

- The next slides discuss the impact of:
  - Battery capacity in the morning

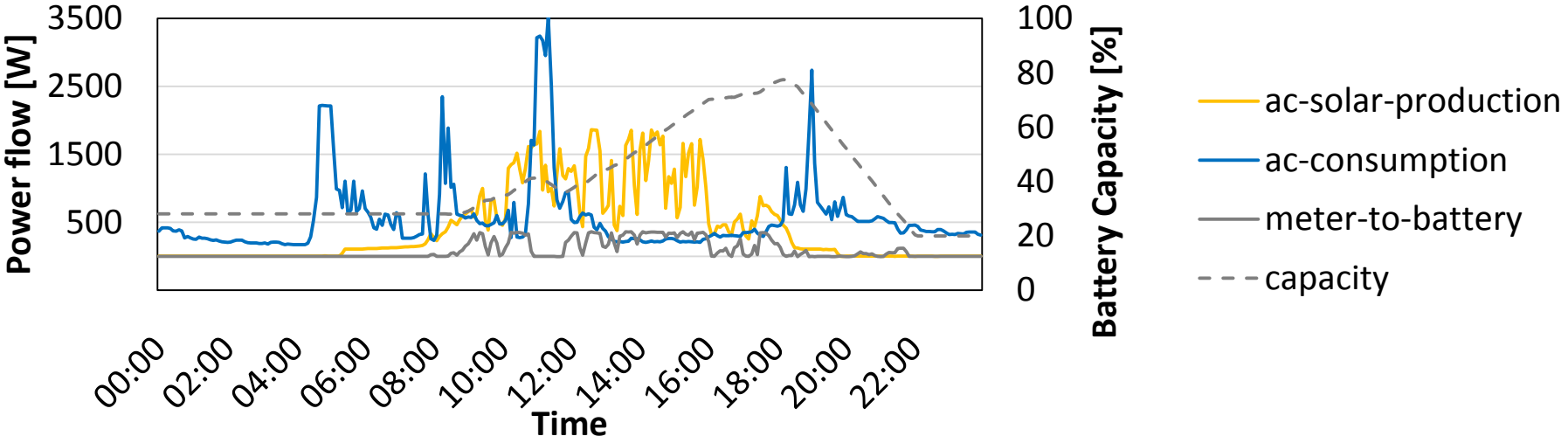
- All data is from house 07df50, for three different days: 24th, 26th and 28th of August 2017

24/08/2017



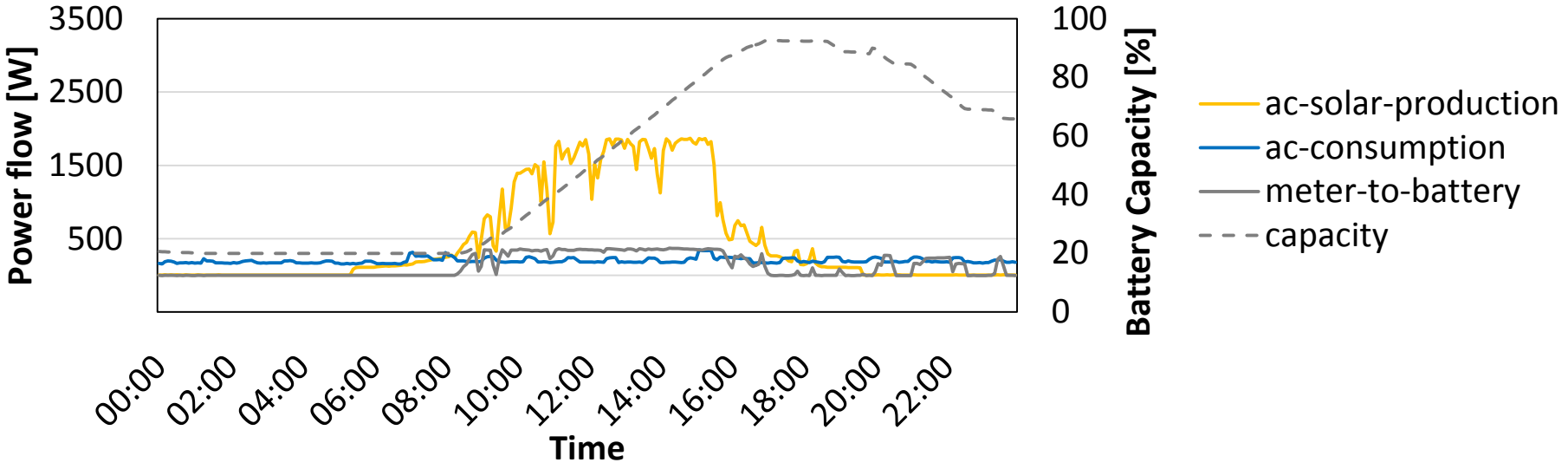
- Low consumption and high battery capacity
- Unable to store much of the generation

26/08/2017 (same as before)



- Strong consumption and a low battery capacity in the morning.
- Able to store part of the generation over the entire period

28/08/2017



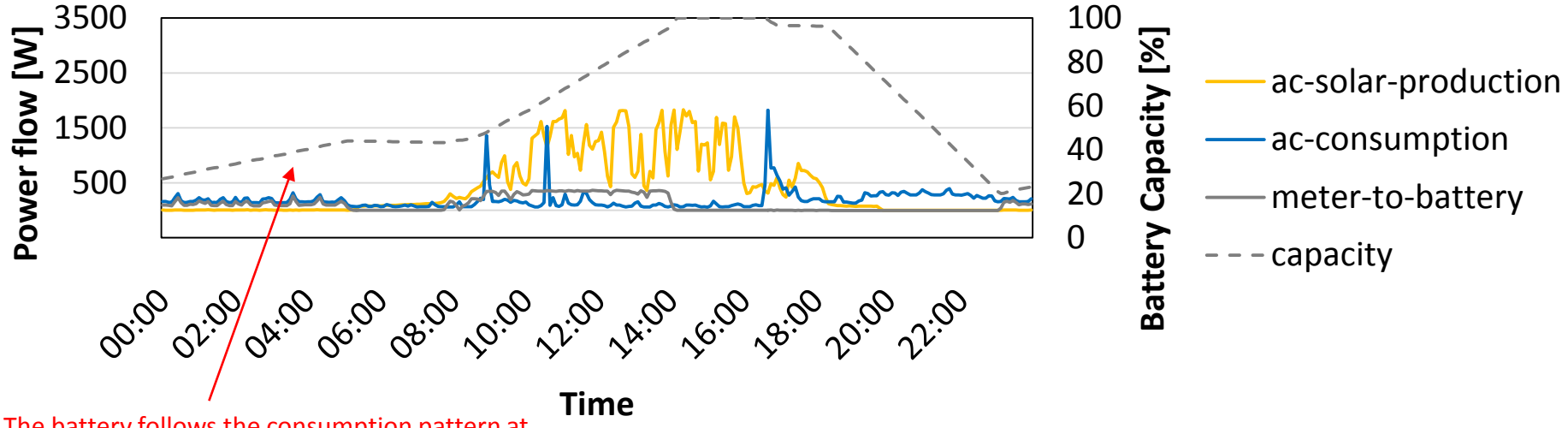
- Low consumption and a low battery capacity in the morning
- Able to store part of the generation over the entire period

Data analysis

- The next slides discuss the impact of:
  - Battery capacity in the morning

- All data is from house b0bfc4, for two different days: 26/08 and 28/08

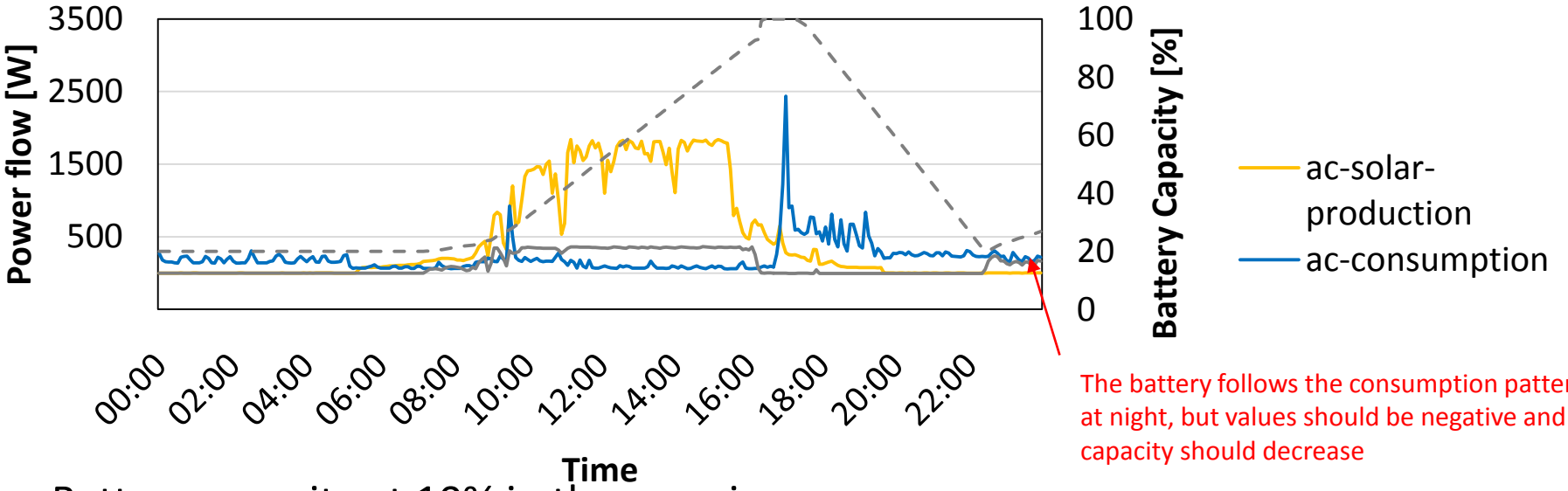
26/08/2017



The battery follows the consumption pattern at night which is odd.

- Battery capacity of nearly 50% in the morning
- Unable to store generation over the entire period

28/08/2017

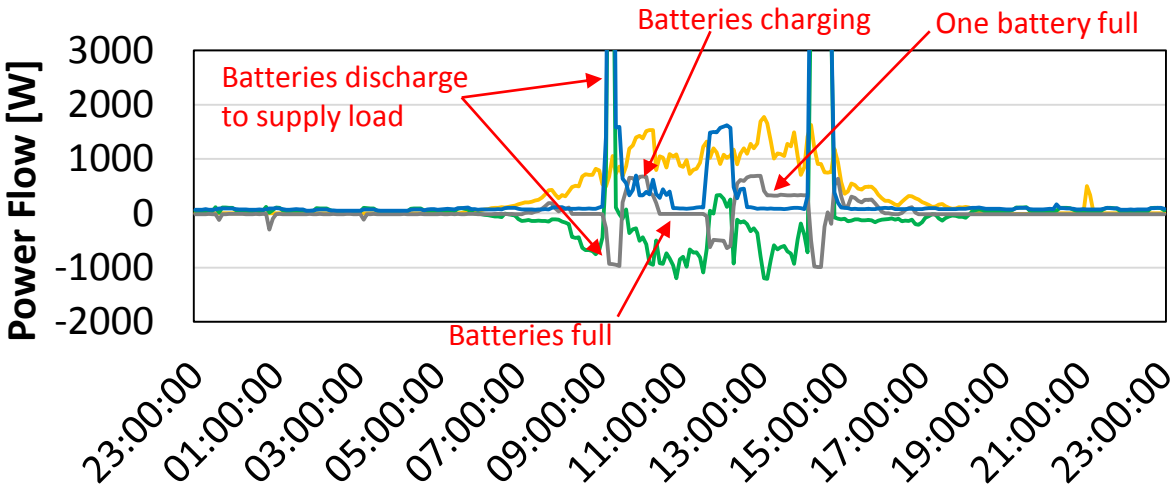


The battery follows the consumption pattern at night, but values should be negative and capacity should decrease

- Battery capacity at 10% in the morning
- Able to store part of the generation over the entire period.
- **Ensure battery is empty by the morning through an active agreement between DNOs & customers**

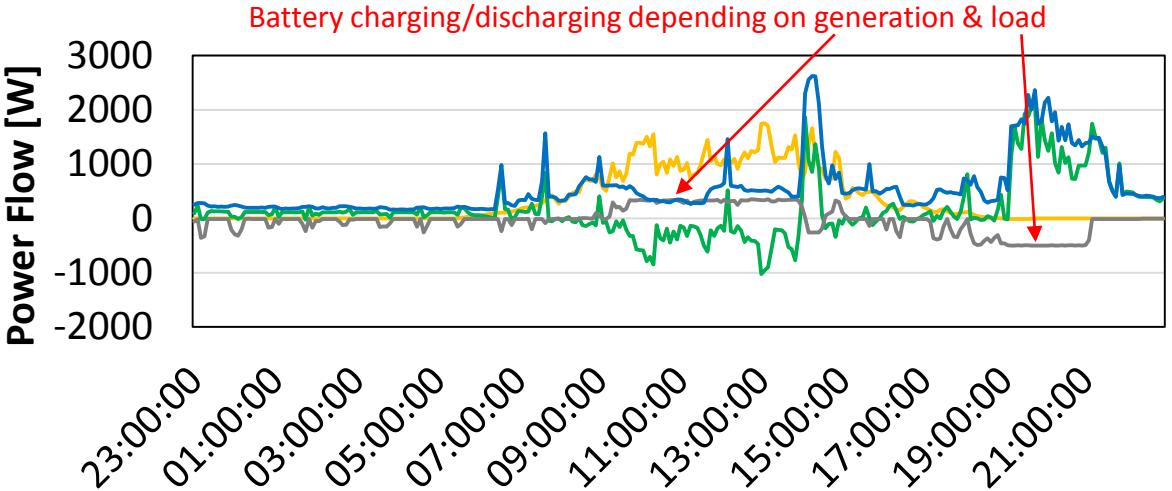
Data analysis

- The next slides discuss the impact of having two batteries installed



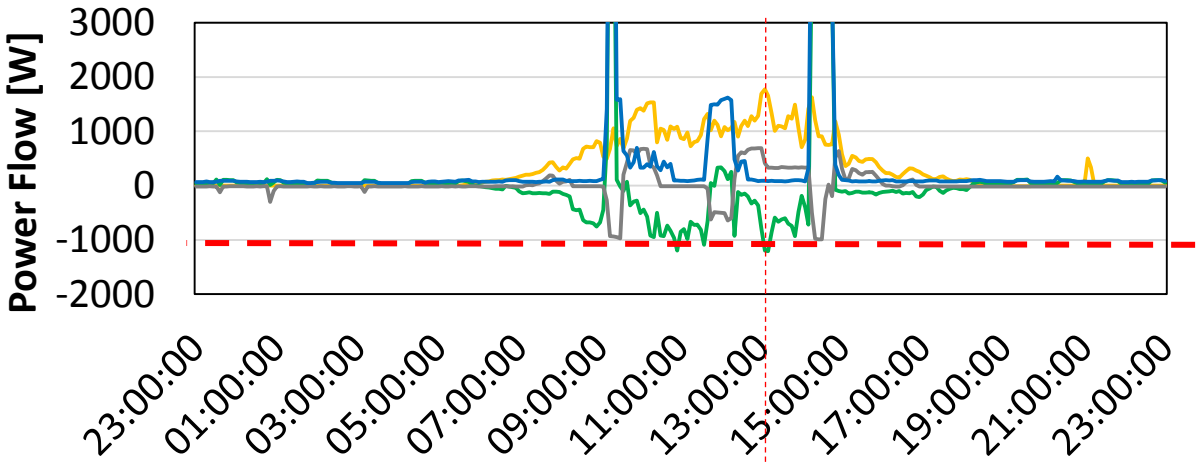
Household with two batteries installed - 25/08 0a7873 & 0c8efc

- smartrail/1 - PV
- smartrail/2 - Grid Import/Export
- core/power/dc/battery total
- core/power/ac/ac-consumption



07df50 - 25/08

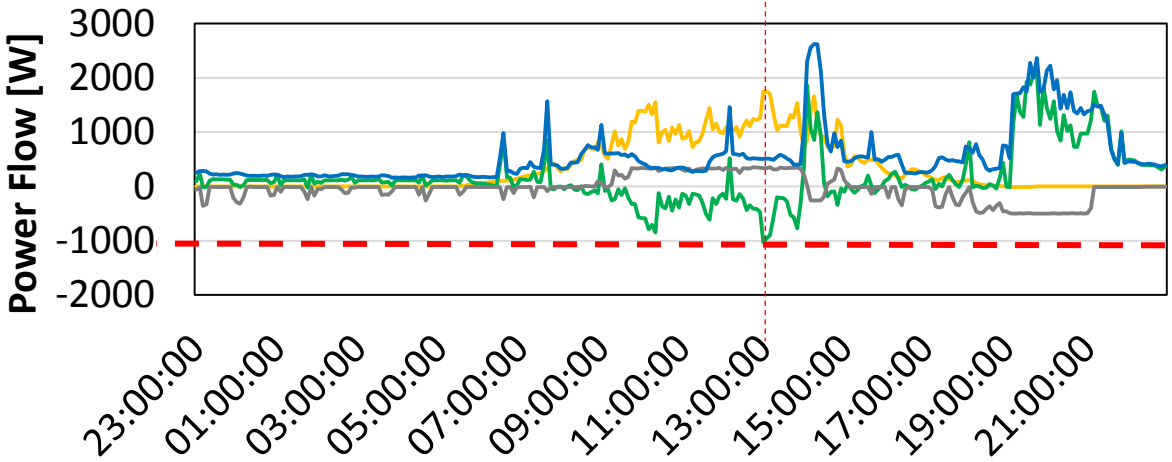
- smartrail/1/W - PV
- smartrail/2/W - Grid Import/Export
- core/power/dc/battery
- core/power/ac/ac-consumption



Household with two batteries installed - 25/08 0a7873 & 0c8efc

- smartrail/1 - PV
- smartrail/2 - Grid Import/Export
- core/power/dc/battery total
- core/power/ac/ac-consumption

At 13:00 the export of the two homes is similar, even though there is almost no consumption in the house with two batteries



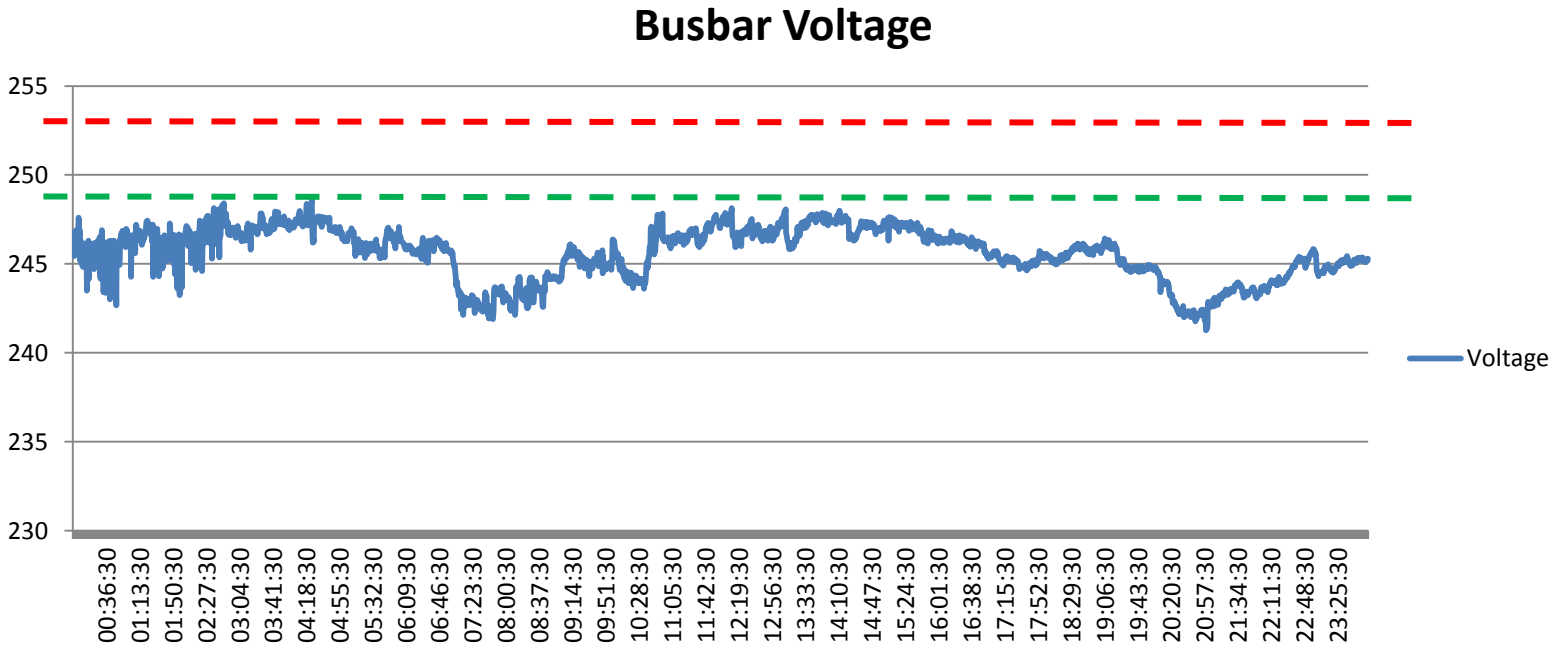
07df50 - 25/08

- smartrail/1/W - PV
- smartrail/2/W - Grid Import/Export
- core/power/dc/battery
- core/power/ac/ac-consumption

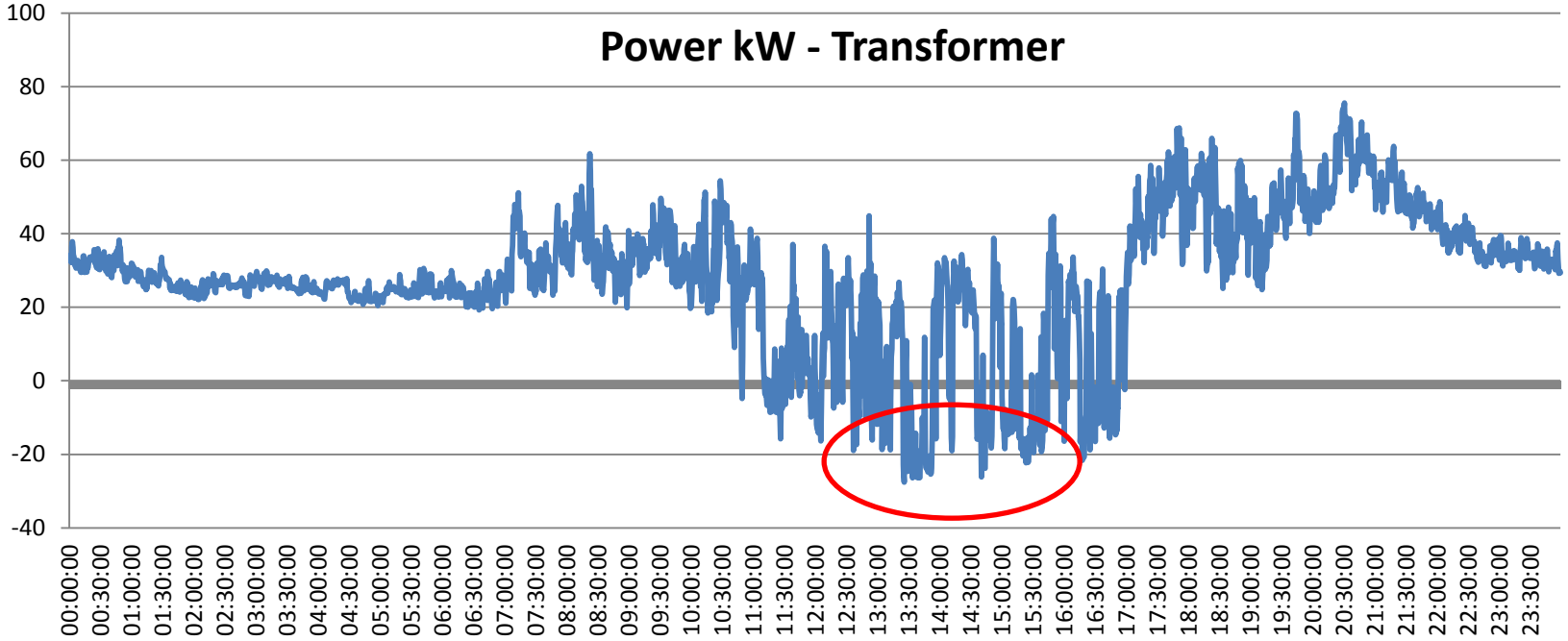
Data analysis

- What about the substation?

Distribution substation – 26/8/2017



Distribution substation – 26/8/2017



Thank you!

Any Questions?

G59 and G83

David van Kesteren

Senior Asset Management Engineer

G83 / G59 – Why two standards?

- Electricity Safety, Quality, Continuity Regs 2002 (ESQCR)
  - Section 22. Parallel operation of generation
- If LV connected and total installed generation is <=16A per phase (3.68kW single phase), customer does not need:
  - specialist knowledge / procedures
  - To comply with any site-specific connection requirements
    - Doesn't need to apply in advance
- But, customer must ensure that:
  - Equipment self-disconnects for loss of supply and meets current British Standard requirements (inherently safe)
  - Equipment complies with the DNO general connection requirements
  - Installer notifies the DNO at or before time of commissioning

G83 – domestic / small commercial

- G83 provides guidance for installers (and end customers) on how to ensure compliance with the ESQC Regs.
- Correctly installed equipment that has been manufactured in accordance with ER G83 will comply with the Regs
- G83 has a suite of simplified protection requirements and settings, which cannot be changed by the customer (preset in the factory)
- ENA holds a register of equipment that has been type tested by manufacturers in accordance with G83
- No need to apply, but need to notify

Multiple G83

- Clusters of small DG can cause voltage issues on the network
- Installer needs to apply (not notify) to allow DNO to check network
- If no reinforcement, installer can progress
- If reinforcement is required, installer may have to wait, or initally install less DG
- DNO pays for any network reinforcement and carries out work in a programmed manner

G59 – anything >=16A per phase

- Standard protection requirements are more complex
- Alternative protection settings may be required by the DNO in the future
- Site-specific connection requirements can be required
- Customer (or their installer) requires more expertise
- Type tested units have been developed for <50kW installations to simplify protection installation
  - ENA register of type approved equipment

G59 relaxation

- Where total installed capacity >16A per phase:
  - Customer must apply for a connection / modification
  - Customer must install G59 protection
- If customer applies to install multiple G83 compliant units then NPg will not insist on full G59 protection requirements
- Connection is still subject to an application and design study

Export Limiting Schemes

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Export Limitation Schemes (ELS)

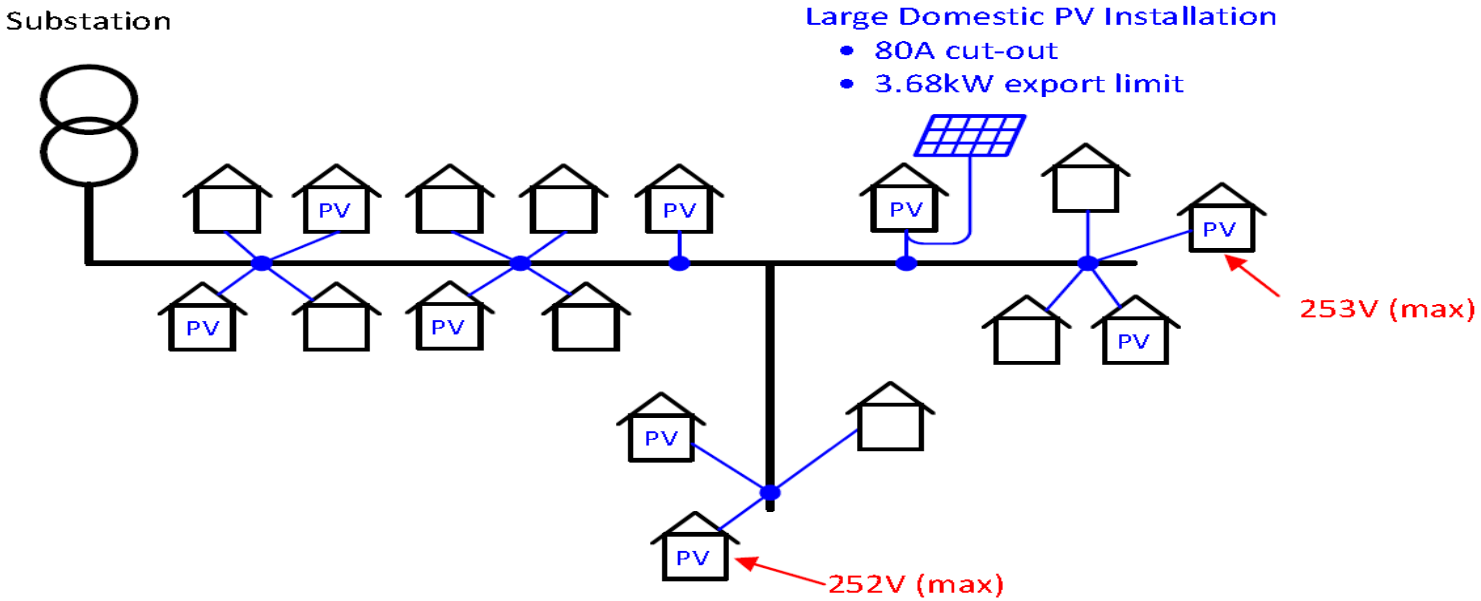
- Solutions for generators
  - where there is limited export capacity on the DNO network
  - network reinforcement is unviable in terms of cost and/or time
- Used for customer energy management
  - By letting over-sizing generation
  - Increased flexibility of onsite demand at peak
- Customer's controller diverts generated power into a load to avoid or limit export
  - Hot water immersion heater
  - Battery storage system
- Generator reduces output / turns off to ensure export agreement is not exceeded
- Can be set for zero export if required

Engineering Recommendation G100

- EREC G100 published in 2016 :
  - Guidance for customers as well as DNOs for connection of customer ELS operated in parallel to DNO systems
- Contains a functional specification for scheme requirements
- Customer responsible for proof of design and installation
- EREC G100 applies mainly to HV/LV; other voltages at discretion of DNO
- NPg COP for ELS; IMP/001/015 mirrors G100.
- Maximum Power Station Capacity (DG size) is smallest of the three:
  - Equipment Thermal Limit: Based on plant and equipment rating (mostly cut-out in domestic scenarios; default is 60A if info not available);
  - Protection Assessment: Limits the total generation to 125% of the highest of the import or export agreement;
  - Voltage Assessment: Limits the total generation so that highest network voltage to be no greater than “Statutory Voltage + 1%” i.e. 230V+1%=255.3V at LV.

Export Limitation Schemes (ELS) example

A domestic **Customer** wishes to install a PV system but the **DNO** has restricted the **Agreed Export Capacity** to 3.68kW due to concerns over voltage rise. The cut-out fuse rating is 80A. An **ELS** is to be installed so that the capacity of the PV installation can be maximised.



Export Limitation Schemes (ELS) example

Thermal Assessment:

The continuous rating of the cut-out and service cable are both in excess of 80A (18.4kW) and the 5s rating is substantially higher than this. The DNO determines that the thermal rating of the installation does not, in practice, limit the **Power Station Capacity**.

Protection Assessment:

The protection assessment restricts the **Power Station Capacity** to the higher of:

- 1.25 x **Agreed Import Capacity** = 1.25 x 80A x 230V = 23.0kW
- 1.25 x **Agreed Export Capacity** = 1.25 x 3.68kW = 4.6kW

The higher of the two values is 23kW.

Voltage Assessment:

The highest voltage that can be accepted on the **LV** network (during the 5s period before the **ELS** operates and restricts the export) is the upper **Statutory Voltage Limit** + (1% of the **Nominal Voltage**) = 253V + 1% of 230V = 255.3V.

The **DNO** calculates that when 10kW of generation is connected at the property the voltage at the end of the circuit reaches 255.3V.

Conclusion

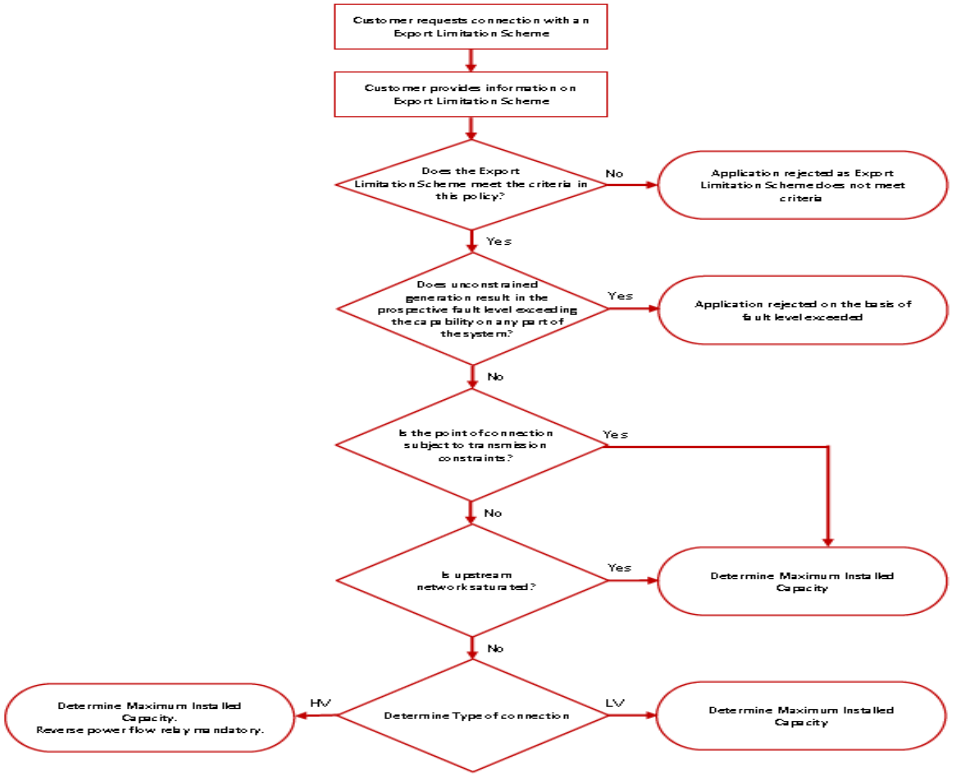
If an ELS is installed that limits the export to 3.68kW the maximum acceptable **Power Station Capacity** is the lower the results from the thermal assessment, protection assessment and voltage assessment. In this case the **Power Station Capacity**, i.e. the aggregate rating of the PV inverters, must be no higher than 10kW.

Export Limitation Schemes (ELS)

- Limitations due to fault level exceedance and any transmission still apply.
- Default export capacity for LV connections 16A per phase; greater than that with ELS must be fail safe.
- Reverse power protection required at HV metered connections as back up and at LV only if DNO deems the ELS is not fail safe.
- Overall ELS accuracy is customers responsibility determined by manufacturer of the ELS.
- ELS = within 5 sec operation.
- Back up systems must have +/-3% accuracy and operate within 5 sec.

Total generator size	Witnessed testing?
<3.68kW	Not required
3.68-50kW	Discretionary
>50kW	Compulsory*

ELS application flowchart



IET Code of Practice for Electrical Energy Storage Systems

David van Kesteren
Senior Asset Management Engineer

Published August 2017

- Purpose
  - Reference for practitioners
  - Understanding of the common terms and operating modes
  - Detailed info on all phases of design and operation
- Scope
  - Electrochemical (battery) storage systems…
  - …in low voltage power systems (AC and DC)
  - Industrial, commercial and domestic installations
  - Alignment with existing standards, regulations and guidance

Topics

- Components and architecture
- Operating states and applications
- Batteries
- Other system components
- Safety and planning considerations
- Specification and design
- **Network connection and DNO approval**
- Installation, inspection & testing
- Handover & documentation
- Operation & maintenance

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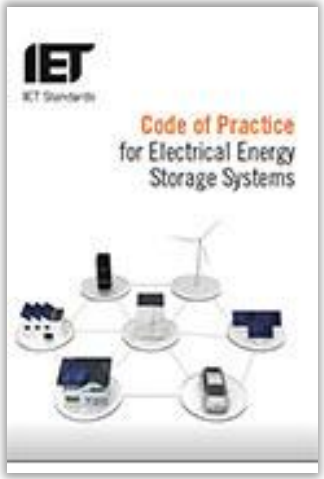

http://www.theiet.org/resources/standards/eess-cop.cfm?origin=video

Section 10 – Network connection

- DNOs consulted on process for getting connected
- Combination of on-site solar and storage often triggers G59
  - E.g. 2kW of solar, plus a 2kW storage (AC coupled) = 4kW total capacity
- Domestic storage can reduce network impact of other on-site DG (eg peak output from solar) if designed and installed correctly
- DNOs recognise benefit at domestic level and want to make the application process easy and slick
- **A fast-track process will be developed for simple DG / storage combinations (up to 16A for DG and 16A for storage)**

EREC Fast Track Process

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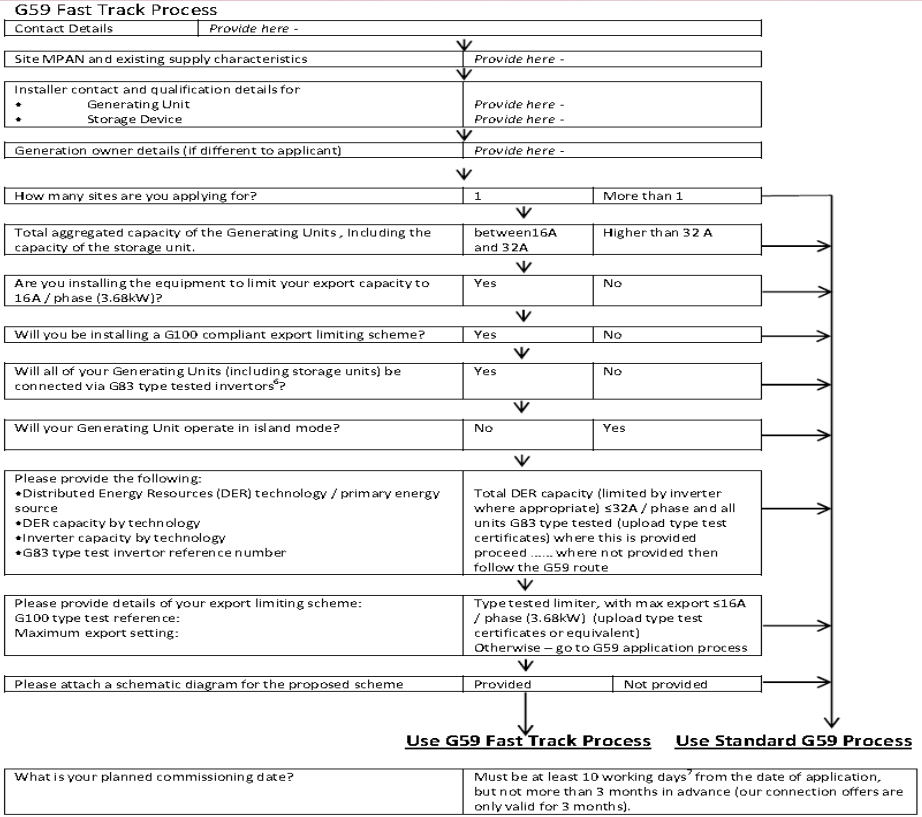
Aims

- To facilitate and expedite the LV connected small scale energy storage.
- Current 45 day GSoP timescales for providing LV generation quote; bit excessive for small scale storage.
- Short term process change; keeping in mind the possible long term solutions.
- Improve customer experience, project viability without sacrificing visibility.

G59 fast track process



- Typically 1ph connections with existing or new G83 DG and G83 storage via separate invertor would be G59: 45d.
- Installation complies with requirements of EREC G100 and export limited to 16A/ph.
- Upper limit for total generation being 32A/ph (16A for DG & 16A for storage) under fast track process to minimize risks to networks.
- Fast track application applies with automated approval within **10 days rather than 45 days.**
- EREC G100 changes pending.

Connection application summary

	Installation Type	Type of Application Required[1]	Network Impact Assessment Required[2]	EREC G59 Witnessing Required	Export Limiting Scheme Designed to EREC G100	EREC G100 Witnessing Required
1	LV installation where total aggregated Energy Sources are ≤ 16A/phase and use Type Tested Inverters	EREC G83 Stage 1	No	No	No	No
2	Multiple LV installations where total aggregated Energy Sources are ≤ 16A/phase and use Type Tested Inverters	EREC G83 Stage 2	Yes	No	No	No
3	LV installation where total aggregated Energy Sources are > 16A/phase but Generation is ≤ 16A/phase and Energy Storage is ≤ 16A/phase and all use Type Tested Inverters[3] but export is limited to a maximum 16A/phase	EREC G59 *Fast Track*	Automated/ Fast-tracked	No	Yes	No
4	Multiple LV installations where total aggregated energy Sources are greater than16A/phase but Generation is ≤ to 16A/phase and Energy Storage is ≤ to16A/phase and all use Type Tested Inverters[3].	EREC G59	Yes	No	Yes if material impact on the network	First Device (if material impact on the network)
5	LV installation where total aggregated Energy Sources are > 16A/phase but ≤ to 50kW/17KW three/single phase and all use Type Tested Inverters and do not meet the requirements of 3 or 4 above[3].	EREC G59	Yes	Not normally, but at the discretion[4] of the DNO[5]	Yes if material impact on the network	Not normally, but at the discretion[4] of the DNO[5]
6	LV installation where total aggregated energy Sources are greater than 50kW/17KW three/single phase and all use Type Tested Inverters[3].	EREC G59	Yes	Yes normally, but at the discretion[4] of the DNO[5]	Yes if material impact on the network	Yes normally, but at the discretion[4] of the DNO[5]
7	HV & EHV Installations of any size.	EREC G59	Yes	Yes[5]	Yes if material impact on the network or managed MECs	Yes[5]

[1] All non-type tested equipment requires a G59 application regardless of size. With the exception of G83 Stage 1 all applications require consent from the DNO before connecting.
[2] All non-type tested equipment requires a network assessment regardless of size.
[3] Under G5-4-1 Customer's LV Equipment having an Aggregate Load or Rated Current greater than 16 A per phase will need to comply with the emission limits of Stages 1 or 2 of IEC Technical Report 61000-3-4 may to allow connection without assessment, subject to the fault level at the point of common coupling being at least equal to the minimum value required in that Technical Report.
[4] The DNO may choose to witness, or waive its right to witness, depending on previous experience with developer, and the overall impact of the scheme on the network.
[5] The DNO shall charge the generator for attendance of staff, for witness testing at its own commercial rates.

Close

Thank you for your participation.