# Open Networks Project

OTS Functional Design and Data Exchange Requirements Report

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WS1B P3
Real Time Data Exchange and Forecasting

## DOCUMENT CONTROL

### Authorities

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TABLE OF CONTENTS

# 1 Introduction

## i. Open Networks Project

The Open Networks (ON) Project is a major industry initiative that will transform the way our energy networks operate, underpinning the delivery of the smart grid. The project looks to change how the networks operate to facilitate the transition to a smart, flexible energy system. A key objective is to bring consistency in approaches across networks through existing and new processes to support the transition to Distribution System Operations, interactions with each other and interactions with customers. Open Networks is being delivered through a number of Workstreams and Products.

Workstream 1B of the ON project focuses on Planning and Forecasting activities. These include Product 3 on Real Time Data Exchange which is intended to cover the data exchange requirements to manage whole system activities including Operational Tripping, Connect and Manage arrangements and Service Conflict Management.

## ii. Scope of this report

This report covers initial work on N-3[1] Operational Tripping Scheme (OTS) arrangements being implemented on DNO networks to enable the tripping of Distributed Energy Resources (DER) for faults on the GB transmission network.

The 2020 Project Initiation Document for the ON project includes the following scope for Product 3 work on OTS arrangements. A report on activity 1 to document OTS requirements including functional and data exchange requirements is due to be completed by June 2020. The work on OTS arrangements are covered by activities 2 and 3 below:

**Table 1 – OTS Activities 1, 2 and 3.**

[1] An N-3 condition in transmission network is defined as a circuit is on planned outage followed by a double circuit fault reducing the transmission capacity by 3 circuits

| Ref | Product Element | Activities | Deliverables |
|---|---|---|---|
| 1 | Identify data exchange specifications & implementation plan for Whole System activities based on Regional Development Programme (RDP) outcomes.<br><br>(This will draw on the implementation of OTS, C&M and Service Conflict Management solutions through RDPs.<br><br>There is a dependency on ESO-DNO commercial agreements.)[2] | **[A]** Operational Tripping Scheme (OTS) design & specification to secure N-3 contingencies on the transmission network.<br>1. Document OTS requirements including functional & data exchange.<br>2. Review the OTS algorithm and review trial results.<br>3. Review end-to-end ESO-DSO system integration and go-live.<br>This work will draw on ongoing OTS work including implementations in the UKPN, WPD and SSEN areas. An initial report will focus on activity 1. This will be extended to cover activities 2 and 3 when OTS implementations are further progressed. | Activity 1 Report Jun 2020<br><br>Activities 2 & 3 Report Nov 2020 |

## iii. Structure of this report

This report is focussed on the requirements for data exchange as identified for ongoing OTS projects. Section 2 of the report recaps the position laid out tin the 2019 report for Workstream 1B Product 3 including the agreed approach to operational tripping arrangements and high level descriptions of the scheme architectures and data exchange requirements.

Section 3 provides more detailed descriptions of the OTS arrangements being installed in the UKPN, SSEN and WPD distribution areas. Section 4 details the performance requirements for OTS arrangements and the data exchange associated with these arrangements.

Section 5 brings out conclusions in respect of the different implementations including areas where a similar or standard approach is being agreed and areas where differences are evident. Emerging good practice is highlighted together with problems that have been identified to date.

In line with network company undertakings to consider where data can be made more transparent, Section 6 considers whether the data being handled for OTS arrangements would have wider value to industry stakeholders and the extent to which the data can be shared more widely.

[2] Progress on certain RDP activities through 2020 is dependent on commercial arrangements being agreed in respect of how services are used. This dependency does not apply to the OTS work.

# 2 OTS Basics and Recap of 2019 Work

## i. Introduction to OTS Arrangements

Historically, OTS arrangements have been used to allow transmission connected generation to operate freely pre-fault in systems where post-fault transmission capacity is limited. In the event of defined network faults occurring, an intertripping signal is sent to certain generators to remove a predefined volume of generation post-fault and so manage thermal, voltage or stability issues. As the generation output would be reduced only in the event of a network fault occurring, the generation will operate freely for most of the time. It is worth noting that the defined network faults, and therefore the activation generation intertripping, are very infrequent events. Historical data shows that a particular double circuit fault in the transmission system is typically a 1 in 100-year event. The double circuit fault happening during another single circuit outage (the N-3 scenario) makes it an even smaller probability event.

With increasing levels of DER being connected to networks, as part of the Regional Development Programmes (RDPs) between NGESO and DNOs, OTS arrangements are being extended to utilise DNO network management systems to curtail DER output under certain N-3 transmission conditions to manage thermal overloads. As well as easing real-time transmission capacity limits, this will increase the connection capacity that is available to DER in an economic fashion. This is an effective alternative to more extensive transmission reinforcements that are likely to take several years to complete.

UKPN, NGESO, WPD and SSEN have jointly agreed to implement N-3 OTS arrangements to curtail DER output following specific faults on certain parts of the transmission network on a ‘trial by doing’ basis. This approach will ensure that regional demand remains secure and avoids scenarios whereby the transmission network could be thermally overloaded under certain N-3 transmission conditions. The three DNOs and NGESO have agreed to implement a “Capped Generation Approach” as part of their RDPs. This approach is based on capping generation in the GSP that has agreed to be curtailed through connection agreements.

It is important to highlight that Operational Tripping will only be used to secure double circuit faults which coincide with other outages on the transmission system. In other words an N-3 condition is a rare event. The transmission network will be secured in line with both the Connect and Manage criteria and the security and quality of supply standards (SQSS) which will rely primarily upon the use of-DER flexibility followed by the N-3 OTS scheme where appropriate.

## ii. Capped Generation Approach

In broad terms, under the Capped Generation approach, if DER curtailment is required post-fault, NGESO would send the DNO a CAP per Grid Supply Point (GSP) (see Figure 1) to ensure that the post-fault transmission boundary capability would not be exceeded. The DNO’s control system would subtract the CAP from the total DER generation behind that GSP to determine the curtailment required for N-3 events affecting that GSP. For example, if GSP1 has 95MW total DER capacity and NGESO sends a CAP of 70MW, to determine the curtailment required for N-3 under that GSP, the CAP of 70MW is subtracted from the total DER capacity of 95MW (95MW-70MW=25MW). To achieve this curtailment of 25MW at GSP1, the DNO control system could send a 10MW curtailment signal to Solar1_1 and a 15MW curtailment signal to Solar 1_2.

As well as the Capped Generation Approach, other logics could be used to curtail DER, for example, predefined MW blocks and delta MW reduction. The Capped approach is preferred as it fits well with existing NGESO processes and allows unconstrained DNO system operation pre-fault including ANM system operation.

The cap for each GSP applies to the generation in the GSP that has agreed to be curtailed through connection agreements and that is part of DNO control arrangements. The cap does not affect all of the distributed generation connected to the GSP as many of the previously connected generators do not have agreements which allow output to be curtailed.

Under the Capped Generation Approach, NGESO would send the required MW values to the DNO as an instruction from an iEMS screen via an ICCP link. This enables the DNO to act on the instruction automatically if it chooses to do so. The DNO control scheme is designed to achieve an overall response time and the DNO must also ensure that OTS actions are not countermanded by other real-time systems acting on the generation, such as ANM schemes.

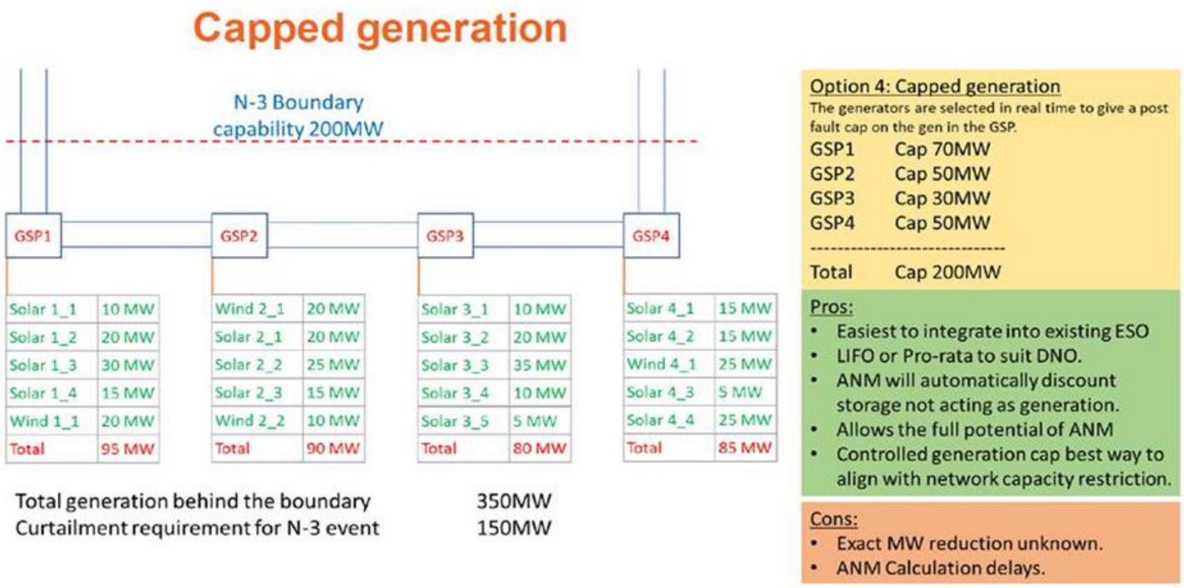



Figure 1 – Capped Generation Approach.

The design and development of the N-3 OTS algorithm with a Capped Generation Approach began in June 2019 between UKPN, SSEN, WPD and NGESO.

## iii. Scheme Architecture and OTS Stages

To manage transmission constraints post-fault using DER, a system is needed to curtail DER quickly by automatic action in the event of an N-3 condition reducing the transmission capacity available in real time. The approach being adopted extends the existing OTS capabilities in such a way that allows managed curtailment of DER. Signals will therefore be sent on a per GSP basis to DNO control systems to curtail generation behind the required GSPs. To enable the successful deployment and utilisation of this new capability, NGESO will instruct the DNO on the requirements for generation curtailment via an ICCP link and DNO RDP partners are fully automating their response to such instructions.

Figure 2 shows the overall communications architecture of the N-3 intertripping system and the 4 key stages to the process – prior to arming, arming, tripping/triggering and disarm/restore. Implementation of these stages can differ from region to region depending on the systems in place. This is discussed further in section 3.

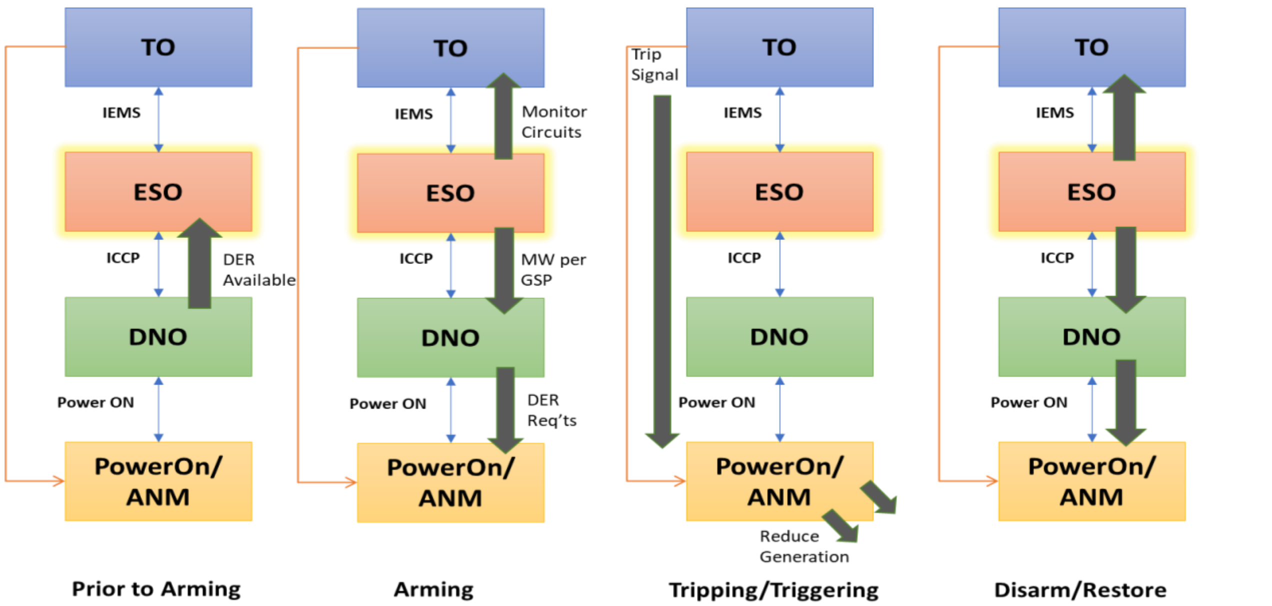



Figure 2 – High Level OTS Architecture and Data Flows.

"***Prior to arming***" (i.e. steady state), the DNO will provide visibility of all DER generation available to be curtailed under each GSP to NGESO. NGESO will continue to monitor the outputs and system conditions.

At the "***arming***" stage, NGESO identifies a possible N-3 event and requests the DNO for a MW volume to be available for reduction on a per GSP basis. At this stage, this is a request to be ready and the DNO control system will not curtail generation. After the generation is made available to be reduced, NGESO will instruct the TO OTS to start monitoring circuits for N-3 outage combinations and enable any transmission outages to be released.

The third stage is the "***tripping/triggering***" phase where, if the fault occurs on the transmission system, a trip signal will be sent from the TO OTS to the DNO control system. Upon receipt of the TO trip signal, the DNO control system will have an agreed duration to reduce the generation to the cap level set at the arming stage.

The fourth stage is to "***disarm/restore***" when the conditions on the transmission system no longer present a risk of an N-3 event. If there is no longer a requirement for the OTS to be armed as system conditions have changed, NGESO will coordinate the disarming of the OTS. If the OTS has operated to curtail generation and system conditions have changed so that curtailment is no longer necessary, then the generation will be restored.

As noted previously, an N-3 event and therefore the activation of the third stage (generation tripping) does not happen very often. The occurrence of a particular double circuit fault in the transmission system is typically a 1 in 100-year event and occurrence during another single circuit outage (the N-3 scenario) makes it an even smaller probability event.

## iv. OTS Performance and Data Exchange Requirements

The OTS will only include DER resources that can be controlled by the DNO and that have had intertripping requirements placed on them through respective Bilateral Connection Agreements (BCAs). It is not proposed to include generators that were connected prior to the inclusion of these specific terms and conditions.

DER resources that are part of an OTS scheme might be quickly tripped or ramped down to meet the OTS requirement. Much of the N-3 OTS infrastructure is being built such that a single software or hardware failure will not result in the whole system being unavailable, though there are some exceptions to this due to cost benefit considerations. For example, the individual DER connectivity to DNO ANM/PowerOn system does not have dual redundancy. The OTS design and level of redundancy is intended to make the operational intertripping of DER equivalent to transmission protection arrangements and will allow NGESO to utilise it in managing the whole system.

To make the OTS arrangements work, a number of data points are expected to be exchanged between the ESO, TO and DNOs. At a high level it is summarised as follows:

- DNOs will share real time controllable DER at each GSP with the ESO. This will be via ICCP link.
- The TO will share outage and circuit status information with ESO. This is a business as usual process.
- The ESO will send arming and restore instructions to the DNO and TO.
- The TO will send trip signals to the DNO via a dedicated link.

OTS performance and data exchange are considered further in section 4 of this report.

## v. Implementation and System Integration

Currently, OTS arrangements are being implemented on the south coast where transmission constraints for certain N-3 conditions are either exacerbated by increasing DER volumes alongside other causes such as HVDCs and offshore wind connection to transmission network. UKPN, WPD and SSEN are working with NGESO and NGET to implement N-3 intertripping arrangements. UKPN already have an ICCP link with NGESO and WPD and SSEN are implementing similar links. At the same time, NGET is working with the DNOs to establish dedicated trip signal links from its OTS systems (Sellindge OTS in the South East and Melksham OTS in the South West). The first OTS will be operational from late 2020 in the South East followed by the South West in Q4 2021.

# 3 Description of Ongoing OTS Projects

The areas to be covered by the 3 OTS projects are shown in Figure 3. NGESO and NGET have developed the transmission OTS arrangements at Sellindge and Melksham so that these also can provide signals to DNOs if any of the N-3 combinations arise. These signals are then used to initiate curtailment of distributed generation that has agreed to be connected as part of an OTS arrangement. With these OTS arrangements in place, the pre-fault transmission capacity into the South East, the South West and along the South Coast will be increased.

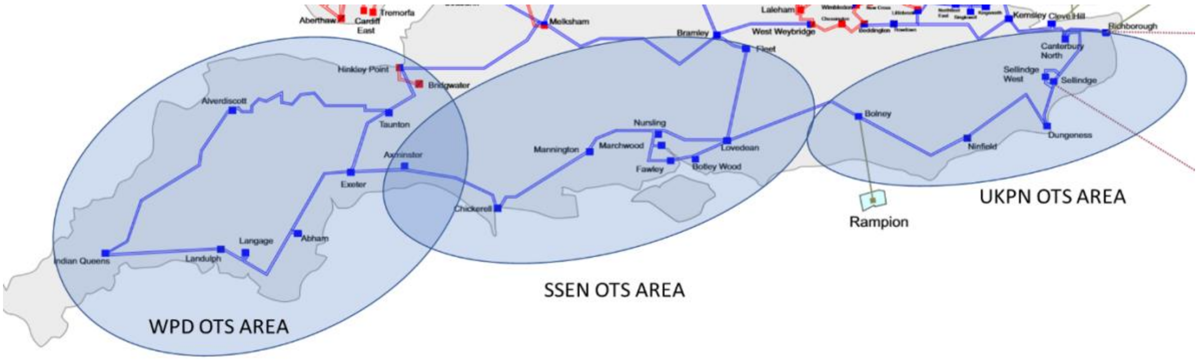



Figure 3 – Areas Covered by OTS Arrangements

## i. Transmission OTS Capability and Interface Development

As noted in earlier sections, the N-3 functionality relies on the ability for NGESO to be able to send curtailment caps to GSPs in each DNO area, coupled with the development of the necessary trip links between existing OTS schemes and the respective DNO SCADA systems.

To achieve this overall functionality, NGESO has had to develop additional capability within core SCADA systems and increase the amount of data sent over ICCP links with each DNO. New SCADA screens have also been developed which enables better overall visibility and control of the DER that will be subject to the N-3 conditions and is one of the first such developments in this area. In addition, business processes and project-specific training has been provided to key resources within the planning and operational control functions to ensure successful delivery of the project outcomes.

NGET have also had to develop additional capability across two existing OTS schemes to ensure the correct transmission apparatus is monitored and the trip signals are generated in accordance with the allowable timescales and post-fault ratings of the transmission network. To achieve this work, NGESO, NGET and the DNOs have collaborated closely to ensure the appropriate transmission system outages were scheduled, specific contractor resource was made available and commissioning activities were co-ordinated. These activities have further demonstrated the ‘whole system’ nature of this project and have laid the foundations for further work in this area, incorporating lessons learnt so far.

## ii. OTS Scheme in UKPN Area

This OTS is being delivered through the NGESO-UKPN Regional Development Programme. It utilises the existing transmission OTS at Sellindge and is intended to help secure critical transmission outages on the double circuit 400kV route from Kemsley through to Bolney. In addition, it means that DERs have continued access to the distribution network capacity without the need for costly transmission network reinforcement. The OTS will cover five GSPs on the South Coast including Bolney, Ninfield, Sellindge, Canterbury and Richborough (once fully commissioned). The UKPN interface substation is at Sellindge.

It is anticipated that around 300MW of DER resources will be available via the OTS arrangements by the end of the ED1 in March 2023. A further 400MW of DER resources could be added during the ED2 period. The generators included in the scheme have agreed to this through their connection agreements and a full list of the generators for each GSP is being maintained through NGESO-UKPN BCAs for the relevant GSPs (Appendix G of the Bilateral Connection Agreement which is updated every month to capture new connections).

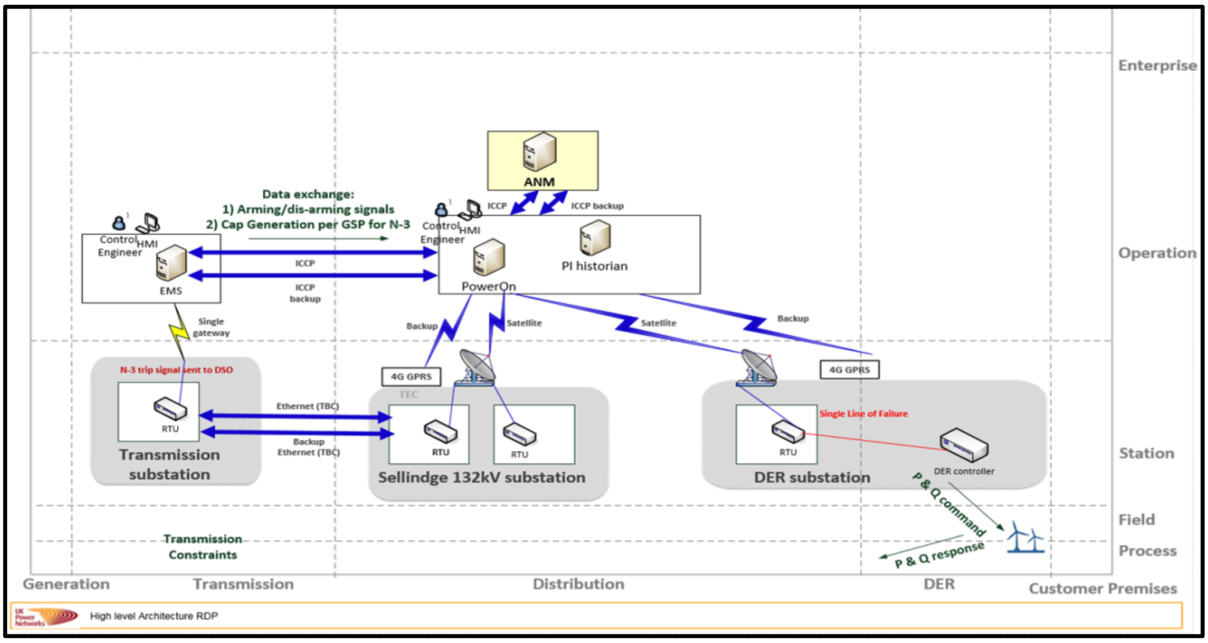



**Figure 4 – UKPN OTS Scheme Architecture**

The UKPN OTS architecture is illustrated on Figure 4. Co-ordination of the DNO OTS operation is being achieved by extending UKPN's Distribution Management System (DMS) PowerOn functionality.

Data Exchange from UKPN to NGESO is via an ICCP Link. (There is an existing ICCP link between NGESO and UKPN in the SPN license area.) UKPN will send the aggregated MW level of generation available to be tripped per GSP to NGESO. Data will be sent on a near real time basis at an interval of 10 seconds. If the UKPN RTU metering data is not updated, a repetitive value will be sent.

Reduction in DER generation output will be achieved via SCADA through tripping of UKPN circuit breakers. PowerOn is also being configured to interact with ANM arrangements to ensure that the ANM system acts in line with the OTS requirements.

Considering the 4 key stages of the intertripping process – prior to arming, arming, tripping/triggering and disarm/restore:

**Table 2 – Four stages of the intertripping process**

| | |
|---|---|
| Prior to Arming | UKPN will provide visibility of the DER controllable generation available to be curtailed at each GSP to NGESO. NGESO will monitor the outputs and system conditions. |
| Arming | NGESO identifies a possible N-3 event and requests UKPN for MW volumes to be available to be reduced per GSP. (PowerOn will not actually curtail any generation at this stage.) NGESO will also instruct NGET to start monitoring circuits for fault outages. |
| Tripping/Triggering | If the relevant double circuit fault occurs, a trip signal will be sent from the NGET OTS to UKPN's DMS System (PowerOn). On receipt of the trip signal, PowerOn will have an agreed duration to reduce the generation to the cap level set at the arming stage. Currently the agreed timescale is 30 seconds. |
| Disarming/Restoring | When system conditions are back to normal, NGESO will coordinate the process of resuming normal system operation. |

Implementation & System Integration

The OTS is being implemented on the South Coast where transmission constraints for certain N-3 conditions are exacerbated by increasing DER volumes UKPN already have an ICCP link with NGESO.

As of November 2020, NGESO, NGET and UKPN had worked through a programme of testing to prove end-to-end capability and the OTS achieved go-live on 20th November 2020. Further information on OTS testing and lessons learned is provided in section 7 of this report.

## iii. OTS Scheme in SSEN Area

This OTS is being delivered through normal connection process arrangements using RDP concepts. It utilises a new transmission NGET OTS at Melksham and is intended to help secure transmission outages on the double circuit lines that support the South West and South Coast (Bramley-Fleet-Lovedean etc). The OTS will cover eight GSPs including Axminster, Botley Wood, Chickerell, Fawley, Fleet, Lovedean, Mannington and Nursling. The SSEN interface substation will be at Fleet and it is anticipated that upwards of 1000MW of DER resources will be available via the OTS arrangements.

The Appendix G process allows National Grid to set additional capacity limits at GSP sites, providing new generation can be controlled and curtailed in response to transmission network issues such as an N-3 scenario. This enables increased connection capacities at GSPs.

To provide the OTS functionality and control the new generation, SSEN are implementing a wide area ANM system which would present a T-D (Transmission to Distribution) interface, monitoring and control functions at generator sites and an overarching control mechanism to facilitate the trimming/tripping of generation across multiple sites to meet the requirements of the transmission network conditions. This system is known as the South West Active Network (SWAN) scheme. The SWAN scheme will interface with SSEN's DMS (PowerOn) to provide alarm and status indications for the OTS.

When the OTS is to be armed, NGESO will notify SSEN via an ICCP link of the MW Cap per GSP. In the event of a transmission circuit trip, the NGET OTS sends trip signals to the SWAN system at Fleet for each GSP at which DER is to be deloaded.

SSEN's implementation of generator curtailment at each GSP is based on a LIFO approach. Signals are sent to selected DERs to ramp down to new generation set points. If this is not achieved within 25 seconds, a trip signal is sent to the DNO circuit breaker to ensure that the generation output is reduced within the agreed timescale of 30 seconds.

The architecture for this scheme is illustrated on Figure 5 below. A process diagram illustrating the interactions between NGESO, NGET, SSEN and the DER is shown in Appendix A.

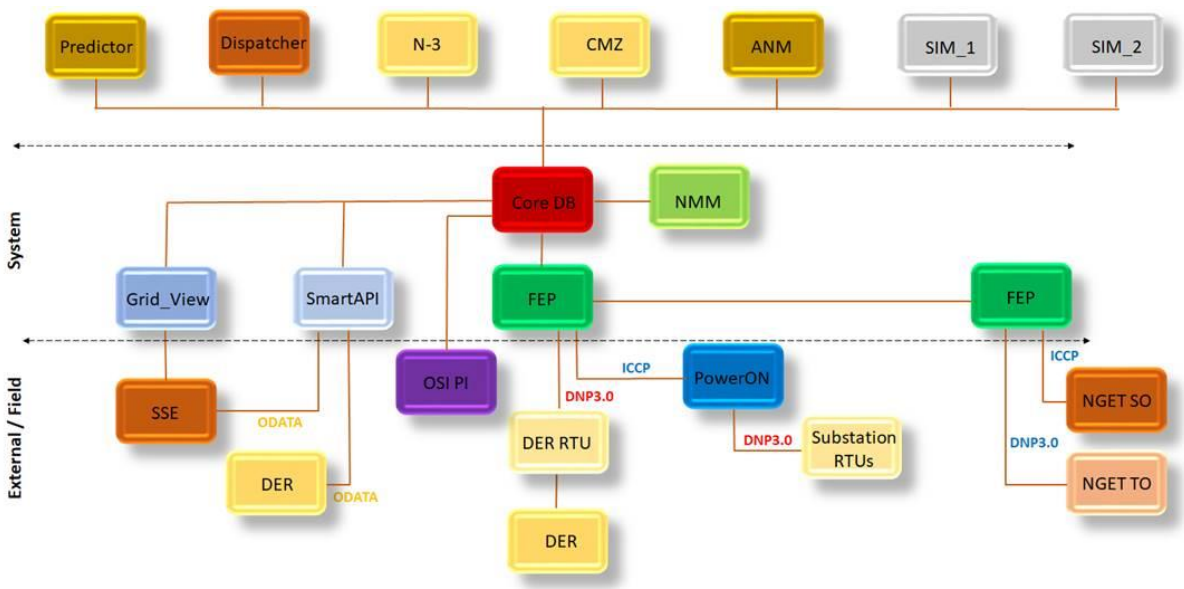



**Figure 5 – SSEN OTS Scheme Architecture**

Implementation & System Integration

With respect to progress, SSEN are completing installation of ANM software. ICCP and DCP3 links have been configured in readiness for testing. Test case development should begin in July 2020. Installation of OTS functionality at generator sites is scheduled to begin in August. By September 2020, N-3 functionality is to be complete across all 8 GSPs with interfaces to the Distribution Management System, the TO and the first two generator local ANM controllers completed.

Overall scheme completion is dependent on the ICCP cable installation. This will take around 12 months such that go-live is likely to be during summer 2021.

## iv. OTS Scheme in WPD Area

This OTS is being delivered through the NGESO-WPD Regional Development Programme. It utilises the new transmission OTS at Melksham and is intended to help secure transmission outages on the 400kV double circuit routes that support the South West (Melksham-Hinkley Point-Taunton, Mannington-Chickerell-Exeter etc). The OTS will cover eight GSPs in the South West including Abham, Alverdiscott, Axminster, Bridgewater, Exeter, Indian Queens, Landulph and Taunton. The WPD interface substation will be at Taunton.

It is anticipated that a maximum of 550MW of aggregated and controllable DER will be available via the OTS arrangements; noting that this maximum is based upon each generator exporting at their maximum capacity.

Co-ordination of the DNO OTS operation will be achieved by extending WPD's PowerOn functionality. Deload or tripping of DER's will be achieved either by utilising existing ANM arrangements, by direct control of DER where this has been established or through tripping WPD circuit breakers at DER sites.

Implementation & System Integration

This OTS is being delivered through the NGESO-WPD RDP. Work is ongoing with procurement almost complete. The ICCP implementation is close and is awaiting WPD approval.

Overall timescales are likely to be driven by completion of NGET's works at Melksham. These have been delayed due to COVID-19 impacts and go-live for the OTS is anticipated around April 2021.

# 4 OTS Performance & Data Exchange Requirements

## i. OTS Performance & Component Redundancy

This section considers the performance requirements of the OTS arrangement in more detail including the need to provide equipment redundancy to increase reliability.

Each OTS will only act on DER resources that that have agreed intertripping through BCAs. The DER resources that are part of an OTS scheme might be tripped or ramped down to prevent thermal overloads on the transmission network. The timescale required to trip or download DER is 30 seconds from receipt of trip signal. So far, for the implementation of OTS schemes, UKPN and WPD are choosing to trip DER resources whereas SSEN is choosing to ramp down DER resources. UKPN can facilitate DER ramp down for those DERs which have fast ramp down rate as part of their OTS solution. The ramp down functionality will be used if a timeline of <30 seconds can be met following rescript of the trip signal from NGESO.

On the resilience of the OTS arrangements, no single hardware or software failure should lead to the loss of the OTS system. To achieve this objective, much of the OTS infrastructure is being built to be fully dual redundant such that a single control system or communications failure will not result in the whole system being unavailable. This includes having two ICCP communication links between NGESO and DNO which are separately routed between different NGESO and DNO locations.

The signalling and interfacing from NGET to DNOs is hard-wired to the interface substation. Dual channels are provided for the transmission signals and the interface to the DNO system (PowerOn or ANM) must also be robust against a single failure. This may require dual DNO RTUs at the interface site with separate electrical supplies, but other approaches are acceptable if a single failure can be secured. As the NGET OTS system interfaces to a single DNO site, 5m separation is required between the dual DNO interfaces. Where 5m separation can't be provided further review should be undertaken.

As per section 2 iv), there are exceptions to the dual redundancy requirements. These include the control and communications links to individual DER sites from the DNO control system. These links and RTUs at DER sites are not duplicated due to cost benefit considerations. Instead, NGESO and DNOs will provide failsafe arrangements. For example, if a link is lost to a DER site, this is detected, and the DNO control system discounts the contribution of the generator.

A summary of the OTS performance and redundancy requirements is given in Table 3.

**Table 3 – Main OTS Elements and Redundancy Requirements**

| OTS Element / Function | Equipment Owner | Dual Redundancy (Yes/No) | Comments (e.g. how redundancy is provided) |
|---|---|---|---|
| DER Monitoring to determine DER Available | DNO | No | DNOs to determine how DER is monitored and the frequency of updates to NGESO. Satellite and radio comms are being used. |
| DNO to ESO comms to notify available DER and ESO to DNO comms to note curtailment volumes and arming requirements etc | ESO/DNO | Yes | 2 way comms are provided via ICCP. Redundancy is provided through the use of physically separate communications routes. The bulk of the comms infrastructure is owned by NGESO with some remote-end elements owned by DNOs. |
| ESO-TO comms to notify circuit monitoring requirements | ESO/TO | Yes | Provided via existing NGESO IEMS system. |
| Transmission circuit monitoring and trip signal generation | TO | Yes | Provided by NGET protection arrangements. |
| TO-DNO interface substation comms to trigger DER tripping | TO | Yes | Trip signals are provided to the DNO interface substation from TO substations included in the OTS. Duplicate trip channels are in place. |

| | | | |
|---|---|---|---|
| TO-DNO interface substation requirement including RTU to receive and handle trip signal | DNO | Yes | At the DNO interface site, duplicate RTUs are provided. |
| DNO system to determine DER tripping/de-load requirements | DNO | Yes | Provided via DMS (PowerOn) or through separate ANM system (e.g. SWAN). |
| DNO system to send tripping /de-load requirements to DER | DNO | Yes | Provided via DMS (PowerOn) or through separate ANM system (e.g. SWAN). |
| DNO communication links to DER substations and RTUs | DNO | No | Dual redundancy is not provided due to cost. Other failsafe arrangements to be used. |
| DNO remote substation RTU to DER interface | DNO/DER | No | In some cases, DER deloading is achieved through circuit breaker trip, in some cases through revising the generator set point. Dual redundancy is not provided due to cost. Other failsafe arrangements to be used. |

Cyber security has been considered as part of the OTS design. In particular, the control room to control room links use the Inter-Control Centre Communications Protocol (ICCP) to link two secure, private networks. The NGESO-UKPN OTS utilises a previously established ICCP link. For the NGESO-WPD OTS, given the establishment of new control room links, the proposals have also been shared with the National Cyber Security Centre (NCSC). To ensure any new ICCP links are suitably future-proofed, NGESO and WPD are currently assessing the options available to provide full end-to-end encryption of data sent between each organisation and a decision will be taken on how to proceed once further analysis has been completed.

## ii. OTS Data Exchange Requirements

A number of data points would be exchanged between NGESO, NGET and DNOs. At a high level:

- DNOs will share the levels of real time controllable DER behind each GSP with NGESO.
- NGET will share transmission outage and circuit status information with NGESO.
- NGESO will send arming and restore instructions to the DNOs and NGET.
- NGET will send trip signals to the DNO via a dedicated link.

Prior to Arming

The DNO will monitor DER and provide the aggregated MW level of DER generation per GSP that is available to be selected to the OTS scheme. Data will be sent on a near real time basis at an interval of 10 seconds. Data Exchange from the DNO to NGESO is via an ICCP Link.

Arming

NGESO sends an arming instruction to the DNO via ICCP Link. This instruction includes the capped generation level for each GSP.

NGESO also sends an instruction to NGET to arm the OTS scheme to produce trip signals in the event of particular transmission circuit trips. Data exchange from NGESO to NGET uses the IEMS system.

Tripping

If a fault occurs, the fault information and likely duration is sent from NGET to NGESO. After an actual N-3 event, NGET will wait 120 seconds before sending a trip signal to the DNO. This delay is to check if the fault is transient in nature.

Adjust/Disarm

Following a trip signal, the DNO control system adjusts MW generation at each GSP based on the capped generation level. The DNO systems should curtail DER on armed GSPs within 30 seconds.

If the OTS is to be disarmed, NGESO will provide an instruction to the DNO and NGET. The DNO control system will cancel the potential DER generation curtailment such that there are no capped values on the GSPs.

**Table 4 – Summary of Data Exchange Requirements for OTS**

| Stage | From | To | Data Exchanged | Comms | Further Detail |
|---|---|---|---|---|---|
| Prior to Arming | DNO | NGESO | Aggregated generation per GSP that is available to be selected to OTS. | ICCP | DER available for curtailment. |
| Prior to Arming | NGET | NGESO | Transmission circuit status. | IEMS | |
| Arming | NGESO | UKPN | Request for DER volumes to be armed and capped level of generation per GSP. | ICCP | This sets the capped DER levels per GSP. |
| Arming | NGESO | NGET | Request to monitor circuits and arm OTS. | IEMS | |
| Tripping | NGET | NGESO | Fault information and likely duration. | IEMS | Look to establish is the trip is transient or sustained. |
| Tripping | NGET | DNO | After 120 seconds. Trip signal from OTS to DNO control scheme. | Hard-wired | This is delayed to avoid tripping DER for a transient fault. |
| Tripping | DNO | DER | Signal to deload generation within 30 seconds of receiving NGET trip signal. | | Could be a signal to deload DER by tripping circuit breakers or by revising generator set points. |
| Disarm | NGESO | DNO | Request to disarm DER volumes. | ICCP | |
| Disarm | NGESO | NGET | Request to disarm OTS scheme. | IEMS | |
| Disarm | DNO | DER | Within 30 seconds, signal to cancel generation curtailment. | | |
| Cancel Trip | NGESO | DNO | Request DNO to stop curtailing after a trip event | ICCP | This is required as NGET OTS will not issue a cease signal after a trip event. |

# 5 Standard Requirements / Differences Across Schemes

This section is to further draw out elements that are standard or different across the three OTS arrangements, emerging good practice and any problems identified to date.

## i. Similarities & Differences across OTS Arrangements

The three 3 OTS's are compared in Figure 8.

**Table 5 – Summary of Data Exchange Requirements for NGESO-UKPN OTS**

| | NGESO - UKPN | NGESO - SSEN | NGESO - WPD |
|---|---|---|---|
| OTS Coverage | South East / South Coast – 5 GSPs | South of England / South Coast - 8 GSPs | South West / South Coast - 8 GSPs |
| NGET OTS Scheme | Sellindge | Melksham | Melksham |
| Interface Substation to DNO | Sellindge | Fleet | Taunton Main |
| DNO Architecture / Control | DMS / PowerOn Being Extended | South West Active Network (SWAN) scheme. | DMS / PowerOn Being Extended |
| DER Type | Generation | Generation | Generation |
| DER Selection | LIFO | LIFO – there is some further selection based on ramp rates to ensure sufficient generation is deloaded. | LIFO |
| Performance | Trip to capped level or more within 30 seconds of trip signal. | Deload to capped level within 30 seconds of trip signal. | Trip to capped level within 30 seconds of trip signal. |
| DER Deload | Achieved by ramp down or via DNO circuit breaker tripping. DER ramp down can be utilised in the OTS solution for those generators which have a fast ramp rate (i.e. <30 seconds). | Achieved by ramp down to new set point within 25 seconds, then trip if this is not achieved. | Achieved by ramp down or by circuit breaker tripping depending on DER. |
| Dual Redundancy | All elements have dual redundancy bar the connections to DER sites. | All elements have dual redundancy bar the connections to DER sites. | All elements have dual redundancy bar the connections to DER sites. |
| Failsafe Arrangements | Utilise manual "work arounds" when DER visibility or control is lost. | Utilise manual "work arounds" when DER visibility or control is lost | Utilise manual "work arounds" when DER visibility or control is lost |
| System Restoration following OTS Trip Event | Restoration through manual actions. | Automated restoration. | Some automated restoration. |

The main differences between the 3 OTS arrangements currently being implemented by DNOs include:

- The SSEN system implements the distribution control requirements in its SWAN system rather than through extension of PowerOn.
- The SSEN system will attempt to deload generation by ramping this down to a new set point rather than trip the generation.

## ii. Emerging Issues & Good Practice

The following points have been identified:

- Cyber security aspects have been discussed with the NCSC. Existing ICCP arrangements are sufficient however, options of further enhancing security using full end-to-end data encryption are being considered.

- DNO network running arrangements may lead to different distributions of DER across GSPs. SSEN are considering how to accommodate this within the design of its control system.
- NGESO, the TO and the DNO need to remain aware of OTS component availability and planned outages. For the NGESO-NGET-UKPN scheme, a “Standard Operating Protocol” is being developed for use by Operational Planners.

# 6 Data Transparency

The nature of the data being transferred to achieve the OTS arrangements is described in section 4 of this report. As the actual data transfers are real-time and rely on secure and dedicated communications links, wider dissemination of this data is not proposed.

# 7 UK Power Networks and NGESO N-3 Deployment Results

The purpose of this section is to summarize what was covered in the N-3 testing phase. This section is also intended to inform the stakeholders about the summary of achievements, test approach and any lesson learned.

Operational Inter-tripping is a mechanism to ensure that the UK transmission network remains operable by reduction of load on it during an N-3 event (Planned Transmission Outage followed by double circuit fault), preparation for which is carried out ahead of the potential event via an 'arming' request from the NGESO ENCC to the UKPN Control Room using a dedicated ICCP link.

This request is concurrently visible to the NG TO Control Room (TNCC) in case of the actual event, the TO OTS will initiate a 'trip' instruction to the DNO ANM/PowerOn (using a dedicated OTS link). The DNO ANM/PowerOn receives the trip instruction and de-loads relevant flexible generation to achieve a pre-defined MW cap within the selected GSP(s).

The capability to manage 'Operational Inter-tripping' at DER level in an efficient and cost-effective way falls within the scope of the Regional Development Program work stream of the UKPN ANM Project.

UK Power Networks and NGESO's N-3 OTS system went live on 20th of November 2020. The deployment of other N-3 schemes on WPD, and SSEN networks have been delayed until late 2021 as a result of the need to undertake further transmission outages to provide the necessary monitoring locations into the OTS.

The architecture diagram for the N-3 to DER inter-tripping Service is shown below.

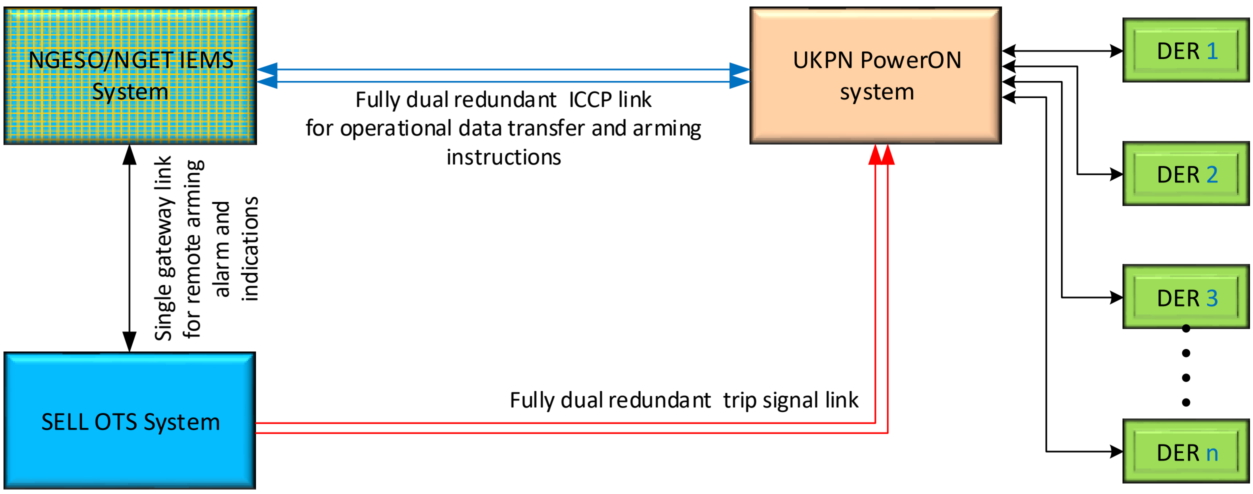



**Figure 6: N-3 to DER Inter-tripping Service Architecture**

## i. Test Approach

The delivery of N-3 intertripping system between UKPN and NGESO followed an agile development/delivery methodology. During the design and development, the business, functional and non-functional requirements are gathered in the form of user stories and use cases. From a test point, an acceptance criterion has been defined to each user story and use case. The test strategy was designed to prove that the acceptance criteria have been met. This means each user story or use case will have one or more test cases attached to them. During the test execution, a test case would be accepted as passed if the acceptance criteria has been met.

## ii. Test stages

The following test stages are defined for the N-3 to DER Inter-tripping Solution:

**Table 6: Test stages**

| Test Stage | Description |
|---|---|
| Unit Testing | Independently of each other UKPN and NGESO will conduct informal bench or unit testing of their respective GE solutions. This will include local simulation of interfaces where required/feasible. |
| Data Point Configuration (Signal Connectivity) Testing | Carried out in conjunction with NGESO to confirm correct data transfer of all signals. |
| Non-Functional Testing | Carried out both individually and jointly by UKPN and NGESO. |
| Regression Testing | Carried out by UKPN to confirm that existing SPN PowerOn functionality is not adversely affected by introduction of the N-3 Solution. |
| System Integration Testing (SIT) | Carried out jointly by UKPN and NGESO against the Functional Test Cases defined by UKPN. |
| User Acceptance Testing | Carried out both individually and jointly by UKPN and NGESO to gain respective Control Room acceptance of the N-3 Solution – expected to be achieved for UKPN by Control Engineer engagement with SIT & E2E testing focused around exercising the N-3 N.O.P. |
| Operational Acceptance Testing (OAT) | Defined as required to provide UKPN Business Stakeholders confidence to authorise N-3 to DER Inter-tripping Solution to be promoted from SPN PowerOn Pre-Production into Production. |
| End-to-End (E2E) Testing | Expected to be a repeat of a subset of SIT tests involving UKPN, NGESO and TO. |
| Production Testing | As required by either NGESO or UKPN, following deployment of the N-3 Solution into this environment. |

## iii. Test Environments, Harness and Simulation

All development and bench testing was conducted on the UKPN Virtual Test environment before migrating the N-3 Solution to the UKPN Main Environments, requiring the interface to the NGESO Pre-Prod environment.

Once testing is complete and Operational Acceptance Testing (OAT) has been achieved the N-3 Solution will be promoted to the UKPN main environment as part of UKPN Go-Live subsequent connection to the live UKPN Electricity Network and the NGESO Main environments.

## iv. Test Environment Exit Criteria

The basis for achieving Business agreement to moving N-3 solution into Production environment is as follows:

a. All planned testing is complete (functional and non-functional).
b. All approved test cases have been run, changes identified and results captured.
c. Business Stakeholders (as part of OAT) have agreed to any planned tests not executed i.e., Suspended or Out of Scope.
d. All required re-work, bug fixes and regression testing cycles completed satisfactorily.
e. All defects fully triaged, root cause identified and fix action assigned with clear resolution timescales.
f. Defects trend and root cause analysed and no underlying systematic defect revealed.
g. No defects significantly impacting User experience – either UI or performance.
h. OAT successfully completed and signed off.

## v. Lessons Learnt

This section consists some of the lessons learnt from defects/issues faced during System Integration Testing and proposed actions in order to avoid same kind of issues in future projects. This is valuable for NGESO and NGET for next N-3 intertripping projects with SSEN and WPD.

**Table 7: Issues and lesson learned**

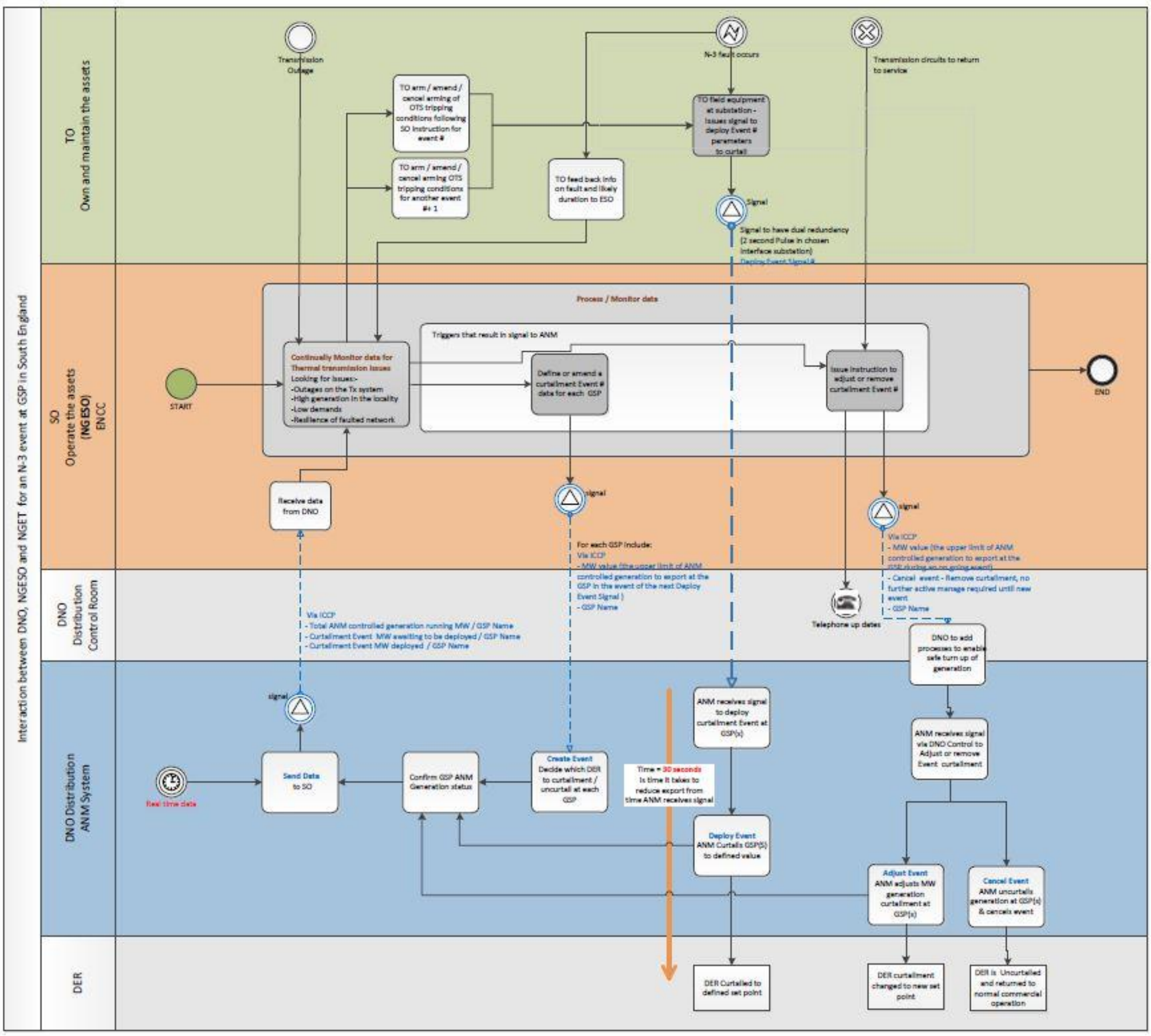
| # | Issue Description | lessons learnt |
|---|---|---|
| 1 | **ICCP link should be ACTIVE on both sides (ESO<-> DNO's).**<br>Link was not active during the start of testing phase, which lead to block some of the test cases. | We need to make sure the ICCP link is ACTIVE on both sides (ESO<-> DNO's) before the starting of SIT. |
| 2 | **Issue with System configuration between DMS and IEMS**<br><br>**Root cause:** In Prod NG the TASE version is 1996 but in DDS NG changed it to 2000 which is now reverted to 1996. | We need to make sure before the SIT starting the versions on both sides should be same. |
| 3 | **Incorrect mapping table for ICCP in the data mapping sheet (earlier IEMS mapping table was provided instead of ICCP).**<br><br>For digital points, the IEMS deals in pure binary; the equivalent status value is either a 0 or a 1. The ICCP protocol deals in 1's and 2's. When ICCP picks up a digital value for onward transmission, it converts an IEMS 1 to an ICCP 1, but an IEMS 0 gets converted to an ICCP 2. This has always worked OK previously, but on | **Action:**<br>This was a missed from NGESO for the interpretation of data point/values between IEMS and ICCP.<br>NGESO updated the Data Mapping sheet with the ICCP values UKPN will receive, with the corresponding states they should convert them to. UKPN updated their program as per the latest data mapping sheet provided.<br><br>For the other DNO's NGESO are planning to test at least few ICCP datapoints are transferring the data |

| | | |
|---|---|---|
| | this occasion, UKPN's PowerOn seems to convert the ICCP 2 to a PowerOn 2. | properly as expected as per the Data mapping sheet before the SIT starts.<br><br>**NOTE:** As of now UKPN has updated the program at their end for this issue but discussions is on how to deal this with SSEN/WPD. It's like whether code fix needs to happen in NGESO side or to inform and send the updated Data Mapping sheet to SSEN/WPD.<br><br>This issue could have been prevented by doing the simulation testing between the IEMS and ICCP data conversion at source. |
| 4 | **Flexible DER set up is not responding to Arming instructions and curtailment event**<br><br>**Root Cause:** The specification provided by NGESO was not covering the IEMS-ICCP interpretation and UKPN's solution aborted as per NG specification before triggering. The spec was revised to match the iEMS systems output and the UKPN Solution was re-written. | The electrical requirement should be presented, and the operational procedure agreed before any algorithm interface points agreed rather than being specified and working backwards. |
| 5 | **Availability of the key resources for the Test activities**<br>We have seen some instances where Key resources from either/both the sides were busy in other BAU activities/priority work. This have delayed the joint testing sessions. | Project need to get the commitments form Key resources for the Project work.<br>Project should share the detailed plan with Key resources well in advance.<br>If there is any deviation to the Project/Test Schedule, the resource manager should be informed, and updated plan should be shared. |
| 6 | **Turnaround time for defect resolution.**<br>UKPN did not have a single defect in the PowerOn N-3 program, there were some issues with the simulation environment, however these issues got fixed for SIT considering a new automation program was designed from scratch. | - If there are any 3rd parties (development team) involved, project should engage the 3rd parties well in advance for any possible issues/support to fix the defects.<br>- Based on the priority of the defect need to accelerate the efforts (daily engagement/mobile support/weekend work). |

# 8 Appendix A

**<u>Process diagram illustrating interactions between OTS parties</u>**

SSEN OTS Process v2.pdf



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