DPlan:
Support for Flexible Urban Networks – LV trial site selection

Table of Contents

Table of Figures

1. Background

DPlan is a distribution planning tool that is being enhanced by CGI and IOA to be able to support additional functionality required for the Flexible Urban Networks – Low Voltage (FUN-LV) project. The initial site selection process has been aided by DPlan in advance of these enhancements. It has been possible to demonstrate the modelling of load and fault current contributions from Soft Open Points (SOP), in a number of ways, including assistance with the identification and location of:

- Customers, their loads and load profiles and the connections to networks;
- Substations with different load profiles including the Radial Embedded Substations (RES) in interconnected networks;
- Method 1 trial sites by conducting fault level studies on the LV network;
- Illustrating the potential load transfer between transformers and networks and the transfer profiles; and
- Confirming the operation of protection systems and particularly for RES under reverse power fault conditions.

When power electronics devices are used in business-as-usual (BAU) scenarios it will be critical for UK Power Networks staff to have access to tools on which they can conduct manual and routine automated studies for FUN-LV solutions. The full requirements for a BAU system are being developed through the FUN-LV project and these are anticipated to include:

- Automated fault level assessment of the inhibit zones associated with Remote Controlled Circuit Breakers (RCCB);
- Automated unbalance load allocation and power factor to match real-time recorded substation RTU data;
- Validation of the protection and performance of RCCB and Link Box Switches (LBS) of Method 1;
- Visualisation of fault current flow direction;
- Visualisation and reporting of HV reverse power;
- Comparison of load profiles and estimation of transfer profiles; and
- Data error identification and management.

The ways in which DPlan has been used to support site selection are described. Some of the future anticipated enhancements that are required to DPlan for FUN-LV are then discussed.

2. Fault level studies

DPlan calculates the fault level at certain types of nodes (presently though not those with just two branches) and highlights the nodes that have nodal fault currents that are more or less than a certain value. This allowed the rapid identification of locations on interconnected networks where fault levels were close to the Prospective Short Circuit Currents (PSCC) declarations. DPlan was therefore able to assist with the identification of where SOPs could have significant value in limiting fault currents so that additional RES transformers can be connected to networks. The DPlan fault level studies also supported the development of some prototype network analytical tools.

This global nodal fault level survey can also be used to determine locations where faults levels are within the specified rating of equipment. It was anticipated that this could be used to help with the selection of sites suitable for Method 1 RCCBs. However, the actual fault currents passing though LV RCCBs are generally more similar to results from radial fault level studies than nodal studies, and are affected by many other factors. The global nodal fault level survey therefore turns out to be unsuited for this specific purpose, but has helped to identify the need for, and develop requirements for, more suitable tools to visualise such key constraints for Business as Usual processes.

DPlan exported outputs have been used to create summary network data analytics to ensure that after network changes have been made all key design criteria are met.

Line-to-Line-to-Line (LLL), Line-to-Line-to-Ground (LLG) and Line-to-Ground (LG) LV fault level studies in DPlan have been used to validate a range of tools used in the selection of sites and the validation of Method 1 configurations associated with the determination of RCCB Fault Level Inhibit Zones.

3. Load flow

Sites that are of interest for capacity sharing include those where adjacent transformers have differing utilisations or load profiles and can be connected together to create automated simple interconnected networks or to allow RESs to be connected to fully interconnected networks via appropriately rated LV circuits. DPlan is critical here not only to visualise and assess the load profiles of individual transformers, but also of the loads on existing LV circuits as shown in Figure 1. The transfer profiles can be visualised simply by utilisation and/or different profile shapes as shown in Figure 2. By examining the load profiles of transformers and potential transfers using DPlan the potential benefits of proposed transfers and potential circuit constraints can be assessed. Multiple substations can be connected together by closing normal open points on existing radial circuits or closing normal open points to existing interconnected systems and examining the profiles of the transformers and connecting circuits.

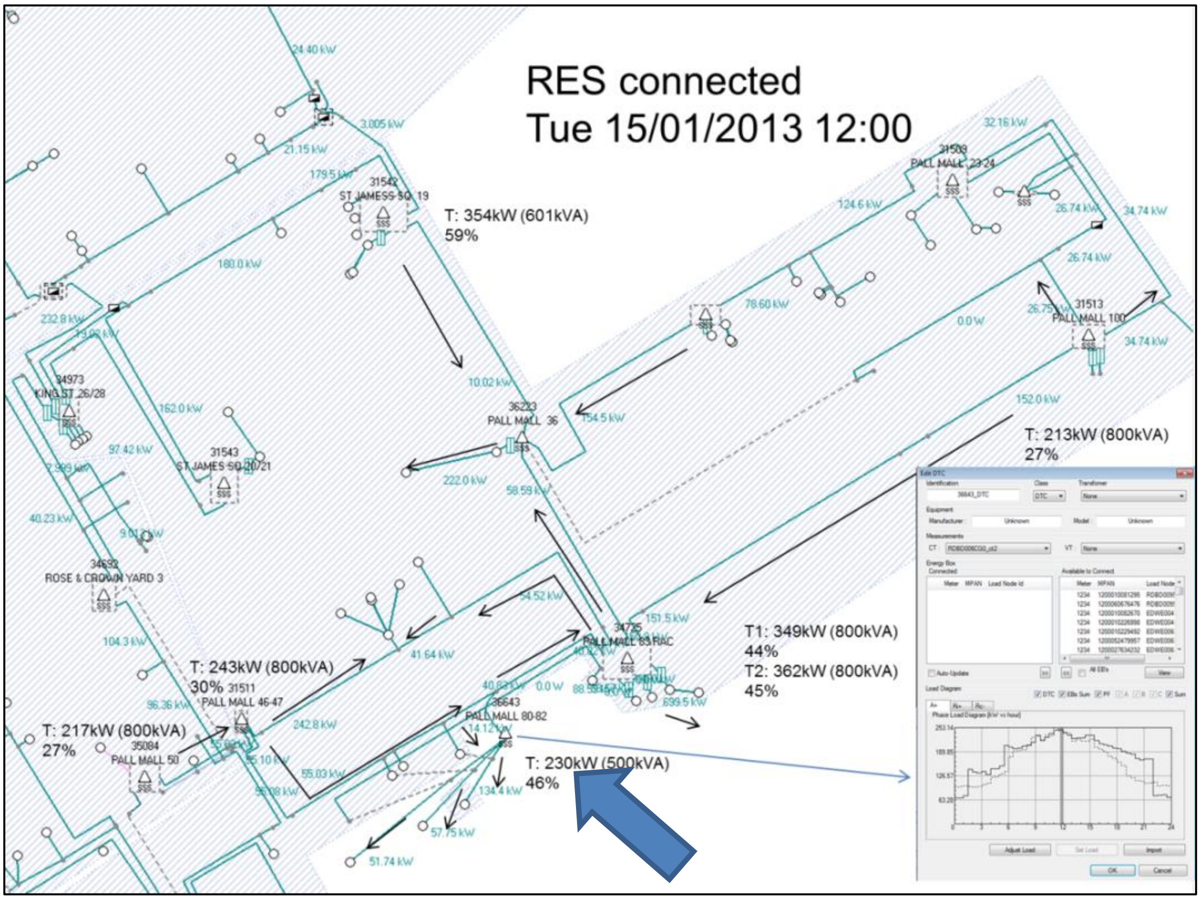
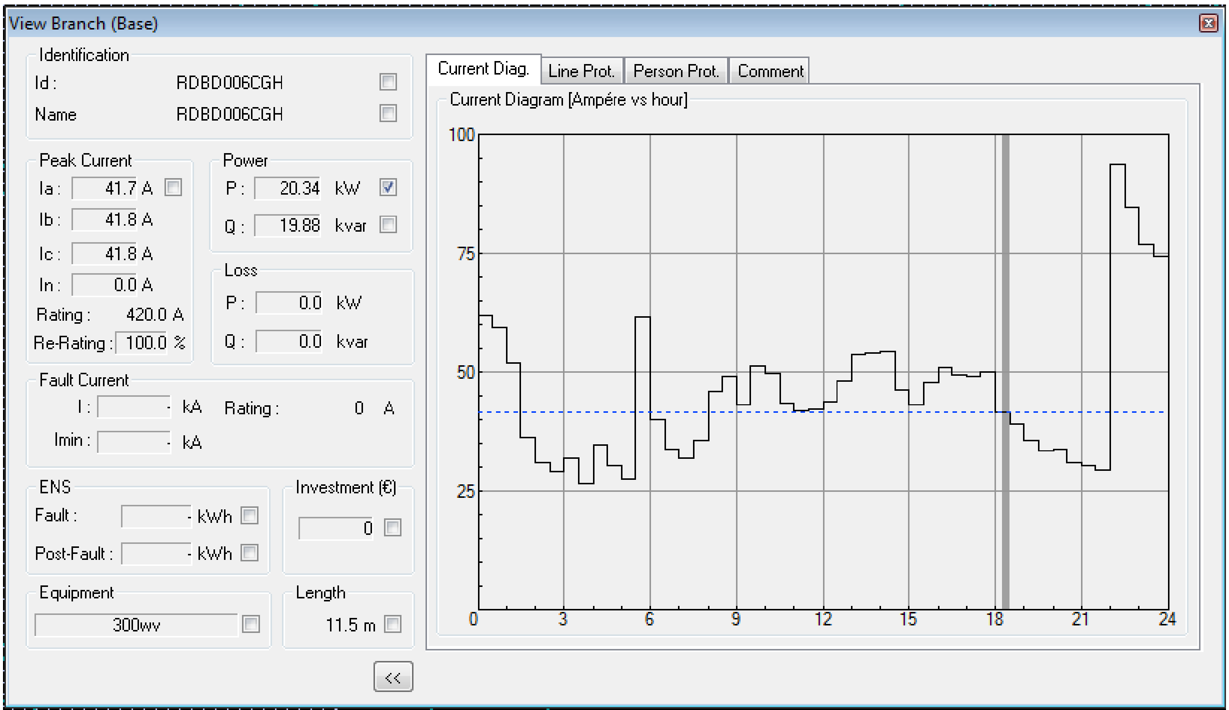


Figure 1. Potential transfer profile of a RES (Pall Mall 80-82)

Some transfer profiles are very different from conventional load profiles and this has significant implications for the application of dynamic ratings, which is the subject of a separate FUN-LV workstream.



This is the visualisation of a transfer profile when a RES is connected to an interconnected network.

Figure 2. Visualisation of transfer profile for a RES using load flows capabilities in DPlan

4. Radial Embedded Substation (RES) identification and transfer assessment

In interconnected networks adjacent secondary transformers are highly meshed and as a result tend to have similar load profiles. However, there is significant potential for load sharing between transformers with different load profiles and the general network. Some substations that only supply specific customers of buildings that are physically connected (through a normally open LV circuit) to interconnected networks may have a very different load profiles and utilisation than that of the other nearby substations. These substations are known a Radial Embedded Substation (RES) as shown in Figure 3.

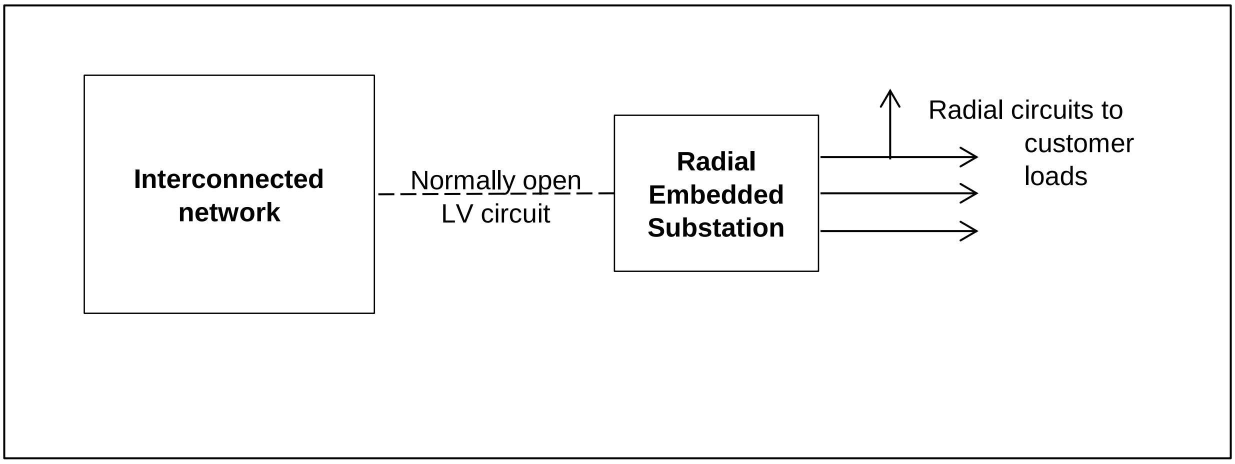


Figure 3. RES schematic representation

RES often have spare capacity and/or different load profiles to the neighbouring network, or occasionally are much more heavily loaded than adjacent network connected substations, and so connecting these to interconnected networks could provide significant opportunities for load sharing.

Simply closing the normally open LV interconnection with a fuse is not however an option, as the additional fault level contribution of the RES would often be sufficient to exceed the Prospective Short Circuit Current (PSCC) declaration made by UK Power Networks to its customers. Furthermore the resultant system may not have suitable protection for LV spine circuit faults or against reverse power flow for HV feeder and distribution transformer faults.

Through the use of a Soft Open Point (SOP), which does not pass significant fault current, the RES can either be connected to the interconnected network via the SOP or the fault level on the network can be reduced sufficiently and without losing load transfer capability, to enable the simple connection of the RESs with a RCCB having Fast-Set, Reverse Power and transformer intertrip protection, thereby obtaining the benefits of load sharing without compromising either load transfer paths or PSCC declarations, or incurring the costs of conventional LV connections, ACBs and protection systems of conventional interconnected networks.

DPlan is able to colour code feeders emanating from a transformer. Where a feeder from one transformer is connected with a feeder from another transformer (or the same transformer) then they share the same colour code. This allows users to easily identify feeders which are connected together (the interconnected system) and those which are radial. Some of those identified as radial may be RESs and at present visual inspection of the DPlan network model is required to confirm the connection of a RES, i.e. whether the connection between the RES and the interconnected network is open. In Figure 4 the interconnected feeders have been coloured pink. One substation Bird Street 8-13 is a radial non-interconnected substation; its feeders are various colours.

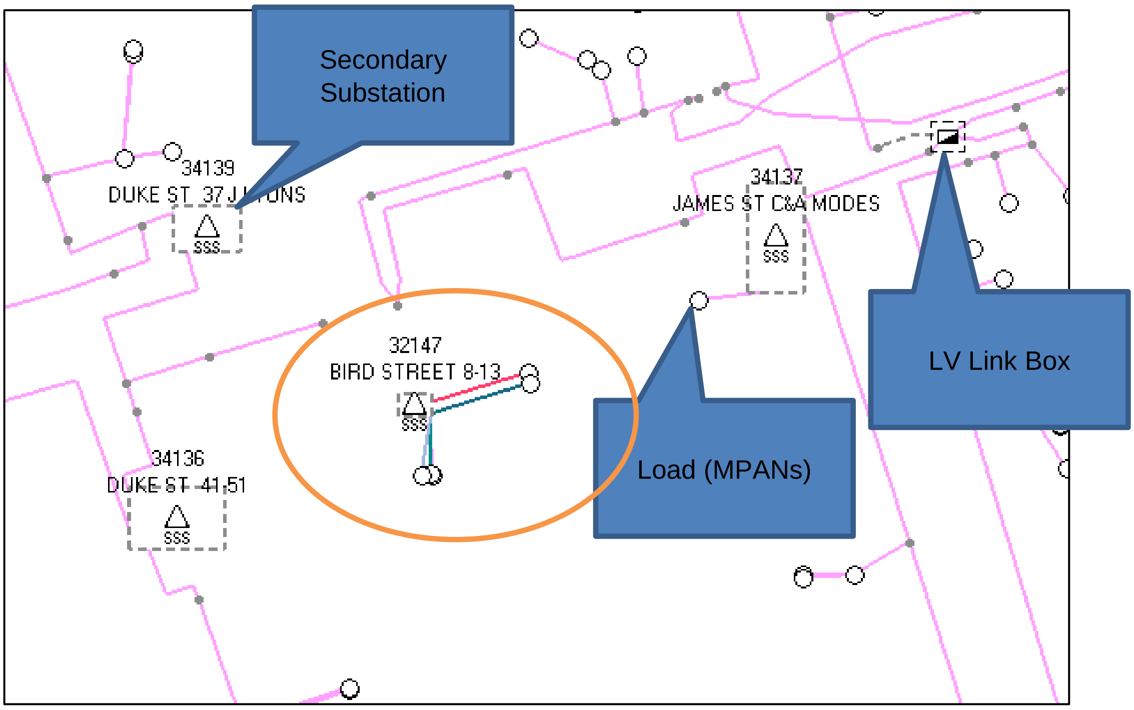


Figure 4.DPlan representation of substations and feeders

Care needs to be taken as for example in the diagram below, the substation 34137 James St C&A Modes has two transformers within the site, one of which is radial and the other part of the interconnected network. This can be shown by exposing the substation internals in Figure 5. The dark green lines represent the 11kV network. It is clear that the lower transformer is radial.

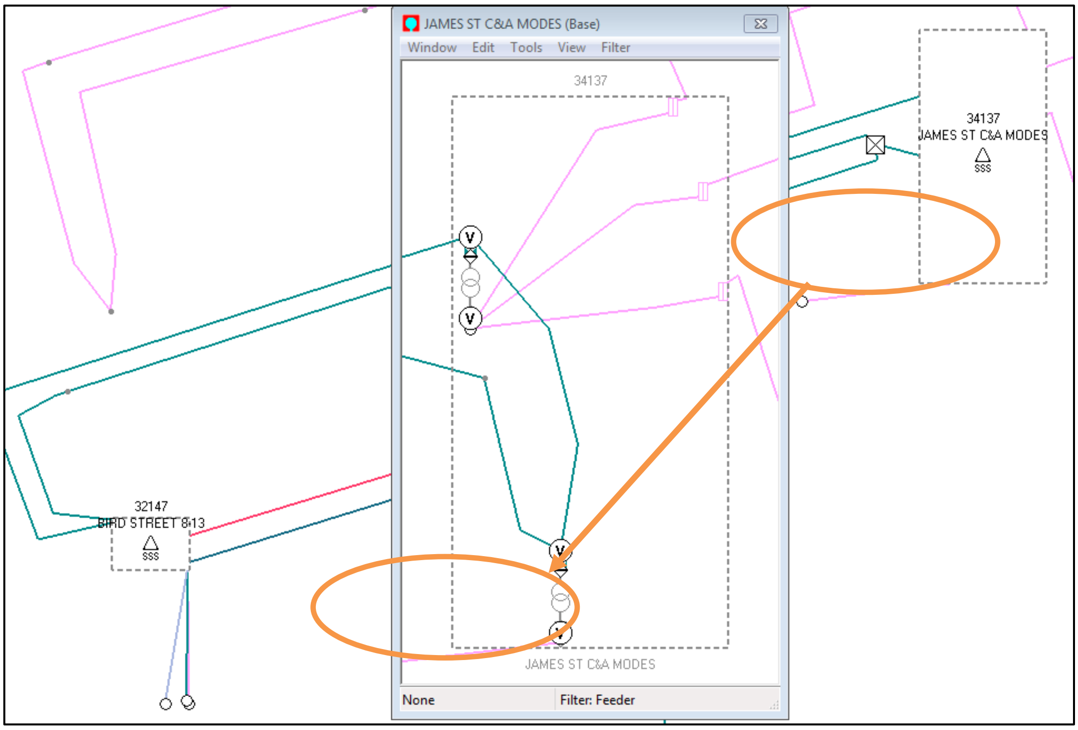


Figure 5. Substation internals exposed for 34137 James St C&A MODES.

The LV feeders shown in Figure 6 are various colours (pink, green, blue and grey) and in each case one LV cable is run open (dashed line). The other LV feeders are LV interconnected (pink).

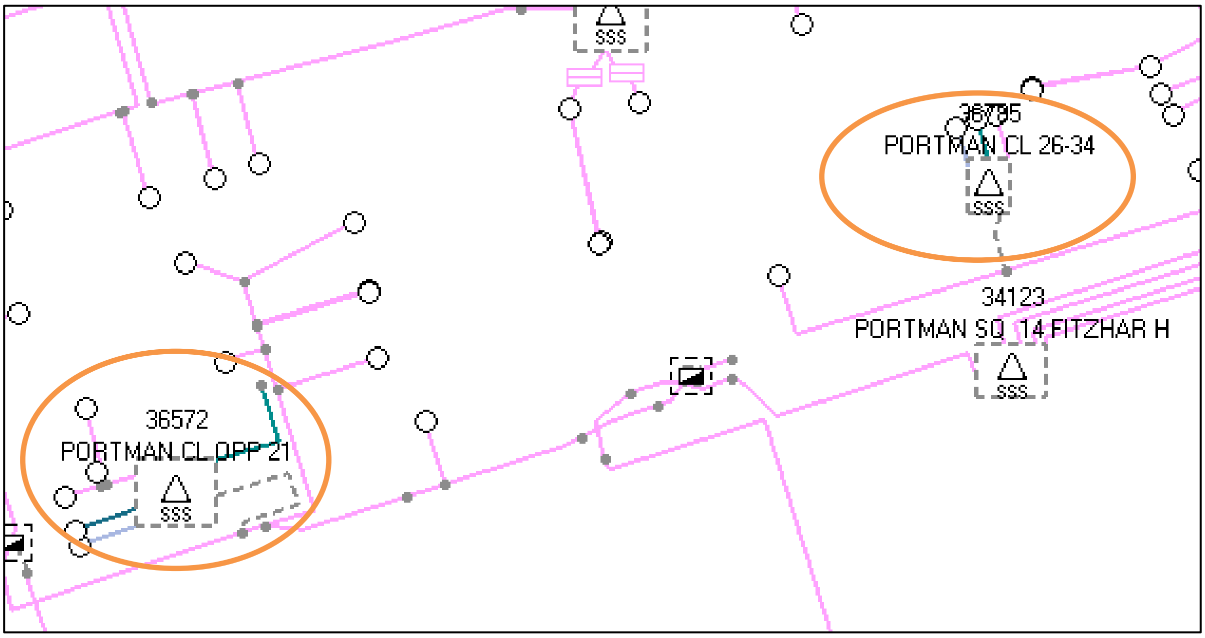


Figure 6. Portman Close opp 21 and Portman Cl 26-34 are RES.

5. Reverse Power

Initial tests have been undertaken on a small section of a fully interconnected network both to validate the operation of DPlan and to validate the fault current flows and adaptive protection arrangements for Method 1 Remote Control Circuit Breakers for use on such networks and particularly under LL and LG HV fault conditions.

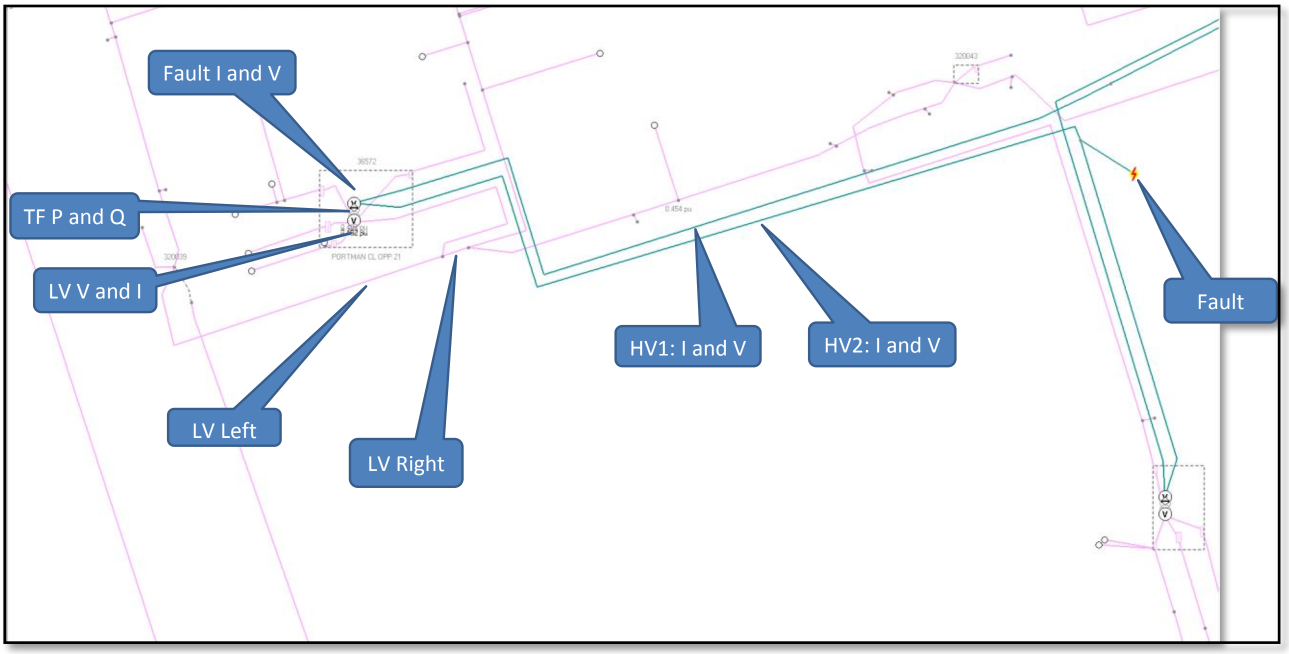


Figure 7. Validation of Reverse Power fault current flows in DPlan

The tests have confirmed the basic operation and helped to identify some of the enhancements that will be needed for Business as Usual.

6. Soft Open Points (SOP)

As part of the FUN-LV project, CGI/IOA are enhancing DPlan to model the behaviour of SOPs under load and fault conditions. Interim approaches using DPlan have been identified to enable site selection validation studies to be undertaken, as validated load data becomes available for:

- Fault level
- Load analysis
- Load transfer
- Voltage
- Reduction of fault levels.

7. Radial Networks

At present most studies have concentrated on interconnected network areas using the network models and metering data developed under previous Low Carbon Network Funded (LCNF) projects including Low Carbon London (a tier 2 project) and Smart Urban Low Voltage Networks (a tier 1 project). The data was validated and adapted to suit FUN-LV studies. Radial network data models are becoming available and a set of modelling and practical field measurement trials are planned, although some of the automated load allocation tools relating to unbalance and power factor are not scheduled to be available until Q1 2015.

The use of DPlan to validate load concepts on radial networks has been demonstrated by taking existing interconnected systems and breaking them into equivalent radial mode systems as shown in Figure 8 before applying Method 1 technology to create simple interconnected automated network as shown in Figure 9. The DPlan results for fault level and load flow studies have been compared to the models than have been used in the initial site selection processes and those used to assess the fault level constraints associated with using Method 1 equipment.

Load flow validation and transfers between pairs of substations and the transfer profiles have also been similarly demonstrated.

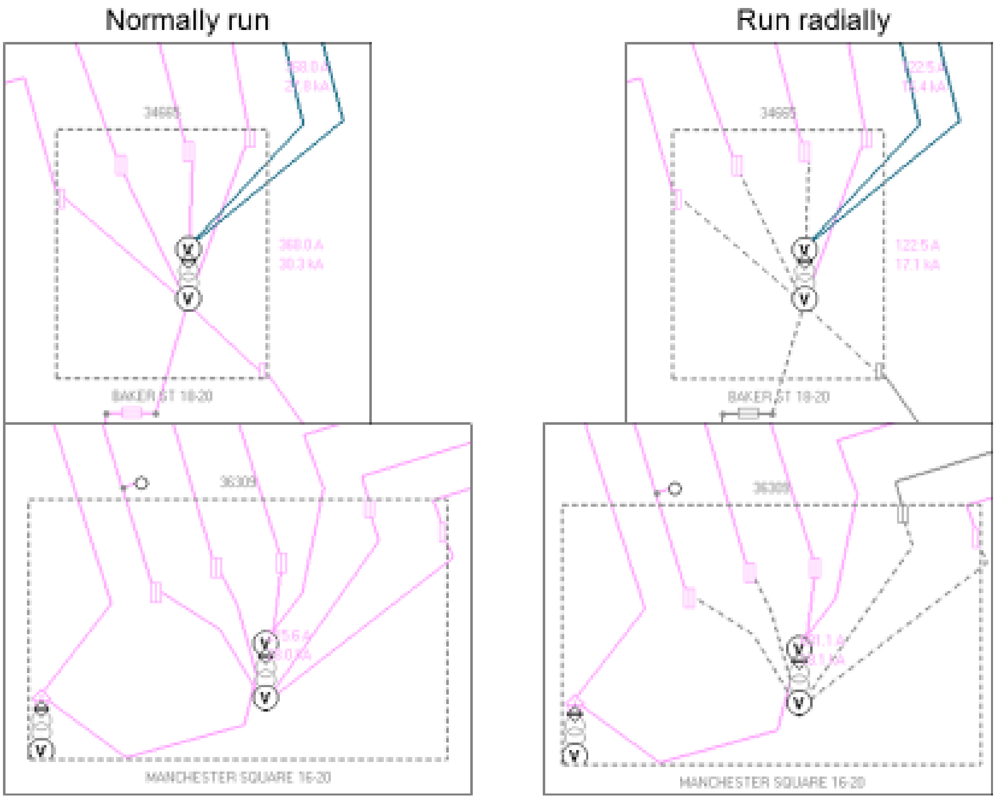


Figure 8. Close up of network reconfigurations for study of radial circuits in DPlan in Figure 9.

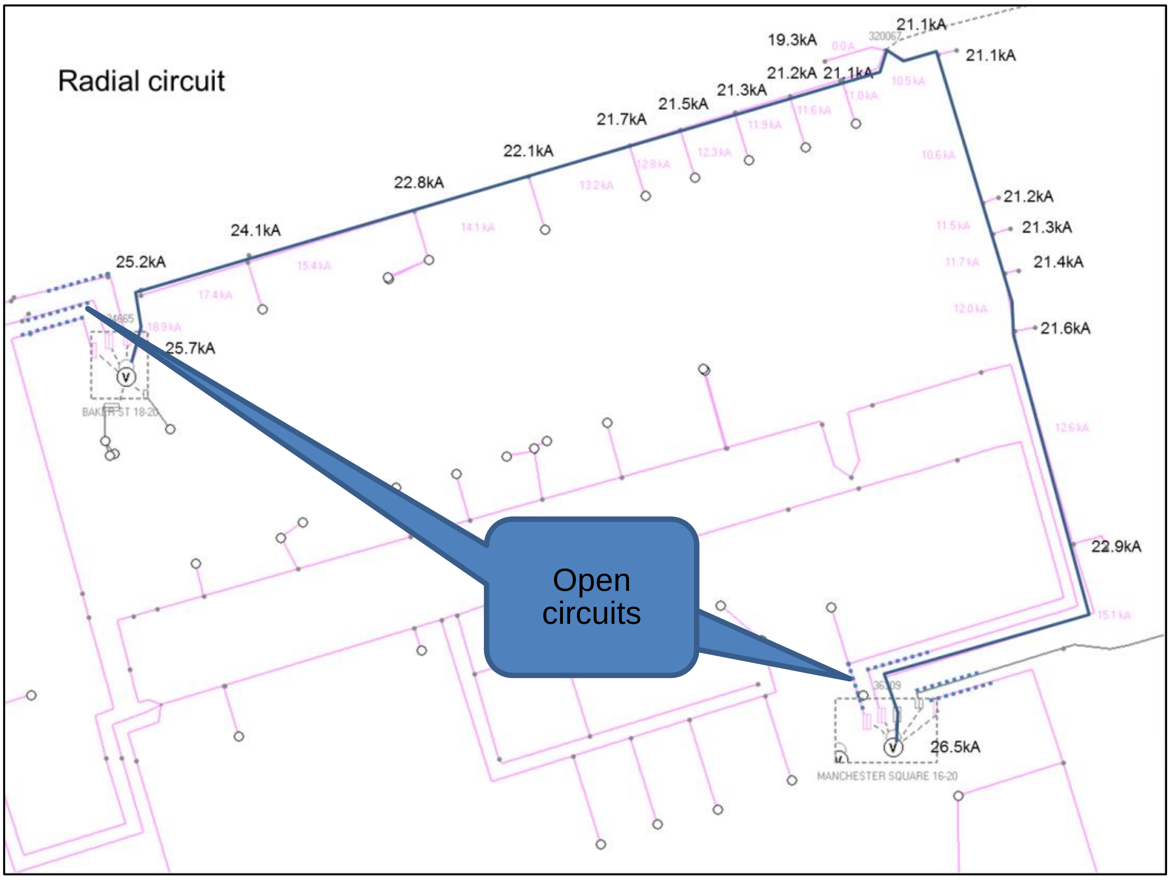


Figure 9. Example of DPlan used for studies for how radial circuits perform when they are meshed

8. DPlan for FUN-LV going forward

DPlan will be developed as part of the FUN-LV project to provide a tool to support the identification, planning and operations of FUN-LV installations. PPA Energy has an activity to specify the business requirements of DPlan for FUN-LV, which is work in progress. The following are the high level requirements for the use of DPlan in FUN-LV relating to site selection:

- Model Method 1 devices and Soft Open Points (SOP) to run analytic calculations and report both visually and statistically to indicate network performance against constraints, including:
  - Fault level studies;
  - Power flow (for at least 24 hours);
  - Load profile of transformers (for at least 24 hours);
  - Comparisons of profiles and transfer potential;
  - Assessment of SOP transfer;
  - Visualisation of fault current direction;
  - Direction of power flow in distribution transformers;
  - Nodal fault levels for all nodes and global display tools; and
  - Summary network data and performance analytics.
- Identify different types of network boundaries (Substation, Feeder Group, Feeder) as the identification of boundaries is key to site selection and method assessment;
- Unbalanced complex power load allocation on radial and meshed networks (full capability expected in 2015);
- Analysis of load profiles and assessment of circuit and transformer utilisation.

CGI will also provide network and load data for DPlan for all the selected sites including Brighton where new network and metering data conversion algorithms have to be designed and validated.

Concepts for modelling Methods 2 and 3 for Fault level and Load Flow studies have been discussed with CGI and preliminary validation of workaround solutions has commenced in order to obtain assurance that the techniques (Method 1, Method 2 and Method 3) proposed will work satisfactorily.