WESTERN POWER DISTRIBUTION

SEASONAL GENERATION

MANAGING PEAK ENERGY DEMAND

Closedown Report

LCN Fund
Low Carbon Networks

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	Name	Company
Prepared by:	Jonathan Berry	Western Power Distribution
Reviewed by:	Roger Hey	Western Power Distribution
Approved by:	Roger Hey	Western Power Distribution

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1. Seasonal Generation Deployment

This project was initially proposed by Central Networks with project ownership responsibility transferring to Western Power Distribution (WPD) as a result of business acquisition in April 2011.

Networks are currently designed and operated by Distribution Network Operators (DNOs) to cater for an unconstrained peak demand (occurring in winter for most locations). As energy consumption switches to electricity from oil and gas (for heating and transport) these peaks are forecast to become much more pronounced. Building networks to cater for an unconstrained peak will become increasingly unacceptable, especially as the quantity of distributed generation and interruptible demand increase. Seasonal Generation Deployment was intended to investigate generation utilisation via innovative commercial arrangements and novel automated control solutions to overcome the temporary stresses witnessed on the network.

2. Executive Summary

This report details the approach taken in seeking to install commercially surplus generation from the UK's fleet of rental assets at constrained points of the distribution network with a view to deferring capital investment. The project had a number of aims.

Technical

- To specify the requirements for a network installation to allow third party assets to be securely stored at locations within the network such as a primary substation; and
- To develop control arrangements that would enable the assets to be safely operated automatically by M2M signals or from the WPD network control room.

Commercial

- To identify the value to asset owners of deploying generation assets used for network support; and
- To verify that the cost to the Distribution Network Owner is more economic than conventional reinforcement.

The project was terminated in summer 2013 when it was proven to be uneconomic for generation owners to deploy units on a seasonal basis at a cost that would be lower than conventional reinforcement. The trial has therefore been halted prior to complete technical installation. Despite the project termination, several learning outcomes were identified within the trial that will assist future projects or business as usual initiatives that consider the use of distributed generation.

The original project budget was £328k with the project costs at the point of termination at £94k.

3. Project Background

Future energy scenarios clearly show that peak demand on the distribution network is set to increase. This project sought to explore a solution to reduce the impact on the existing network from such peaks. Testing the technical aspects associated with controllable demand and automated generation, and the development of innovative commercial arrangements for generation availability and operation. The project would deliver new learning on the cost effectiveness of such arrangements.

The project was to consist of two phases:

Phase 1 - the installation of a single point of generation at an 11kV substation site. The key objective of phase 1 was to initiate, develop and deploy the engineering interface, commercial arrangement and first stage generation control methodology.

Temporary generation was proposed to be implemented on to the existing 11kV distribution network to test the principle of deferring capital reinforcement and reduce network stresses. The addition of temporary generation may also reduce the losses seen on a distribution network, by injecting the required power closer to the point of demand. The connection was to be at Harbury Primary Substation, on to the existing 11kV switchboard. The Primary substation was chosen by investigating the times at which the network is overstressed. It was envisaged that temporary generation installation could be an effective method to negate excessive winter peak demands.

Western Power Distribution partnered with aggregator Flexitricity, to provide generators at times of network overstressing, typically borne by the winter cyclic rating of a transformer. It was proposed to operate the generators under the Short Term Operating Reserve (STOR) agreement with National Grid in order to supplement any payments by WPD for provision of a demand response service. Flexitricity would own and operate this contractual agreement with National Grid. During seasons 5 and 6 of the STOR calendar, Flexitricity would operate the generators in window 1 for STOR and window 2 would be at the sole discretion of WPD to determine operation. Other seasons of the STOR calendar could be utilised, at the sole benefit of Flexitricity and their generation asset provider.

It was envisaged that there would be limited commercial issues associated with the integration of a third party’s generator units on to WPD’s land. The commercial model in this instance would be arranged between WPD and Flexitricity. It would centre on issues such as, occupation of WPD land, connection charges, running costs per kWh and maintenance.

In order to make the connection of temporary generation intelligent, it was proposed to install and operate a new, specifically developed, control mechanism. This should constantly monitor the load demand on a Primary Substation. A load limit would be set as to what the existing infrastructure could provide without the support of the generation units. Set points could then be defined against the load versus substation firm capacity and generators employed automatically to avert breach of rating. The control of the generators would be automated, therefore negating the need for manual intervention. However, the operation of the generator units should also have the facility of remote operation by WPD's control teams, for the aiding of planned work, outages and network optimisation.

Phase 2 to utilise existing network connected generation along with strategically placed generation connected to a contiguous section of 11kV network, which would be a test within a more complex network environment. This would provide a platform for commercial arrangements and control methodologies to be further developed.

4. Scope and objectives

The scope and objectives of the project, as detailed in the original LCNF Tier-1 Proforma, are:

- Develop and deploy an automated network generation control system. To provide network support through the integration of an automated demand triggered generation system;
- Develop and deploy an Availability and Commercial Operating arrangement - "DNO to DSO";
- Provide a commercial arrangement similar to the "STOR " Short Term Operating Reserve" arrangements between aggregators and National Grid (NG), but specifically tailored to reflect the needs of the local grid rather than GB system balancing;
- To increase network flexibility and security through the use of robust generation;
- To ensure that the engineering model and commercial framework are aligned in order to provide maximum benefit for existing assets and end user customers; and
- Assess the benefit from capital deferment, by complimenting existing network assets with strategic generation thus maximising asset life.

This report explains and provides evidence as to what extent the project has achieved its original scope and objectives.

5. Success criteria

The success criteria detailed below were identified at the point of project registration. These success criteria will be used to determine the positive and negative learning throughout this report.

- Install and commission seasonal generation set;
- Ability to accommodate additional load without the need for large-scale network reinforcement through peak lopping techniques;
- New commercial arrangements reflecting the needs of the local grid;
- Development of an engineering interface and control methodology; and
- Assessment of the business case for deferring capital expenditure on the network.

6. Details of the work carried out

The original objective of the trial, as detailed in the project registration document, was to utilise existing or new network connected generators provided for standby generation purposes, export with a power purchase agreement (PPA), or generation for short term operating reserve (STOR), along with seasonal generation (typically only currently operated during summer at large festivals and concerts). The generation in all instances would be owned and operated by either a customer and/or an aggregator. Through commercial arrangements and control methodologies WPD would utilise this generation on a seasonal basis (winter) to provide controllable peak demand management.

For phase 1, seasonal generation was identified to be of benefit at Harbury Substation in Warwickshire (WPD East Midlands);

The East Midlands Load Index (LI) document identifies that Harbury primary substation was at times running above its firm capacity of 9.8MVA. The overstressing of the substation ranged from 0.1 MVA to 2MVA.

Over three previous years, 2008, 2009 and 2010, there was a significant increase in the level of load seen at the substation.

Year	Days overstressed	Days close to overstressing (<0.5MVA headroom)
2008	0	4
2009	7	21
2010	30	31

Table 1. Harbury Primary S/S Overstressing Data

From the East Midlands LI document it is predicated that if no remedial work is carried out the growth of maximum demand is likely to reach 12.85MVA by 2014/15.

A typical winter daily load profile is indicated in Figure 1. It can be seen that for the majority of the day the load demand on the system is less than that of the firm load capacity (9.8MVA). This drove the proposal to utilise intelligent generation operation to support the network at times when it was required, opposed to previous generation support examples that ran for an extensive period of time at full output. Also, there was an existing 1MW generator connected to the 11kV network fed from Harbury Primary Substation, installed within a customer's premises that would, at uncontrollable points in time (due to there being no additional contractual arrangement in place with the generator), output power to the system, reducing the network demand. By utilising seasonal generation with an advanced operational and control methodology, which considered the real time load demand of the system, the level of generation required could be minimised. This is indicated by the generation operation line in Figure 1, where Level A indicates the firm capacity of the Primary Substation and Level B indicates the point at which the seasonal generation will be initiated.

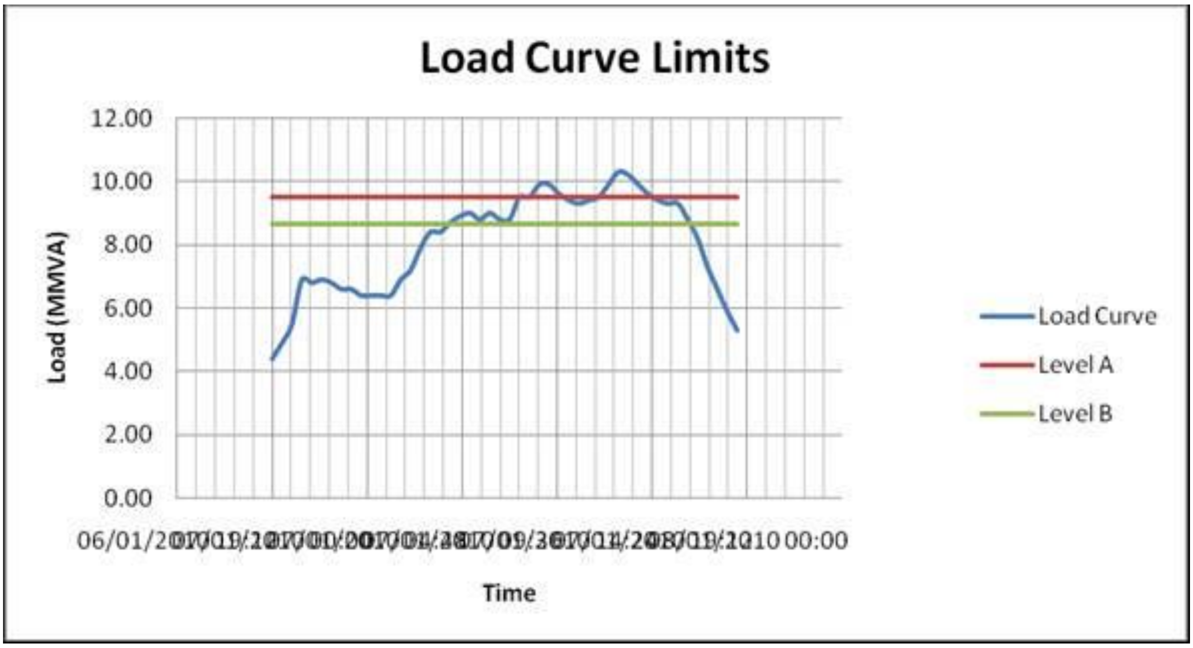

Figure 1. Load profile curve

Following this detailed investigation of the proposed site, Harbury primary substation, WPD commenced a detailed connection study to gain internal approval to facilitate the generation to be connected. This document is attached as *Appendix A*.

Prior to the registration of the project the costs required to deliver this solution were outlined and represented in the total Tier-1 allow expenditure requested (£300,000). In order to minimise the expenditure of the Tier-1 fund the project was to utilise the existing revenue streams associated with distribution generation connected to the network, STOR, TRIAD and PPA:

- STOR – Short Term Operating Reserve
  - A commercial arrangement with National Grid to provide short term generation to support the grid at times of high system load. The contracted generation receives finance for being available and then for being utilised.
- TRIAD – Transmission Network Use of System charges (TNUoS)
  - There are three TRIAD periods per year and by using less energy or supporting the grid with generation at these times a payment from National Grid is provided.
- PPA – Power Purchase Agreement
  - The export value (kW/h) of the generation provided to the grid.

This method was proposed as it was originally seen that seasonal generation connected to the system would be value added to an existing financial structure currently employed by energy aggregators. This project was looking to generate electricity at the times of greatest load on the network, winter peaks between the months October and March. These months align to the existing STOR seasons 5 and 6.

This initial work was developed in partnership with Flexitricity, a UK based energy aggregator, who have significant experience in the STOR and TRIAD markets.

As the owner operator of the UK's largest rental fleet of generators Aggreko were proposed to provide the generation that would be operated by the aggregator, Flexitricity, who were keen to further develop their automation platform and use their existing commercial contracts to create an additional income stream as the returns on new STOR contracts were diminishing.

Following the detailed connection study on the requirements to connect the seasonal generation it was decided to connect it within the primary substation boundary. Installing the generation within the substation for phase 1 of this project had significant benefits:

- To provide a closely controlled environment to deploy the commercial and control models and methodology; and
- Where the physical connections and dependencies could be fully considered and controlled, which in turn should significantly minimise the project's risk.

Phase 1 was intended to allow a future real network environment to be demonstrated, which would evidence the original objectives.

The initial engagement was with the aggregator, who was of the view that there was adequate potential within their existing business model to encourage the owners of underutilised assets to deploy them 'rent free', with a view to accessing alternative income opportunities.

A base level of income expectation was identified by Flexitricity based on their experience of existing services. From this a financial proposition was developed that would provide the asset owner with an annual profit, after fuel and maintenance, per MW of around £37K, which included a suitable payment for the operation of the asset during the peak winter periods where constraints were most likely to occur. The details of this initial financial model can be seen in Table 2 below. The information provided in the table is based on a 3MW generation installation where the STOR is predicted to operate for 55 hours, the TRIAD payments over 15 hours and the seasonal generation operating for 90 hours at 50% (1.5MW).

From Table 2 it can be seen that the finance model used meant that the seasonal generation revenues were small compared to the values attributed to both STOR and TRIAD, being 12 (£8,087/£68,431) and 23 (£8,087/£34,443) per cent respectively.

Based upon the principles discussed, Flexitricity engaged Aggreko to secure their participation within the trials and all initial activity was positive where both third parties were confident about the ability to agree commercial terms and complete any site commissioning for a 2011/12 winter demonstration.

WPD seasonal generation project				
STOR annual revenue and costs				
Availability	£62,720			
Utilisation	£26,419			
Value of generated electricity	£8,250			
Fuel cost	-£28,958			
Maintenance cost	£0			
Annual export charge	£0			
Annual STOR value to Energy Partner	**£68,431**	**equivalent to**	**£22,810**	**per MW**
Triad annual revenue and costs				
Triad charge avoided	£0			
Export triad benefit	£59,955			
Electricity import avoided	£0			
Electricity export value	£2,250			
Gross total triad revenue	£62,205			
Fuel cost	-£7,898			
Maintenance cost	£0			
STOR availability payments lost	-£5,103			
Net triad benefit	£49,204			
Annual triad value to Energy Partner	**£34,443**	**equivalent to**	**£11,481**	**per MW**
Seasonal Generation Revenues				
Availability	£6,248			
Utilisation	£18,782			
Export electricity value	£6,750			
Fuel cost	-£23,693			
Annual WPD benefit to Energy Partner	**£8,087**	**equivalent to**	**£2,696**	**per MW**
Annual net benefit to Energy Partner	**£110,960**	**equivalent to**	**£36,987**	**per MW**

Table 2. SGD Revenue Breakdown

Senior representation within Aggreko was secured and a number of meetings took place to agree the specification of the generators, method statements for installation, contractual arrangements, interface specification and commercial terms. Again the initial progress was positive with some of the technical parameters which were a progression of the core competencies of the third parties establishing a feasible solution to connect and control the generation as required.

WPD therefore made suitable arrangements at the substation site to facilitate a safe and secure area at Harbury that would allow Aggreko to connect and maintain their assets for the purposes of the demonstration. This involved the installation of appropriate electrical infrastructure to enable the integration of the generation, a 630A rated ring main unit (RMU) and an 11kV cable to the point of generation installation.

At the same time as the start of the physical work to connect the generators to the system Flexitricity also commenced the development of an automated control interface. This control would be used to receive load status signals that would automatically allow substation telemetry to trigger a sequence of up to 3 x 1MW generators to start and stop at appropriate set points in order to alleviate engineering constraints within the substation. The detail of this system is provided in Appendix B. This formed the basis of the intelligent connection of the seasonal generation to the system, allowing the minimum level of generation to be used for the minimum time required. This automated control interface can be summarised by the following steps:

- Real time monitoring of the energy flow through the primary transformers;
- Comparison of real time data against pre-defined generation triggering set points;
- Operation of generation in 500kW portions to ensure firm capacity of the primary substation is not breached; and
- A definable minimum operating time to avoid constant switching of generation.

During the advanced stage of commercial negotiations it became apparent that there were difficulties in concluding an agreement:

- The generation asset owners would have significant capital outlay associated with the deployment of the generators;
- While generators are sometimes underutilised it emerged that the associated ancillary equipment such as control equipment and portable transformers are in limited supply and rarely idle;
- Revenues such as STOR & TRIAD, which account for the majority of annual income, are not guaranteed and expose the asset owner to excessive potential commercial risks; and
- The nature of substations being unmanned sites presents increased risk of theft & vandalism and associated insurance premiums.

Despite the best endeavours of the project partners to develop a suitable contract and financial terms under which to operate the demonstration, this could not be achieved ahead of a deadline necessary to ensure engineering completion. With a view to ensuring the technical learning objectives were met, WPD had continued work in parallel to prepare the site for the generation and support control system development by Flexitricity. As a result of this WPD incurred costs for the project site works at site that included

- Installation of Ring Main Unit – to allow network connection of generator;
- Installation of Plinth and housing for RMU; and
- Installation of 250m 11kV cable – to allow connection of generator to existing network.

Having failed to reach an agreement for the 2011/12 winter season WPD, Flexitricity and Aggreko altered the scope of the trial to allow a further attempt during winter 2012/13. (in the hope that STOR prices would be higher and less volatile).

In addition the project scope was increased to explore a number of alternative approaches to the commercial development work in an attempt to ensure that all potential options were investigated. These included:

- WPD direct engagement with asset owner (Aggreko) to mitigate aggregator charges;
- Aggregator approach other generator suppliers to test appetite of other potential asset providers;
- Aggregator source long term generator deployment by third party owner out with rental industry; and
- WPD hire generation under typical market terms & receive the STOR & TRIAD revenue to mitigate cost.

Based on the extended scope and the desire to exhaust all feasible commercial engagement models WPD submitted a ‘programme change mandate’ to Ofgem seeking an extension to allow a 16 month extension on the proposed demonstration end date. There was no request for an increase in project expenditure. The extension of the project’s length was driven by the seasonal nature of the project.

Despite the increased time to negotiate the originally proposed model it was apparent that the learning generated from this was that there was simply insufficient value for the generators/aggregators coupled with undesirably high financial risk to justify participation.

Figure 2 illustrates the changes in both the availability and utilisation payments associated with STOR over a three year period. Although there is an increase in the availability payments year on year there is also a yearly decrease in the utilisation payments, meaning that the overall value of a STOR contract has reduced.

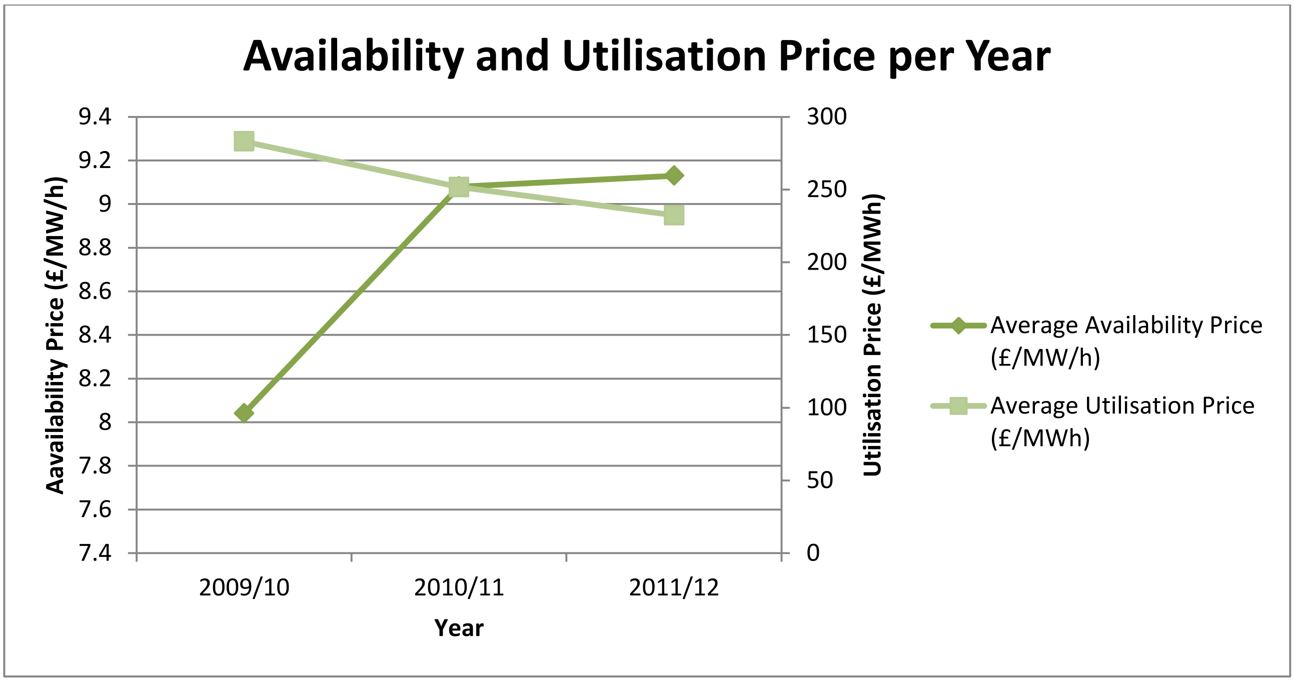

Figure 2 - Graph showing Availability and Utilisation Prices

This is further outlined in Figure 3 which highlights the total amount of utilised STOR against the cost of STOR per gigawatt-hour. It can be seen that although the utilisation of STOR has risen, the value associated with it has significantly reduced. This phenomenon illustrated the downturn in the contract values associated with STOR and weekly rejections over the prior winter of many flexible contracts held by aggregators, which would further erode the potential value of the Seasonal Generation Deployment financial model proposed the previous year.

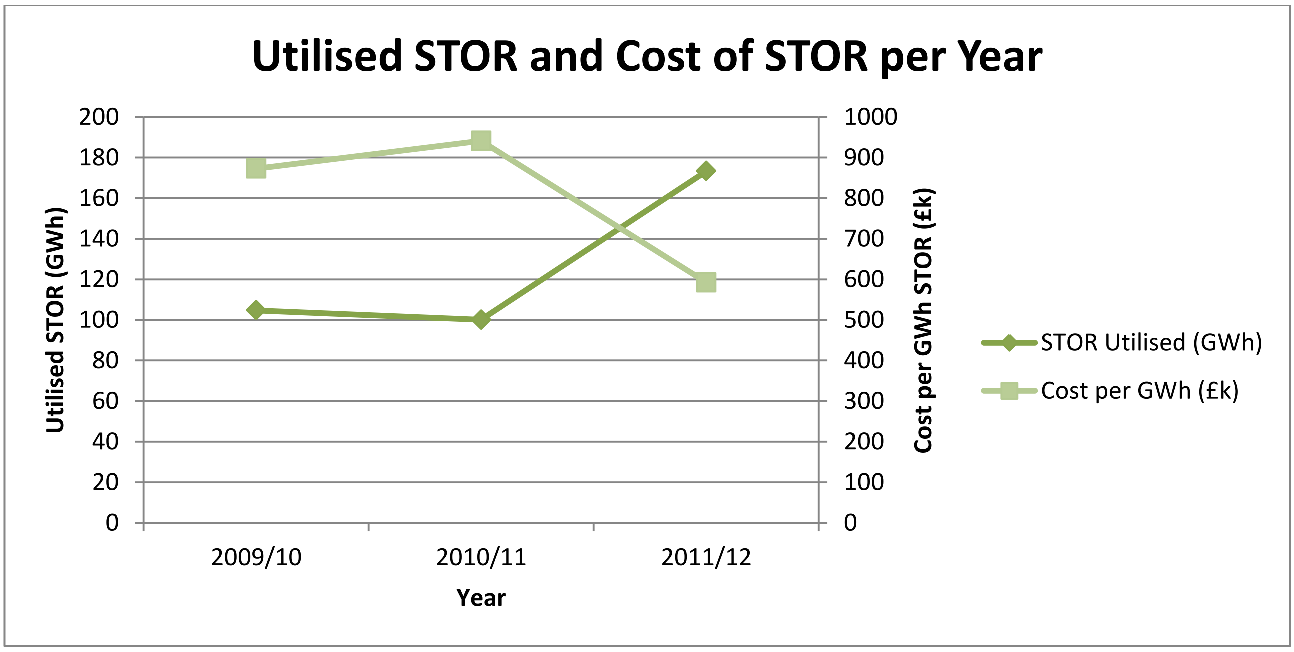

Figure 3 - Utilised STOR and Costs per Year

Figure 4 shows both the availability and utilisation charges for the six STOR seasons for the financial years 2009/10, 2010/11 and 2011/12. The figure shows that the greatest charges are generally in Seasons 5 and 6, which this project was focussing on. This indicates that these seasons are the most financially viable seasons for a DNO to use the generations for additional load support, due to the aggregator and/or generator maximising its revenue through traditional STOR agreements, for the situation where fixed revenue is required for the generation asset.

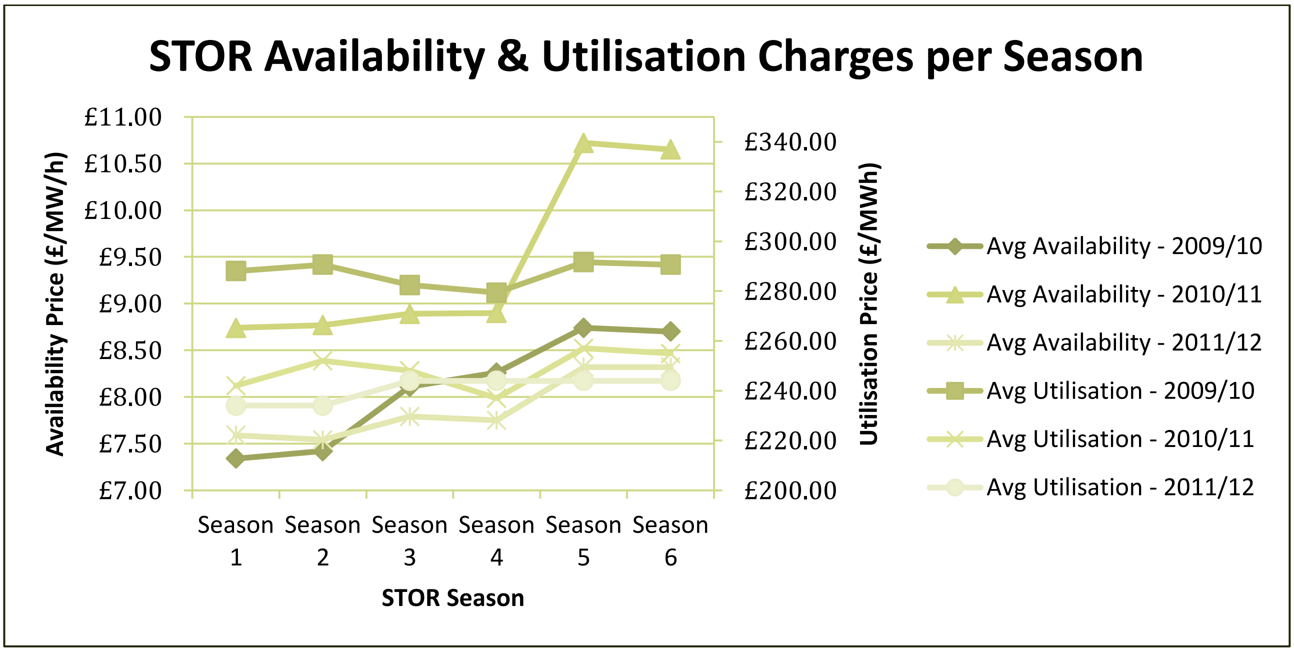

Figure 4 - Availability and Utilisation charges per season

Direct engagement with the asset owner would serve to take the aggregator share of the revenue from up to 30% of service fees and attribute them as incentive to the business case. This highlights the value of the services provided by the aggregator as it would then require the asset owner to develop the control and integration of the generators. Beyond this technical capability the aggregator also provides a great deal of skill and knowledge in the acquisition and execution of competitive STOR contracts and their interaction with the other commercial opportunities. Without the benefit of an aggregator it is also likely that an asset provider would be limited to deploying a minimum installation capacity of 3MW which, however not in this instance, is likely to be larger than many DNO sites could feasibly accept. Even with the potentially increased revenues from direct engagement the financial model was not attractive to Aggreko without an increased contribution from WPD for the operation of the winter peak load management.

Flexitricity also widely circulated an invitation for expressions of interest to a large number of generator owners including alternative generator rental companies in an attempt to see if the original financial offer may be attractive. There was a moderate initial response seeking further information and clarification of the terms of engagement. This reduced the number of interested parties to a single rental company who confirmed that in order to fulfil the engineering requirements they would be required to go to Aggreko themselves to hire ancillary equipment such as transformers, and the cost was too great to make the opportunity attractive.

During the ‘expressions of interest’ process, Flexitricity also identified an alternative source of generators from an organisation that acquired used assets being decommissioned from organisations upgrading their stand-by arrangements. This model did initially look potentially feasible but the asset owner required an agreement with a contract term well in excess of the trial in order to safely absorb the mobilisation and commissioning costs associated with siting the generators at Harbury primary substation. This approach may be appropriate for DNOs to consider as an alternative to conventional reinforcement.

Finally, the remaining alternative model was for WPD to enter into a conventional asset rental agreement to locate 1MW of generation at Harbury primary substation. WPD would then seek to recover some of the expenditure by offsetting the rental & running costs by contracting with Flexitricity to operate the asset within STOR and TRIAD duties. Whilst this would have presented the opportunity where WPD could progress the demonstration by paying for commissioning and asset rental fees, the magnitude of the charges associated with this arrangement would be unsustainable as a realistic alternative. A decision was therefore reached that the trial would not provide an acceptable outcome for the LCNF demonstration.

7. The outcomes of the Project

The description of the work carried out, in section 6 of this report, outlines the challenges presented in seeking an alternative approach to conventional network reinforcement, particularly in relation to the complex commercial challenges that are presented, when exposed to multiple party agreements and revenues that are associated with exposure to market or performance risks. This has become apparent not only within the specific use of third party assets to support distribution networks but is common with the demand response market more broadly. At both domestic and industrial scale the challenge of balancing incentives, guarantees, capital investment and risk is an area of regular debate. This is reflected in the questions and market assessment contained within Ofgem's recent consultation on 'Creating the right environment for Demand Response'.

This project has identified a clear outcome for the industry in confirming that there is currently inadequate incentive to the owners of assets to locate assets on an ad-hoc basis in order to work within a dedicated programme of revenue generation based upon the range of current commercial services. The barriers to overcome in order to affect the situation as to offer a positive recommendation are extensive and WPD identified the following significant factors:

- Capital costs for commissioning sites in not insignificant for either the DNO or Asset Owner;
- Insufficient on-going revenue to justify dedicated use;
- Share of income between multiple third parties such as aggregator & asset owner not acceptable to all parties;
- Aggregation capability is necessary for sites below 3MW in order to access the STOR market;
- Many sites would not be capable of hosting 3MW;
- Perception of asset owner is that they are taking the majority of commercial risk;
- Long term asset deployment likely to have reduced risk perception but seeking longer term engagement than WPD can currently consider within the scope of an LCNF demonstration;
- Limited guarantees associated with revenue streams determine projects as high risk; and
- Security of unmanned sites also deemed as high risk for theft or vandalism of assets.

As the Demand Response market continues to develop there continues to be discussion amongst various stakeholders of similar propositions and the learning gained during Seasonal Generation Deployment should guide future work that seeks to demonstrate the viability of such proposals.

The negative learning provided by this project relates specifically to the ad-hoc deployment of generation of generation on a seasonal basis. It does not directly counter the positive learning from other LCNF projects about the role of distributed generation and demand response in future network operations (most notably Project FALCON for WPD). Nor does it mean that localised deployment of generation assets is uneconomic in all cases. For example, WPD have as part of business as usual operation independently identified a substation site in South Wales that has benefitted from the installation of 8MW of distributed generation installation. This has been provided through a third party asset owner on a long term basis. The contract includes the lease of a suitable location for siting the generation by WPD and agreeing specific terms of generator operation that would allow it to support the network.

On a technical level the demonstration did manage to develop a clear control strategy and methodology that could be effectively employed to manage assets either automatically and/or remotely to support the network during periods of constraint and maintenance. Findings regarding the technical outcomes can be viewed in Appendices A and B. This learning will be useful to other LCNF projects exploring demand side integration.

8. Performance compared to the original Project aims, objectives and success criteria

This project's primary objectives were intended to meet at least three of Ofgem's LCNF specific requirements:

- A novel arrangement or application of existing Distribution System equipment (including control and communications systems and software);
- A novel operational practice directly related to the operation of the Distribution System; and
- A novel commercial arrangement with a Distribution System User.

There were four key areas of focus:

1. Development and deployment of an automated network generation control system;
2. Development and deployment of a 'STOR type' commercial arrangement – "DNO to DSO" by developing the opportunities of a DNO managing and operating integrated generation;
3. Increase network flexibility and security through robust generation installation; and
4. Capital deferment business case.

The performance and success of this project relating to the four key areas is described below.

1 – Based on their extensive experience on remote operation, Flexitricity proceeded with development of the systems necessary for objectives set out in the Seasonal Generation Deployment. As a result a conditions based methodology was created along with all the associated status detection, communication and notification to facilitate the desired operation of the assets automatically or remotely. This system was significantly bench tested to prove its viability for network operation. The hardware to provide this system was created and installed on site in preparation for generation deployment.

2 – The trial was unsuccessful in either developing or deploying a 'STOR type' commercial arrangement for the variety of reasons detailed in section 7. A significant issue with being successful in this aspect of the project was the lack of ability to develop a DNO lead commercial arrangement that could positively interact with the existing STOR market framework; this is described further in section 11.

3 – This has not been achieved due to the inability to agree suitable contractual arrangements to enable the installation of generation assets on to the system.

4 – A financial arrangement could not be agreed with any third parties and therefore there, at this stage, is no business case developed for capital deferment.

9. Required modifications to the planned approach during the course of the project

Following the investigation of the approaches explained above, the decision was made that for a temporary installation of generation, in the region of one to three years, to defer the investment of additional network assets the financial remuneration that aggregators and generator owners/operators are looking for is not compatible. Therefore, at this point, the decision was taken, within WPD, to suspend this project.

Figure 5. Project Timeline

10. Significant variance in expected costs and benefits

10.1. Costs

Description	Forecast	Actual	Variation (%)
Project Management	£39,253.16	£ 14,512.90	-63%
Connection & Commercial Works	£90,000.00	£ 4,358.07	-95%
Ring Main Unit	£20,486.00	£ 20,486.00	0%
Installation & Commissioning	£77,936.58	£ 54,210.58	-30%
Availability & Utilisation Payments	£100,000.00	£ -	-100%
Total	**£327,675.74**	**£ 93,567.55**	**-71%**

Table 3. Cost breakdown

10.1.1. Project Management

This element of work is associated with the running and managing of the project. Due to the early termination and seasonal nature of the project the actual cost is 37% of the planned cost.

10.1.2. Connection and Commercial Works

A cost of £4.4k was encountered for the payment of work carried out by the aggregator and supporting function to investigate the availability of the other options once the original methodology was discovered to not be feasible.

10.1.3. Installation and Commissioning

The actual cost of the installation and commissioning works is 30% lower than originally forecast. This is due to the fact that although a significant element of the electrical infrastructure was installed in preparation for the installation of generating assets, the final connection requirements and commissioning works were never required.

10.1.4. Availability and Utilisation Payments

The forecast spend on the availability and utilisation payments was £100k. This was split between phase 1 and 2, £30k and £70k respectively. Due to the unavailability to reach a sufficient commercial arrangement, whereby the availability and utilisation payments for phase 1 were within the £30k budget, none of this forecast spend was realised.

10.2. Expected Benefits

10.2.1. Ability to accommodate load without the need for large-scale network reinforcement

The actual demonstration of this was not successful due to the explanations provided in sections 7, 8 and 9. Whilst this was unable to be trialled on the complete network the work in Appendix B details the requirements of the system to ensure that additional or existing load placed on the system at times of high demand can be accommodated, without overstressing the existing assets on the system through the use of temporarily connected generating plant. This system was designed to ensure that the minimum amount of generation support was required, by ensuring that appropriate real time data was used to ensure that the maximum load on the system was understood.

10.2.2. Explore the integration of controllable distributed generation on to the network

Despite not having the opportunity to advance this to the stage of installing generation at the primary substation, the aggregator, Flexitricity, developed an interface system to allow the controllable operation of the generation on the system and bench tested it. This system allowed the connected generation to be connected and disconnected in 500kW units based on the real time maximum data it received. This was a development to their standard interface which currently operates a large number of generators on critical sites for STOR aggregation.

10.2.3. Develop the experience in Distribution System Operation and better understand the role and business value

During the period that has elapsed since the initial project registration there has been an ever increasing level of interest in demand side response (DSR) offerings and the overall market structure. It is generally recognised that DSR in various forms will play a significant part in the design and operation of future networks. Learning encountered within Seasonal Generation Deployment has gone on to influence the planning and execution of related activities such as Project FALCON and WPD’s contribution to National Grid / DNO Shared Services Framework.

10.2.4. Potentially simplify the operation of a network to meet demand

Not proven. Whilst the connection of the generators to the 11kV system is well understood and the key elements of the control system were built and bench tested the financial element was not suitable to trial the complete system. However time to deployment would be in the region of three months as opposed to three years for the replacement of two primary transformers, for example.

10.2.5. Possible reduction in longer-term capital spend on network capacity increases

This was proven to be unfeasible for phase 1 of the project. The costs that were required to install and operate the generation in each of the proposed cases were above that of the capital spend required to install traditional network assets to meet the network capacity increases.

Phase 2 of this project was looking at the opportunity of using generation that was already installed on the system in the areas requiring network reinforcement now or in the future. However, since the registering of this project several Tier-2 LCNF projects are looking to use this in variety of formats, for DSR etc. As WPD will specifically be looking to do this within their FALCON project it was deemed that due to significant scope overlap that the progression to phase 2 after the negative learning from phase 1 was not appropriate.

10.2.6. Greater management of network with increasing flexibility and security

Not proven.

10.2.7. A connection model for future 'DSO' operated generation

A significant barrier to this was the contractual conflicts between STOR and DNO operation models. The financial requirement for an aggregator to omit some of their assets from certain STOR windows for the use of these assets by a DNO is currently too great to make it financially viable for a DNO. In order to allow a DNO to move towards being a DSO there needs to be the ability for an aggregator to operate both in the STOR market as well as providing an ancillary service to DNOs. Several other LCNF projects regarding DSR operations within a DNO environment to move towards a DSO model have had several, significant, factors preventing them from being financially successful in this current market.

10.2.8. There are currently no registered projects investigating this area of network development

Phase 2 of this project is now incorporated into many LCNF projects (including WPD's own project FALCON.) Due to the delays in Phase 1 many of the more recent projects have deployments ahead of this project.

11. Lessons learnt for future Projects

The two distinct elements of this project have been the technical and commercial aspects. There has been significant learning relating to both these aspects, positive learning for the technical elements whilst negative for the commercial aspects.

The main areas of learning surrounding the technical elements of this project are that the connection and control of the generation required to provide intelligent operation of the generation to successfully meet the requirements; to mitigate against excess loads on the network. The connection of the seasonal generation to the existing network has been proven to require the same design principles to that of a normal generator connection to the system. Details of this can be found in Appendix A. To facilitate the appropriate operation of the generation, to minimise the usage (previous generation installations have provided full output for a continuous season), a full control system was developed. This learning is detailed in Appendix B. This design, although not installed in a real network environment, has been bench tested, where simulated load signals from two primary transformers (4-20mA) were provided and the operation of the generators appropriately simulated.

The commercial learning of this project centres on the ability to provide appropriate levels of generation for a period of high load on the network, usually winter, at a reduced capital cost of that compared to the capital cost of conventional network investment, usually larger power rated primary transformers. This project has provided learning that due to a variety of issues and external factors this is not currently possible.

The first contributing factor is that there are no significant spare assets at the disposal of the generator owners in the winter months. This information meant that the generator was looking for returns on their assets that they would for any other installation, whether that is for use within the STOR market or to provide generation for events such as festivals and sporting occasions. This significantly changed the financial position in terms of the project's viability when comparing the installation of generation to the capital cost of installing additional or larger transformers.

An example of a suitable cost for operating seasonal generation as an alternative to installing new, larger firm capacity, transformers would be in the region of a total cost per year under £25,000. This is based on the cost of a two 33/11kV transformer change at an existing Primary Substation, costing £800,000 to £1,200,000, where the asset life is measured at 40 years.

Another significant element of commercial learning was the value that a generator owner/operator attributes to the certainty of revenue in terms of the length of the contract to secure their assets' connection to the electricity network. STOR contracts are typically in the regions of 10 to 15 years, however WPD were looking to contract for a period between one and three years. The lack of security in financial return meant that a larger return was sought for the time the generation was installed.

Finally, during the lifetime of this project there was a significant reduction in both the availability and utilisation rates offered by National Grid as part of their STOR contracts. This reduced income revenue meant that aggregators/generators were looking to gather the same income, meaning that the costs to WPD, or any other DNO looking to employ seasonal generation, were increased. The aggregators/generators were not willing to reduce their income stream in line with the current STOR market. The key learning here is that reliance on other mechanism co-funding an alternative to grid reinforcement carries risks beyond the direct control of the DNO. Further that emerging markets for aggregator and demand response services are still highly volatile making them potentially unsuited for use as long term investment alternatives. Therefore, for a successful trial to take place the STOR rates for both availability and utilisation would have to stabilise and, in most cases, increase for aggregators and/or generator providers, who are looking for a secured level of revenue on their assets. Other options for the implementation of a successful trial could centre on the coordination between a DNO and National Grid to facilitate the operation of STOR and Seasonal Generation in the same availability window, meaning that a generator/aggregator could operate in both markets, if required. This would provide a further degree of certainty and availability to capture their required revenue.

12. Planned implementation

This learning set out in this report will be used to support the implementation of DSR in other WPD projects, like FALCON, and business as usual solutions going forwards. It will also be fed into the industry working groups on DSR including the DECC/Ofgem initiatives forming part of the Smart Grid Forum.

13. Facilitate Replication

Elements of this project will be replicated in other WPD projects, such as FALCON, where DSR will be used to optimise the use of the existing 11kV network. The basis of this project and the supporting work in terms of the value of reducing the risk of overstressing a substation will also be taken forwards in to WPD business as usual activities that are planned and on-going at this point.

Appendices

Appendix 1:

Generation Connection Study & Design

Generation Connection Study & Design

3MW Diesel Generation connection on to the 11kV distribution network
Harbury Primary Substation

Jonathan Berry
22.10.2012

This document details the availability and requirements to introduce 3MW of diesel generation at Harbury Primary Substation, connected at 11kV. This generation is to be included to support the Low Carbon Networks Fund Tier-1 Project, Seasonal Generation Deployment.

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1.0 Abstract

Seasonal peak demand habitually causes an issue to Distribution Network Operators (DNO). That is where for a season, namely winter, there are much greater stresses placed on the network, borne by increased load requirements. Historically, the correction of issues relating to the overstressing of assets and statutory limits, both for load and generation, has been done so by reinforcement of the affected asset(s).

With the cost of network reinforcement increasing and the temporary nature of the overstressing, it is planned to investigate, under LCNF, innovative solutions to the temporary load and generation stresses witnessed on the network.

This report will outline the availability of the 11kV network to include 3MW of additional diesel generation and propose any action that may be required to facilitate its inclusion.

2.0 Substation Background

2.1 Transformation

Harbury Primary Substation consists of three voltage levels, 11kV, 33kV and 132kV. The transformation is from 132kV to 33kV and then to 11kV. This project is primarily involved in reducing the network stress of the 33/11kV network assets, which are two 7.5/10.85MVA transformers. The detail of the transformers tap-changers are not known; therefore a conservative approach has been taken to the availability of the reverse power capabilities, 50%.

2.2 11kV Load Detail

Table 1 provides detail of the maximum load for the years 2009, 2010 and 2011, generated from Data Logger[1].

Year	Firm Capacity	Max Load	Max Load / Firm Capacity	Date	Time
No unit	MVA	MVA	%	No unit	No unit
2009	9.8	10.5	107%	14-Jan	18:00
2010	9.8	11.8	120%	20-Jan	14:00
2011	9.8	10.4	106%	05-Jan	17:00

Table 1. Maximum Load Detail Harbury 11kV Substation

The firm capacity of Harbury 33/11kV Substation is 9.8MVA[2]. The previous three years maximum load demands provide an average of 111% of the firm capacity, where the largest maximum demand was seen in 2010, 11.8MVA (120% of firm capacity).

It is noted that there is 1MW of generation connected to the 11kV busbar at Harbury Substation, no account of this has been taken in the load detail provided. Therefore, the data provided could be inaccurate to the point of being 1MVA lower than the real demand on the system at any instant.

[1] Data Logger – A database of historic substation information relating to Volts, Amps and Power
[2] Long Term Development Statement for Western Power Distribution (East Midlands) plc’s Electricity Distribution System

3.0 Network Study

The three main network factors when connecting generation are to be considered, thermal capacity, voltage stability and fault level.

3.1 Thermal Capacity

The proposed generation to be connected to the network is 3MW (3MVA @ pf=1). All circuit breakers are rated at a minimum of 630A (12MVA) and the new cable to connect the generator to the network is to be a minimum of 300mm^2 Al XLPE, with a rating of 9.8MVA. The new network switchgear to be installed will be rated at 630A, therefore there are no perceived thermal capacity constraints foreseen.

3.2 Voltage Stability

The main areas of consideration are the voltage rise due to the addition of 3MW of generation and the voltage step change for the instance where the generation is suddenly, and unexpectedly, disconnected from the network.

3.2.1 Voltage Rise

The 11kV busbar voltage at Harbury Primary Substation is 1.031pu (where 1pu is 11kV) prior to the connection of the generation.

The 11kV busbar voltage at Harbury Primary Substation is 1.033pu post connection of the generation.

The rise in voltage due to the connection of 3MW of generation has been considered at minimum load to ensure the worst case network condition is considered. The voltage rise is 0.002pu, which equates to 22 Volts. This rise is determined to have no detrimental effect on the system.

3.2.2 Voltage Step Change

The voltage step change represents the change in voltage at the 11kV busbar for the situation where the generation is disconnected from network without any time for the network to suitability react, i.e. change tap positions. The voltage step change condition is modelled with maximum load on the network to ensure that worse case network condition is considered.

The 11kV busbar voltage at Harbury Primary Substation is 1.025pu with the 3MW generator connected.

The 11kV busbar voltage at Harbury Primary Substation is 1.021pu with the 3MW generator disconnected (with taps locked).

The voltage step change is 0.004pu, which equates to 44 Volts. This is a 0.4% change in voltage, which is satisfactory as P28[3] recommends a step change of 3% maximum on the 11kV network.

3.3 Fault Level

It is imperative that no fault level ratings of equipment are exceeded; Table 2 details the fault level ratings of the existing 11kV switchgear at Harbury Primary substation.

	Equipment Rating		**Policy Rating**	
	kA	*MVA*	*kA*	*MVA*
Make duty	50	953	32.8	625
Break duty	20	381	13.1	250

Table 2. Harbury 11kV Switchgear Fault Level ratings

Table 3 provides both the existing and predicted fault level values at the 11kV busbar.

	Voltage (11kV)	**Make duty**	**Break duty**
Fault Level	pu	*10ms*	*70ms*
Existing (MVA)	1.031	391.403	139.811
3MW Gen Connected (MVA)	1.033	442.858	152.839

Table 3. Harbury 11kV Fault Level data

It can be seen that the data provided in Table 3 (modelled data) is lower than that provided in Table 2 (switchgear ratings), therefore fault level is not considered an issue.

[3] Engineering Recommendation P28 1989 – Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom

4.0 Connection Design

To integrate the 3MW of generation on to the existing network at Harbury Substation, new assets are required to be installed. The existing 11kV infrastructure at Harbury Substation is provided by a ten panel switch-board (2x Tx incomers, 1x Bus-section CB and 7x Feeders). One of the existing feeder circuit breakers (CB) currently feeds a 100kVA 11/0.4kV distribution transformer (which provides the Substation power), where the protection is provided by the 11kV CB protection. To provide a separate and protectable connection for the 3MW of generation, this existing 100kVA transformer is to be changed for a new, 315kVA, distribution substation. The installation of this new 315kVA unit will allow the connection of additional equipment to the 11kV CB, as the protection for this unit will now be provided by TLFs (time limited fuses).

This 315kVA distribution substation will be connected to the existing 11kV CB through a new, 300mm^2 Al XLPE cable, which will be terminated at the termination box of the 11kV CB and the incoming switch on the 315kVA substation. This 315kVA substation will be located on the existing plinth at Harbury substation, which has been installed previously for this project. The LV connection will be provided through a 3-phase way on the LV pillar, where an LV cable is to be straight jointed to the existing LV cable. The location of the 315kVA substation is indicated in plan:

170001-1 – 315SS – V001 – 22.10.12 (Appendix A)

A 630A RMU is to be used to connect the generation to the 11kV network. This 630A RMU is to have the following features:

- Metering Unit to provide VT measurements
- Automation to open and close the CB – (Talus 200 E and actuators/trip coil)
- Suitable relay to provide the following protection:
    - OC
    - EF
    - UV
    - OV
    - NVD

The 630A RMU is to be sited in the existing 33kV Substation site. It is to be housed in a standard GRP housing on a concrete plinth. The proposed location is indicated in plan:

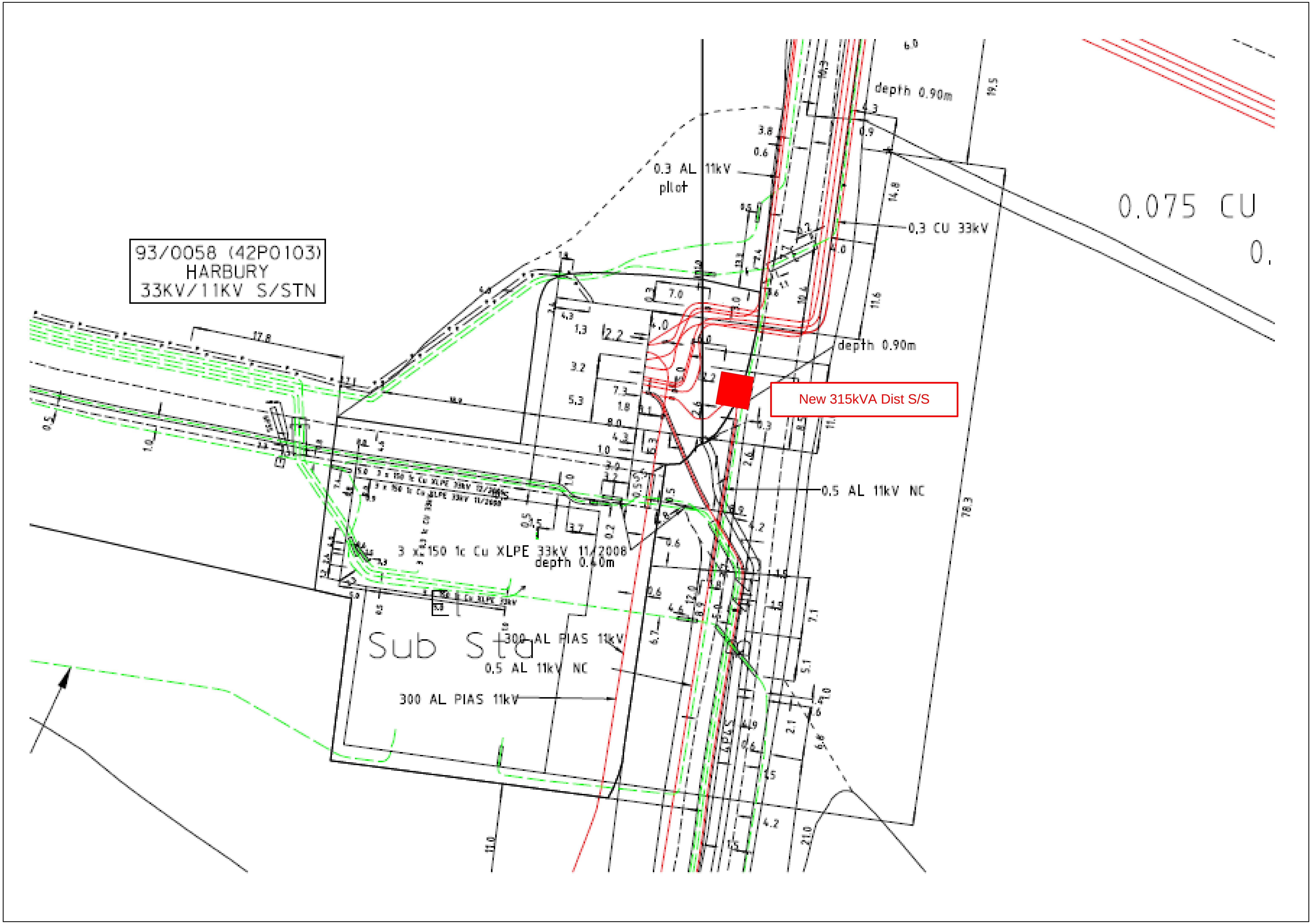
170001-1 – NRMU – V001 – 22.10.12 (Appendix B)

The 630A RMU is to be electrically connected to the 11kV network via the outgoing switch of the 315kVA distribution substation. The 11kV cable for this connection is already installed at Harbury Substation.

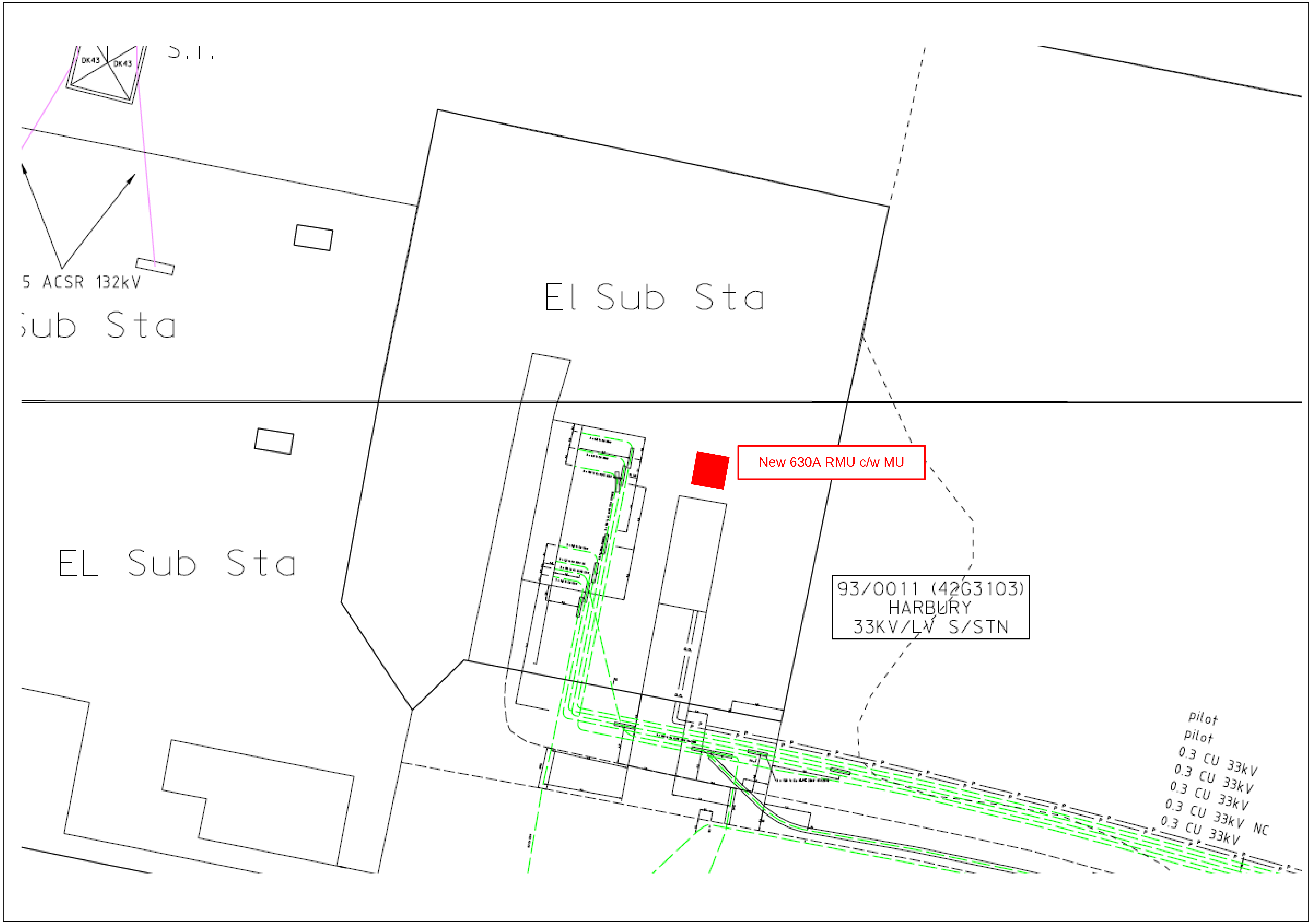
The overall electrical requirements are provided in a schematic network and line plan:

170001-1-HVSCHM-A - V003 - 10.10.12 (Appendix C)
WPDT1005 – 401 – 001 (Appendix D)

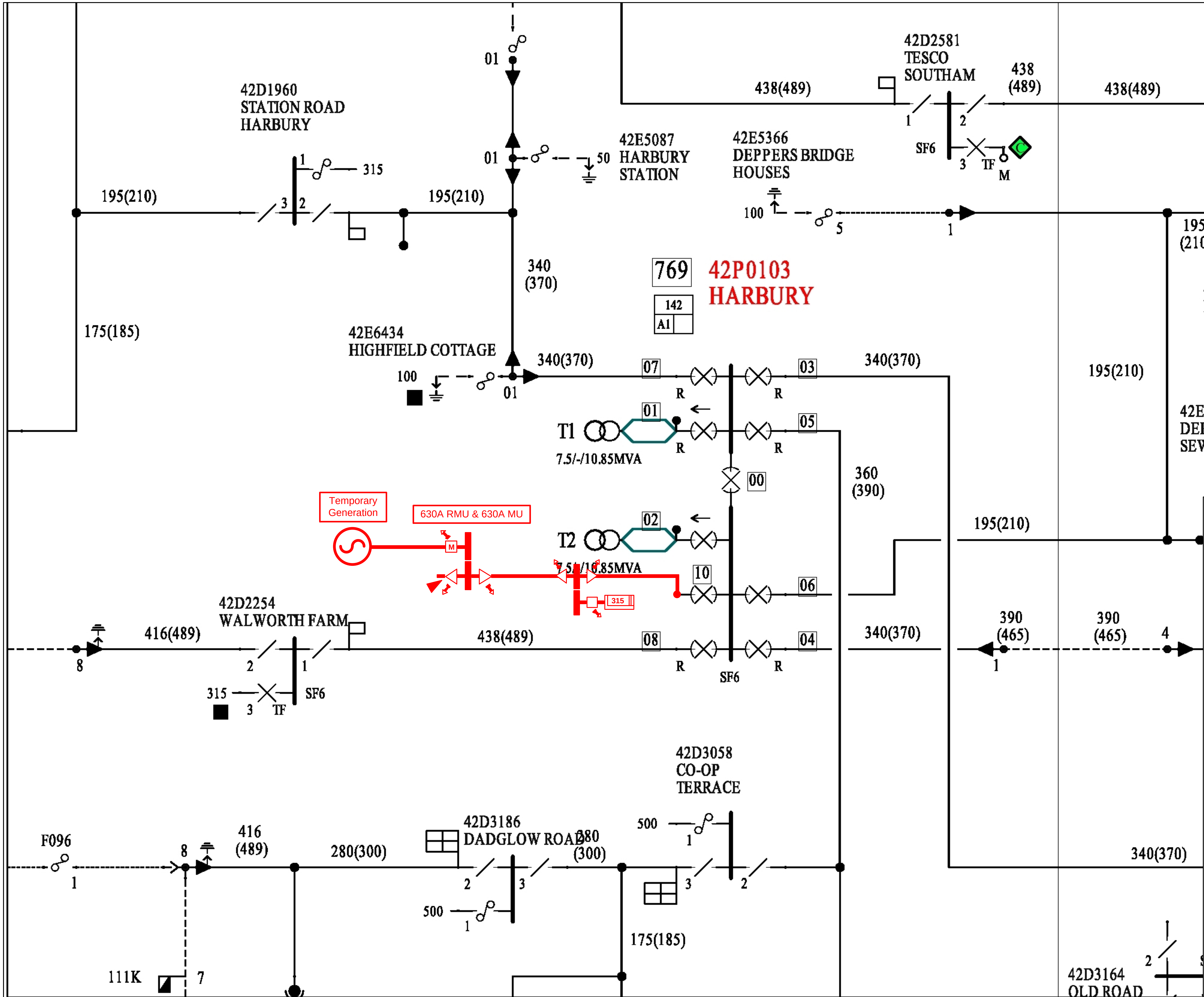
Appendix A: Installation of additional 315kVA distribution substation


93/0058 (42P0103)
HARBURY
33KV/11KV S/STN
New 315kVA Dist S/S
0.3 AL 11kV
pilot
0.3 CU 33kV
depth 0.90m
depth 0.90m
0.075 CU
0.5 AL 11kV NC
3 x 150 1c Cu XLPE 33kV 11/2008
depth 0.60m
Sub Sta
300 AL PIAS 11kV
0.5 AL 11kV NC
300 AL PIAS 11kV

Appendix B: Installation of a generator RMU


DK43
DK43
S.T.
5 ACSR 132kV
Sub Sta
El Sub Sta
EL Sub Sta
New 630A RMU c/w MU
93/0011 (42G3103)
HARBURY
33KV/LV S/STN
pilot
pilot
0.3 CU 33kV
0.3 CU 33kV
0.3 CU 33kV
0.3 CU 33kV NC
0.3 CU 33kV

Appendix C: Complete HV Schematic



WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

Western Power Distribution
Toll End Road
Tipton
West Midlands
DY4 0HH

Required Substation Site:	Y
Required Easement:	N
Required Wayleave:	Y

Project Title:
Harbury Seasonal Generation

Project No: 170001

Drawing Title:
Proposed HV Schematic

Drawing No.	Scale:	NTS
17001-100-2	Date:	10.10.2012
	Drawn By:	Jonathan Berry
Ordnance Ref:	N/A	

COMPASS

IMPORTANT NOTE

CABLE DEPTHS ARE NORMALLY BETWEEN 0.4 AND 1.5 METRES. THOSE MARKED * HAVE BEEN LAID AFTER 1.10.88 GENERALLY AS FOLLOWS

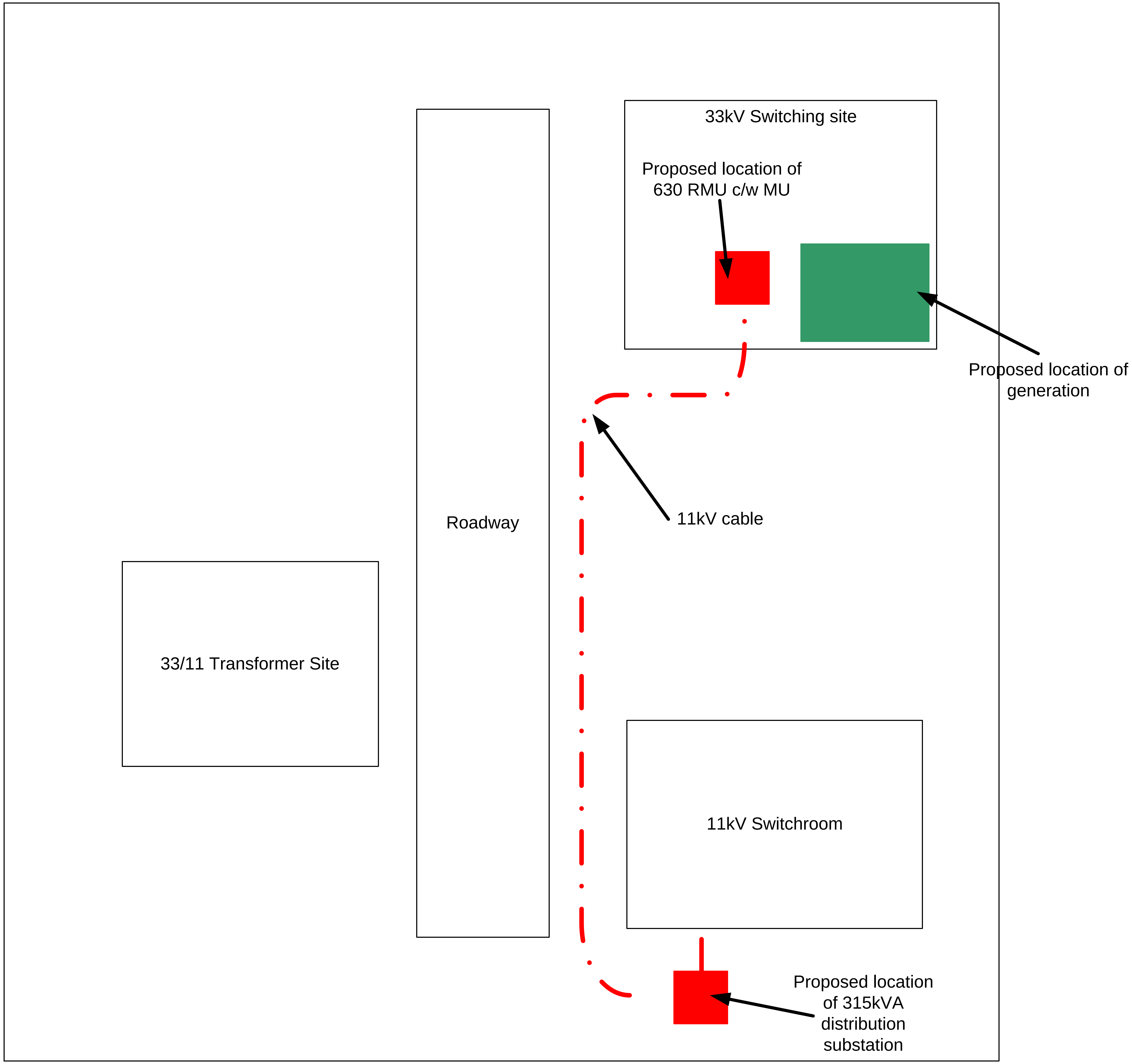
LV INCLUDING SERVICES	0.4 – 0.6 METRES
HV	0.5 – 0.9 METRES
ALL ROAD CROSSINGS	0.6 – 1.0 METRES
33 – 66 – 132kV	0.9 – 1.5 METRES

ANY DEPTHS SHOWN ON THIS PLAN ARE SPECIFIC TO THAT POINT, AT THE DATE INDICATED OR TIME OF INSTALLATION TO THE BEST OF OUR KNOWLEDGE AND BELIEF.
NOTE THERE MAY BE WIDE VARIATIONS FROM NORMAL OR EVEN INDICATED DEPTHS FOR VARIOUS REASONS E.G. CHANGED SURFACE LEVELS AND UNDERGROUND OBSTRUCTIONS. THEREFORE ALL CABLES IN THE VICINITY OF WORKS MUST BE CAREFULLY LOCATED ON SITE.
GUIDANCE FOR SAFE WORKING PROCEDURES IS CONTAINED IN HEALTH AND SAFETY EXECUTIVE GUIDANCE BOOKLET HSG47 AVAILABLE FROM HSE BOOKS.
NO LIABILITY IS ACCEPTED BY CENTRAL NETWORKS FOR ANY ERROR IN OR OMISSION FROM THE PLAN WHETHER DUE TO NEGLIGENCE OR OTHERWISE THIS SHALL NOT AFFECT LIABILITY FOR DEATH OR PERSONAL INJURY RESULTING FROM NEGLIGENCE.

IMPORTANT

Legal permissions will need to be secured
Before works can commence on site

Appendix D: Complete Schematic plan



WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

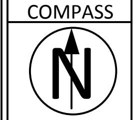
Western Power Distribution
Toll End Road
Tipton
West Midlands
DY4 0HH

Required Substation Site:	Y
Required Easement:	N
Required Wayleave:	N

Project Title:	Seasonal Generation Deployment: Harbury
Project No:	WPDT:1005
Drawing Title:	Proposed: Layout

Drawing No.	WPDT1005 – 401 - 001	Scale:	NTS
		Date:	22.10.12
		Drawn By:	Jonathan Berry
Ordnance Ref:	SP 390 591		

COMPASS



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CABLE DEPTHS ARE NORMALLY BETWEEN 0.4 AND 1.5 METRES. THOSE MARKED * HAVE BEEN LAID AFTER 1.10.88 GENERALLY AS FOLLOWS

LV INCLUDING SERVICES	0.4 – 0.6 METRES
HV	0.5 – 0.9 METRES
ALL ROAD CROSSINGS	0.6 – 1.0 METRES
33 – 66 – 132kV	0.9 – 1.5 METRES

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Appendix 2:

Interfacing & Hysteresis Definition and Requirements

Seasonal Generation Deployment: Interfacing and hysteresis definition and requirements

Abstract

To successfully install and operate the deployed Seasonal Generation it is imperative that the interfacing and hysteresis requirements are accurately and correctly defined.

This document will provide the basis for the interfacing and hysteresis requirements between Flexitricity and Western Power Distribution, including the physical works required.

The requirement of the hysteresis for this project is to ensure that the operation of the Seasonal Generation is at a level to provide suitable learning, however, this must be balanced by the optimisation of the Generation utilisation, in line with providing best value for Western Power Distribution (WPD) and supporting the Low Carbon Transition.

Interfacing

The interfacing requirements between WPD and Flexitricity are primarily centred on providing the correct information at the appropriate time. These are a Substation Load Signal (SLS) and an Availability Signal (AS).

The SLS is required in order to provide Flexitricity the instantaneous load on the 33/11kV transformers. This is to be provided in the form of no.2 separate signals, which will be the power or current flow through each of the transformers 11kV Incoming Circuit Breakers. These figures will be derived from the existing signals on site and are expected to be in a 4-20mA format. It has been agreed that Flexitricity will provide the summation facilities to provide a total system load figure. It is this figure that is to be suitably managed through the appropriate operation of the installed generation.

The AS is to be provided by Flexitricity to WPD. This signal is necessary in order for WPD operatives to be fully aware of the generator availability in order to manage the surrounding network appropriately. There are to be no.4 850kW generators installed on site by Aggreko, therefore it is proposed that there will be no.1 availability signal per 850kW generator. This signal is to be in the form of a “green light” system, indicating that the generator is available. The availability is to be determined by its mechanical availability as well as the fuel level; initial thoughts are that it must have a number of days (TBC) of fuel to operate no.3 units for 5 hours.

Hysteresis

In order to operate the generation efficiently and effectively there needs to be set determinants for operation. A Level A and Level B is required, where Level A is the prescribed firm capacity of the Substation and the level at which the generation will be initiated. Level B is the level at which the generation shall be disengaged.

Level A as described above it to be determined by the firm capacity of the Substation and utilising this value to engage the generation; as this is a demonstration project Level A is to be determined to provide appropriate learning and operation, not necessarily the firm capacity at Harbury Substation.

Level B is to be a value related to Level A, which provides a suitable load level to disengage the generation's support to the network. This value should be decided upon to ensure that generation operation signal flickers between states.

Level A and Level B must be programmed in such a way that they are changeable.

Operation modes

The operation of the generation is to be condition based, these conditions are to be:

- *If load is at or above Level A for time period **X** then Generator1 (G1) is to be initiated*
- *If G1 is initiated and load is at or exceeding Level A for time period **G1 start up + X** then engage G2*
- *If G2 is initiated and load is at or exceeding Level A for time period **G2 start up +X** then engage G3*
- *If G3 is initiated and load is at or exceeding Level A for time period **G3 start up + X** then engage G4*

The ceasing of generation operation is also condition based, these conditions are to be:

G1 only operation

- *If load is at or below Level B for time period **Y** then G1 operation is terminated*

G1 and G2 operation

- *If load is at or below Level B for time period **Y** then G2 operation is terminated*

  Then

- *If load is at or below Level B for time period **Y** then G1 operation is terminated*

G1, G2 and G3 operation

- *If load is at or below Level B for time period **Y** then G3 operation is terminated*

  Then

- *If load is at or below Level B for time period **Y** then G2 operation is terminated*

  Then

- *If load is at or below Level B for time period **Y** then G1 operation is terminated*

G1, G2, G3 and G4 operation

- *If load is at or below Level B for time period **Y** then G4 operation is terminated*

  Then

- *If load is at or below Level B for time period **Y** then G3 operation is terminated*

  Then

- *If load is at or below Level B for time period **Y** then G2 operation is terminated*

  Then

- *If load is at or below Level B for time period **Y** then G1 operation is terminated*

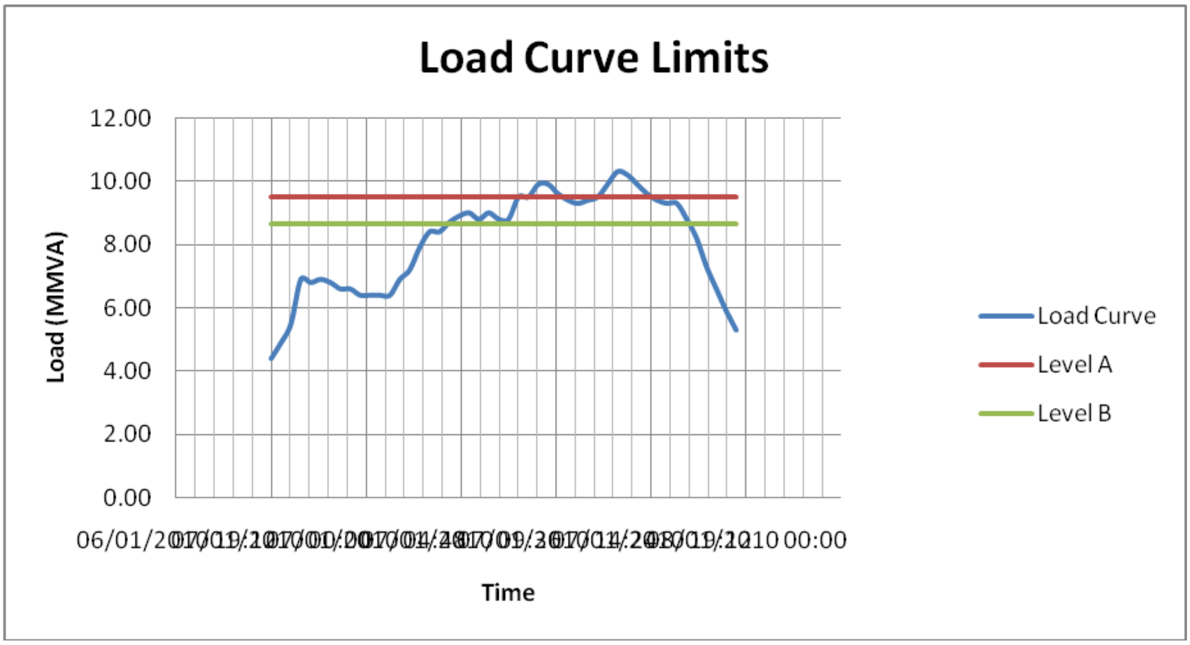

Figure 1. Graph showing typical load curve and set levels

Physical connections

It is expected to install the 11kV RMU and Flexitricity's Control Unit in or close to the existing 11kV switchroom. Below is an indication of the proposed layout of existing and new equipment to be installed.

There are to be connection from WPD's existing and new 11KV switchgear to Flexitricity's Control Unit along with a connection between Flexitricity's Control Unit and Aggreko's. The latter connection is to be facilitated by the installation of an Ethernet cable between the existing 11kV Switchroom and existing 33kV Switching site, where the generation is to be housed. This cable is to be installed along side the 11kV cable to be installed for this project.

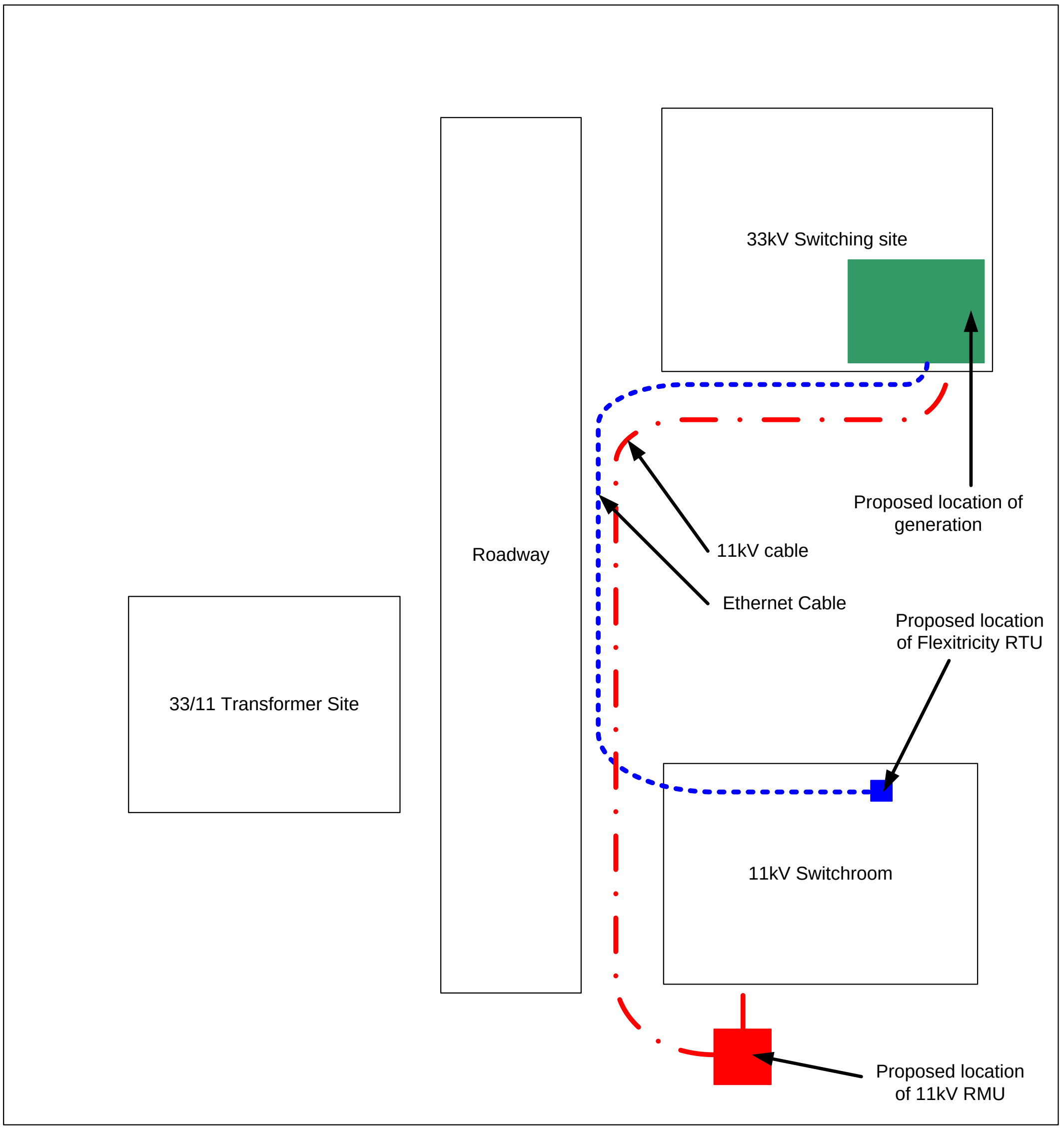

Figure 2. Proposed connections at Harbury