Flexible DG connections
Post-connection assessment of operational Active Network Management systems
UK Power Networks – July 2016
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1. Executive Summary

This report reviews the performance of the Active Network Management (ANM) currently deployed in the Eastern part of UK Power Networks’ distribution network and used to enable Flexible Distributed Generation (FDG) connections. The FDG connection offering aims to provide a point of connection within the existing network without the need for/or ahead of reinforcement.

The FDG scheme has currently contracted 165MW of distributed generation. These are projects that would not otherwise been developed due to the high costs of network upgrades. The ANM system has now been operational with connected customers for approximately 18 months.

The report highlights the types of issues experienced to date; resolution actions taken; optimisation and enhancements applied; and future developments actions. The report captures the learning gained from the the Flexible Plug and Play (FPP) trial and follows through the evolution process as the trialled solution is rolled out in the business.

The review has shown that the systems that comprise the end to end solution operate functionally as designed however additional effort is required to ensure that are fully stable as one solution.

The overall genuine curtailment on the system has been very low. Fail-safe actions have caused most of the curtailment events. The fail-safe actions have been driven by a number of issues that are covered in section 4. UK Power Networks with its supply chain partners has undertaken significant work to fix those issues and in majority has achieved to do so. Further improvement actions are currently underway.

Section 5 summarises the key actions that came out from a customer workshop that UK Power Networks ran with its operational flexible customers in July 2016. These focus on improving resilience and ensuring investor confidence on these operational schemes. UK Power Networks is taking forward these actions and will provide a progress update in Quarter-4 2016/Quarter-1 2017.

UK Power Networks is committed to continuously improving the service that the FDG customers receive and over the last twelve months has invested in developing the skills, recruiting the resources and delivering the business change required to fully embed these new capabilities into BAU.

2. Background

There are parts of the UK Power Networks distribution network where due to constraints such as capacity, voltage or reverse power flow issues the cost of connection is very likely to be higher than expected and take longer to complete. This is because it will include a significant element of reinforcement work in order to overcome these technical challenges.

The Flexible Distributed Generation (FDG) connection offering aims to provide a point of connection within the existing network without the need for/or ahead of reinforcement. The customer must be willing to accept temporary reduction to their export to ensure the network is kept within operational limits and the constraint is not breached.

The FDG connection offering was developed as part of UK Power Network’s research demonstration project Flexible Plug and Play (FPP). The FPP project ran from January 2012 to December 2014 and it was the first demonstration in mainland UK of how distributed generation can connect in constrained parts of the networks without the need for expensive and lengthy network upgrades.

The FDG connection is enabled by:

- The Active Network Management system, a software automation product that monitors the network in real-time and and automatically controls the output of the participating generator. The Active Network Management is designed to ensure safety of the public, the UK Power Network employees and the network infrastructure and as such it delivers fail-safe instructions if it detects abnormal operation of any of overall system components including the generators.
The Telecommunications network that supports the deployment area and ensure that data are exchanged between the generator sites, UK Power Networks substations and UK Power Networks Control Centre.

SCADA and measurement equipment that is used to acquire network real-time network information from the grid.


### 2.1 Benefits to the Distributed Generation customers

The customer savings of connecting using the FPP/FDG methods compared to the cost of the traditional solutions are estimated to be in excess of £70million. In addition, the FPP/FDG schemes have been much faster in terms of their delivery timescales allowing these projects to access the favourable financial support incentives that they aimed for. As customers have fed back, in most instances these projects would not have been developed.

### 2.2 Contracted Capacity Register

UK Power Networks have currently two operational ANM zones. The first one is at March and Peterborough area and the second in Norwich zone, both in the Eastern part of UK Power Network’s network as shown in figure 1 below. The March Grid and Peterborough areas are electrically and commercially separate, hence they are reported as separate constrained areas in tables 1 and 2.

![Figure 1: FDG operational deployment map](image)

The current capacity register for the three constrained areas are given below.

**March Grid Reverse power flow constraint**

<table>
<thead>
<tr>
<th>Project</th>
<th>Technology</th>
<th>Capacity (MW)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG1</td>
<td>Wind</td>
<td>10</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG2</td>
<td>Wind</td>
<td>1.5</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG3</td>
<td>CHP / AD</td>
<td>0.5</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG4</td>
<td>Wind</td>
<td>0.5</td>
<td>CONNECTED</td>
</tr>
</tbody>
</table>
### Peterborough overhead line constraint

<table>
<thead>
<tr>
<th>Project</th>
<th>Technology</th>
<th>Capacity (MW)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG1</td>
<td>Wind</td>
<td>8</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG2</td>
<td>PV</td>
<td>4.95</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG3</td>
<td>PV</td>
<td>5</td>
<td>CONNECTED</td>
</tr>
</tbody>
</table>

### Norwich ANM zone constraint

<table>
<thead>
<tr>
<th>Project</th>
<th>Technology</th>
<th>Capacity (MW)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG1</td>
<td>PV</td>
<td>15</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG2</td>
<td>PV</td>
<td>25</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG3</td>
<td>PV</td>
<td>3.75</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG4</td>
<td>PV</td>
<td>4</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG5</td>
<td>PV</td>
<td>10</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>DG6</td>
<td>CHP</td>
<td>0.5</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>DG7</td>
<td>PV</td>
<td>7.7</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG8</td>
<td>PV</td>
<td>3.85</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG9</td>
<td>PV</td>
<td>3.85</td>
<td>CONNECTED</td>
</tr>
<tr>
<td>DG10</td>
<td>PV</td>
<td>3.85</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>DG11</td>
<td>PV</td>
<td>3.85</td>
<td>ACCEPTED</td>
</tr>
<tr>
<td>DG12</td>
<td>PV</td>
<td>3.75</td>
<td>CONNECTED</td>
</tr>
</tbody>
</table>

UK Power Networks will update the contracted capacity registers for these areas once a year and publish them on the Flexible Generation website pages.
2.3 ANM System Design

The Active Network Management system controls generators in real-time based on network measurements. The ANM solution is designed to cater for single or combinations of constraints and is able to evolve and adapt to changes in network conditions caused by addition of new generators. As shown in figure 2, the conceptual ANM architecture covers three main components:

1. The ANM central controllers located at a secured infrastructure within the control centre. The central controllers comprise of software applications hosted on commercial off the shelf enterprise IT servers.

2. The Local ANM controllers at the substation level comprise of software hosted on an Intelligent Electronic Device (IED) or Remote Terminal Unit (RTU). The local ANM interfaces with the DG control system to implement active control of the power export to the distribution network.

3. The telecommunications infrastructure that supports data transfer. The Norwich deployment is enabled by the satellite network that UK Power Networks uses for its main Grid/Primary SCADA telecommunications. The March/Peterborough deployment is enabled by the wireless radio mesh system that was delivered as part of the FPP project.

![Figure 2: ANM conceptual architecture](image-url)
3. Review of historical performance – issues and improvements to date

3.1 Performance issues identified to date

Figure 3 provides a high level overview of the assessment representing the timeline of 2 years from 2015 to 2016. A pattern was also observed when assessing the performance from early 2015 which followed the characteristics of a typical bathtub curve. It shows that there was a surge of issues just after March 2015 when eight flexible generators connected to the network within a very short space of time in order to meet the deadline for the change of DG financial support incentives. A number of issues were observed which led to the optimisation of settings or alteration of design parameters on both the UKPN and the generator equipment.

This also required UKPN to develop some short term and long term fixes that were introduced as system upgrades in Quarter-2 and Quarter-3 of 2015.

A similar pattern was again observed after the end of March 2016 when 12 generators connected again within a very short space of time. Due to the standardisation of the ANM to the generator interface design, the system experienced significantly reduced interface integration issues in 2016. However, there was a repeat of issues of 2015 relating to the characteristics of the individual generator technologies.

This is one of the main going challenges as every generator control technology can be different and can have different characteristics with varied response capabilities.

The analysis has shown that the systems that comprise the end to end solution for the customer have worked functionally as designed however additional effort is required to ensure that are fully stable as one solution.

The overall genuine curtailment on the system has been very low. Fail-safe actions have caused most of the curtailment events. The fail-safe actions have been driven by a number of issues. UK Power Networks has undertaken a lot of work to fix those issues and in majority has achieved to do so.

Further improvement actions are currently underway.

The ANM issues that have been experienced to date can be categorised into four types;

1. **Telecommunications issues**: Communication faults have been one of the common causes of fail-safe actions for the ANM system. Radio technologies can have short term failures and if those
durations exceed the observation timer, the ANM takes a fail-safe action by curtailing the generator. The settings have now been adjusted to allow longer failure durations before the fail-safe actions. This has addressed the issue of intermittency in the communications network.

In addition, measurement update rate was also found to be a cause of curtailment and trip events. The communication systems have bandwidth limitations, the update frequency of the change of measurements are throttled at the substation Remote Terminal Units (RTUs) using deadband settings. Deadband settings enable the measurement data to be reported to the ANM only after exceeding a specified percentage of change in magnitude or persisting for a specified duration of time. Various iterations of settings were tested to strike the right balance between update frequency and saturating the communications network.

2. **Settings issues**: Initial conservative settings made the system very sensitive to certain network conditions such as power flow spikes. As more operational experience was gained on each scheme the settings were relaxed and made more practical in order to stabilise and optimise the overall system.

3. **Generator technology specific issues**: These are malfunction issues in the customer’s installation that only became apparent after commissioning. In response, UK Power Networks is introducing an additional phase of thirty days after site commissioning as an operational acceptance phase where both the suppliers for the ANM and the customer’s generator controller are committed to closely and pro-actively monitor the operation of the system and resolve the issue as they arise.¹

4. **Component failures**: The system is designed with redundancy at multiple layers of the architecture. However, there are single points of failure in the measurement points on the network. The impact can be minimised by increasing the resiliency of the solution. This is currently being looked under further improvement actions.

### 3.2 Key improvement actions completed – Technical Solution

The following table outlines the various causes of the events and the resolution actions already put in place to mitigate them or minimise the impact.

<table>
<thead>
<tr>
<th>Event</th>
<th>Cause</th>
<th>Response to date</th>
</tr>
</thead>
</table>
| Curtailment event             | Network constraint breach            | • Optimising constraint threshold observation timers to reduce sensitivity of the ANM and reducing frequency of curtailments.  
• Increase of export headroom. At March Grid the initial 10% safety operating margin has been removed considering the continuous and emergency ratings of the transformers.  
• Increase of release rate of the generators after a curtailment event. The initial release rate of 0.5MW/min has been doubled to 1MW/min allowing generators to reach its maximum output faster. |
| Failure of ANM components     |                                      | • Communication observation timer has been increased from 3 minutes to 10 minutes. This means short term failures on the wireless radio network do not lead to unnecessary fail-safe curtailments.  
• Monitoring and improvement of the performance communication links. |

¹ The 30-day operational review is strictly limited to the ANM aspect of the installation. All other commissioning procedures and timescales (including G59) will remain as currently described in UK Power Network’s standards.
• Improve support and response capabilities to reduce the turnaround time of issue resolution.

Communication failure between the ANM and Generator equipment (Generator fail safe)

• Working with generator customers to improve the performance of the communication links.

Planned Outage for upgrade and maintenance

• Advance notification as much as possible to generators to allow scheduling of maintenance activities during the outages.
• Schedule outages at times with least impact to live generator export wherever possible.
• Quality assurance in pre-testing and post testing to avoid issues and repeated changes. An end to end test environment is being developed to mirror the operational system in order to facilitate accurate.

Measurement data inaccuracy

• Resolution of the scaling discrepancy of the export measurement relay (one-off issue).

Non-compliance: Generator not responding to ANM instructions

• Generator export power measurement tolerance increased from 3% to 5% in order to allow more flexibility to all types of generator control systems and avoid unnecessary trip events.
• Working with generator customers to improve the performance of the generator control system to ensure compliance.

Non-compliance: Generator unable to fail safe during a communication failure to ANM

• Working with generator customers to maintain performance of equipment and battery backup to ensure compliance.
• Introduction of new test requirement as part of commissioning for generators to demonstrate their fail-safe capability in the event of a power failure.

Table 4: Key improvements – technical solution

3.3 Key Improvement actions completed - Standardisation

Various aspects of the design have been standardised from the early 2015 following the learning from the FPP project trial. This has helped to increase clarity of design activities to all parties from the start of the connection process and greatly reduced delays during the design and the commissioning process.

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Actions completed</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexities in ANM to DG interface design process due to flexible multiple DG control system technologies.</td>
<td>Issue of flexible DG connection requirement specification document with FAQs at the kick off meeting with the customer.</td>
<td>Efficient and faster design process.</td>
</tr>
<tr>
<td>Re-occurrence of issues in the integration between ANM and DG interface resulting in delays during commissioning.</td>
<td>Introduction of a requirement of bench testing the DG customer control equipment.</td>
<td>Reduction of issues and delays during commissioning.</td>
</tr>
</tbody>
</table>
Lack of information of ANM events to the DG customers.

ANM alarm and signals sent to UKPN central system are also made available to DG control system from the Local ANM controller as an standard design.

DG customer have ability to monitor ANM event signals to have visibility of ANM events as UKPN does.

| Table 5: Standardisation improvements |

4. Improvements actions in progress

4.1 Improvement in visibility of the operational status of the ANM system

One of the key areas of feedback from distributed generation customers has been the lack of visibility of the operational status of the system. This has been identified as a key requirement and two initiatives have been progressed from late 2015:

- **Event email notification:** An event notification system is being implemented that can email all parties on a ANM initiated event with details of the cause of the event. This has successfully been tested and is undergoing internal evaluation process before it will be rolled out to the external customers in Quarter-3 2016.

- **Customer web portal:** An external website is also being developed to provide an overall visibility of the constraint and issues on the geographic ANM zones. This is planned to be commissioned by August 2016. Figure 4 shows the prototype site being trialled internally before releasing to the public domain. This has also been optimised for the use in smart phones.

![Figure 4: Customer web portal sample](image-url)
4.2 Support capability

The ANM system support is a new function for the distribution business and as such, requires new resources, new skills, new tools and new business processes. UK Power Networks is delivering a plan to have fully embedded the ANM capability in business as usual by the end of 2016.

As part of this plan, UK Power Networks created a number of dedicated roles within its Asset Management, Information Systems, Operational Telecommunications, Automation and Control teams that are focused on operational support and strategic development of the flexible generation capabilities.

Three full time Engineers are currently dedicated in delivering a fully stable and business embedded ANM capability by the end of 2016.

Specific to operations, the following capabilities are being delivered:

4.2.1 Control desk capabilities

The first port of call for the generator customers is the control desk so it is important that they have the essential skills and information to manage any type of events. The following actions are being progressed from 2015 to enhance the capabilities of the traditional control centre.

- Training of Control Engineers on the operation of ANM schemes.
- Development of Network Operational procedures for the ANM system.
- Improvement in the integration of ANM symbols and functionalities in the existing Network Management system.
- Development of a web based interface for the ANM system for easy access to the users.

4.3.2 Operational support capabilities:

If Control desk is not able to resolve an issue or answer a customer query, a dedicated ANM support service is available. This service is provided 7 days a week in an extended hours basis from 7AM to 10PM. This service is currently delivered by UK Power Networks and Smarter Grid Solutions, the ANM supplier.

The development of the support capabilities is represented by Figure 5.
5. Generation customer feedback and action plan

UK Power Networks organised a DG workshop in July 2016 to present the findings of the assessment and gain feedback on the additional requirements and further improvements.

This has fed into the overall action plan to improve the performance of the ANM system as shown below.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Customer request</th>
<th>Status</th>
<th>Action</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications resilience</td>
<td>Use of backup communications to provide dual redundancy at DG sites.</td>
<td>There are two potential options. The first one is the development of dual communication functionality by the supplier. This is a scheduled functionality in the supplier's product roadmap estimated for Q3 2017. The second one is to implement intelligent communications equipment which is able to switch between Main and Standby links. However, this option introduces another single point of failure.</td>
<td>A feasibility to be carried out and select the best option to pursue for development.</td>
<td>Dec-16</td>
</tr>
<tr>
<td>Measurements resilience</td>
<td>Currently associated DGs are curtailed as fail safe action if RTU or measurement devices fail. Use of back up measurements to reduce curtailment.</td>
<td>Back-up measurements would require development of custom logic in the ANM system and the provision of another measurement device or derived measurements. The ANM system would need to be configured to fail over to a second measurement device after a period of failure of the first one.</td>
<td>UKPN to work with supplier to scope out the necessary development activities and implement the functionality where possible.</td>
<td>Oct-16</td>
</tr>
<tr>
<td>Increase intelligence</td>
<td>Can more intelligence be developed so that DGs are not curtailed not on communication failures but on actual constraint status? Can the system cross check with the previous state/thresholds and take a more measured approach by looking at generation profiles, times of day,</td>
<td>This is a scheduled functionality in the supplier's product roadmap estimated for Q2 2017.</td>
<td>UKPN to engage with supplier to establish if the development can be accelerated and produce an earliest possible delivery date.</td>
<td>Nov-16</td>
</tr>
<tr>
<td></td>
<td>Can planned maintenance and forecasted curtailment info be given to DG.</td>
<td></td>
<td>Carry out feasibility study to check if this is possible</td>
<td>Oct-16</td>
</tr>
<tr>
<td></td>
<td>Opportunity cost of curtailing the different generators and how could it be optimised.</td>
<td>This is being looked as part of UK Power Networks' DSO strategy.</td>
<td>Provide updates and gain input from customers.</td>
<td>Dec-16</td>
</tr>
</tbody>
</table>
6. **Next steps**

UK Power Networks is committed to providing innovative and cost effective solutions to our generation customers to connect to our network. The Active Network Management system has now been operational for 18 months. Improvements have been delivered which in most instances have stabilised the system and are delivering the expected performance.

However, further work is required to ensure consistency in the performance and to provide the right level of information to the customers to maintain theirs and their investor’s confidence. A set of actions has been identified and will be taken forward with a progress update workshop to be organised in Quarter-4 2016/Quarter-1 2017.

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**Table 6: Action plan**

<table>
<thead>
<tr>
<th>Customer visibility and Investor confidence</th>
<th>How can ANM operational information be made more visible to customers.</th>
<th>Email notification has been developed and currently being trialled internally.</th>
<th>Commission the functionality</th>
<th>Aug-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer web portal has been developed and currently being trialled internally.</td>
<td>Customer web portal has been developed and currently being trialled internally.</td>
<td>Commission the functionality</td>
<td>Aug-16</td>
<td></td>
</tr>
<tr>
<td>Regular communications and data provision on system performance and UKPN improvement actions.</td>
<td>Regular communications and data provision on system performance and UKPN improvement actions.</td>
<td>Setup periodic update to customers (next planned for Q4 2016/Q1 2017) and workshop session as required.</td>
<td>Oct-16</td>
<td></td>
</tr>
<tr>
<td>Can the issues related curtailment be explained in detail in connection offer.</td>
<td>Can the issues related curtailment be explained in detail in connection offer.</td>
<td>Currently not included in the feasibility study.</td>
<td>Oct-16</td>
<td></td>
</tr>
<tr>
<td>Review Information provision in offer for fail safe scenarios and probabilities.</td>
<td>Review Information provision in offer for fail safe scenarios and probabilities.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>