2.10 Annex

SP Energy Networks 2015–2023 Business Plan

SP Manweb urban network

SP Energy Networks

June 2013

Scope

This annex to the SP Energy Networks 2015-2023 Business Plan provides background information specific to the SP Manweb licence area.

Here we outline the fundamental design differences between traditional electricity distribution networks in the UK, and the Manweb urban network design. We discuss capital and operational costs and compare and contrast performance. This annex also comments on previous operational efficiency reviews, the implications of change and our current philosophy on continued operation of the Manweb urban network design.

Comment is provided on the SP Manweb ED1 expenditure proposals in relation to the continued stewardship of the urban network.

Introduction

SP Manweb provides electricity to 1.5 million customers across a diverse geographical foot print that encompasses both large urbanised areas of Merseyside together with rural areas of Cheshire, North & Mid Wales and Shropshire

Over 66% of our customers live in the major urbanised conurbations of Merseyside and the Wirral, together with other large towns and cities across Cheshire, where the electricity network is primarily constructed from underground cables. Our remaining customers across our semi urban and rural networks are connected to our network which more generally comprises of a mix of overhead lines and underground cables.

It is recognised that not all electricity networks are the same. At industry privatisation in 1989 our shareholders inherited an electricity distribution network that is unique in the UK and overall delivers the highest customer performance outside central London; it can be argued that the design of the urbanised network delivers the best customer performance in Great Britain.

The SP Manweb urban network was designed and built throughout the 1950-1970s with a design philosophy of high transformer utilisation to target lowest economic costs based on commodity price forecasts at that time. Smaller transformers than industry standard are run constantly interconnected at all voltages and standard cable sizes are used throughout.

To supply our customers over our geographical footprint around 55% of the SPM network is designed and run as an “X-Type” network, solidly interconnected at 33kV, 11kV and LV. Of the remaining, 23% of the network is designed as a “Y-type” network, solidly interconnected at 33kV and 11kV but less so at LV and 22% is designed as a radial network with single transformers feeding a non-interconnected 11kV and LV.

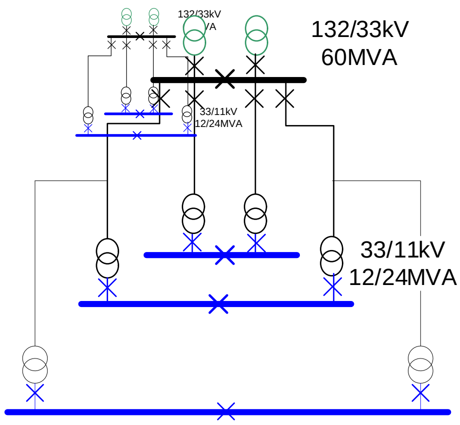
This annex describes the electricity network that supplies the SP Manweb customers in the urban areas (X Type Networks).

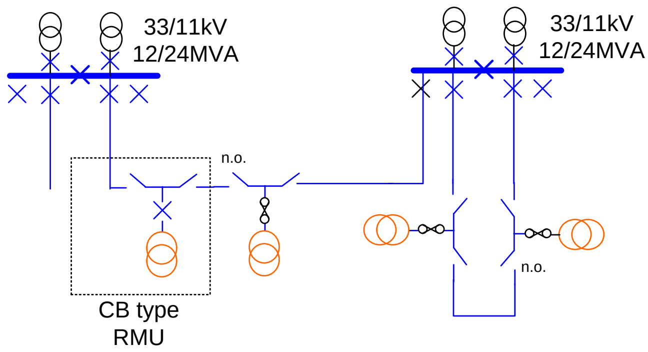
Traditional Industry Network Design

Before considering the SP Manweb Urban Network philosophy it is worth while briefly summarising the traditional network design in use across the wider GB network (including SPD).

The accepted industry wide design is based on duplicate radial transformer feeders, operated in parallel as show below.

At 132 and 33kV, the transformers can be connected singularly or banked with multiple transformers (at up to 3 substations) connected to the higher voltage or source circuit breaker.





33kV networks tend to radiate outwards from 132kV bulk supply points, similarly 11kv networks tend to radiate outwards from primary substations. Historically companies will have tapered the network cables, as the cable travels further form the supplying transformer, but more recently uniform (standardised) cables have been employed.

11kV networks fed from primary substations can be constructed as radial 'or looped' circuits back to the same substation, or can be built as an interconnector to an adjacent primary substation to provide post fault support and resilience. In all cases the circuit must be run with a split or 'normal open point 'at an electrically convenient point on the circuit.

The LV network whilst having the capability to offer interconnection will in all cases be run radially with fuses or links removed at substations, LV surface mounted pillars or beneath ground link boxes.

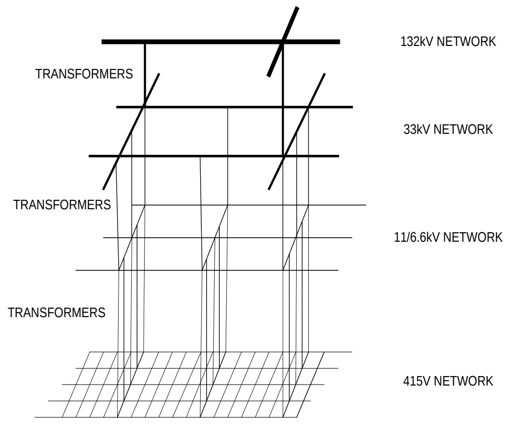
The recognised benefits of this network philosophy are in its simple design, simple protection arrangements, requiring less distributed switchgear and protection with consequential reduced capital and operating costs.

Some of the pertinent limiting factors of this design are that of Fault Level management, transformer utilisation factor is limited to 50%, triggering reinforcement and hence capital expenditure at earlier point of overall load growth, and customer interruptions (CI's) are increased over that of an interconnected network design. It is recognised however that advances in network controllable points and automation algorithms has improved the quality of supply performance on these networks in recent years.

Cables emanating from large substations are often non-uniform along their length, and are often tapered as the distance from the substation increases. By nature these networks are not readily extended without considerable effort and expenditure to develop a new substation, and laying more cable to increase the circuit capacity, therefore they are not considered as "Smart ready" as interconnected networks.

SP Manweb Urban Networks

The origins of the Manweb Urban Network design can be traced back to the period shortly after the electricity industry was nationalised in 1947, and it was developed and expanded over the next 30 years and continues to be modified and extended today. The design methodology varies significantly from the traditional industry network design described above of duplicate radial networks, emanating from transforming stations, and is based on a design philosophy of high transformer utilisation, where smaller transformers than industry standard are run interconnected at lower voltages and standard cable sizes are used throughout. Each voltage layer providing support to the voltage layer immediately above (LV, HV, EHV and 132kV) offering a fully integrated and interconnected network



SYSTEM OF NETWORKS FOR DISTRIBUTION OF ELECTRICITY

The design was developed by Peter d'E Stowell the former Manweb Chief Engineer, and whilst there are elements of similar design in restricted parts of Edinburgh, and throughout the Central London area, the SP Manweb urban network is considered unique in the UK.

The underlying principle of the Manweb urban network is to maximise the utilisation factor of high voltage transformers supplying any given load group through the combination of 3 key features, uniformity, interconnection and unit protection.

Uniformity

The uniformity of the Manweb network design takes two separate forms, uniformity of equipment ratings and uniformity of application.

Although design and specifications of component parts of the Manweb network have evolved throughout the last 50 years, the ratings of these component parts have remained extensively the same.

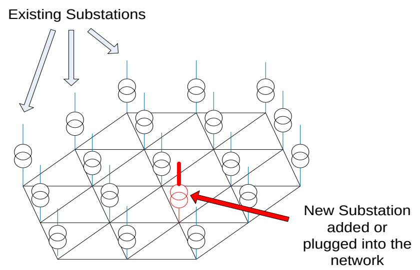
Typical ratings are as follows:-

- 60 MVA grid transformers (132/33kv), with 20MVA 33kV circuits
- 7.5 MVA primary transformers (33kV /hv) with 3.5MVA hv circuits
- 500kVA hv/lv secondary transformers (hv/0.415kV) with 170kVA lv circuits ,

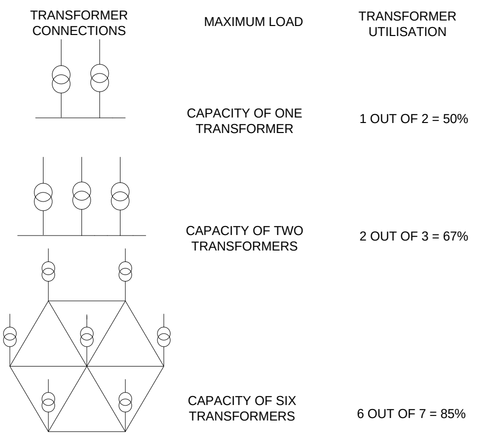
At each voltage level therefore there is a standard rating for circuits, between each voltage level there is a standard transformer rating, and at each voltage layer there is a standard design covering switchgear, protection and relay settings.

This uniformity of equipment and ratings provides opportunity for expansion in line with network growth and facilitates reinforcement by the addition of a new transformer with minimal cable laying and no change to protection or settings. This was a key driver through the expansion period of the electricity network in its early years and is equally pertinent today as it delivers a scalable solution to meet the demands for the anticipated load growth on the distribution networks as we migrate to, and accommodate Low Carbon technologies.

Interconnection



DISTRIBUTED INFEEDS TO A NETWORK



TRANSFORMER UTILISATION

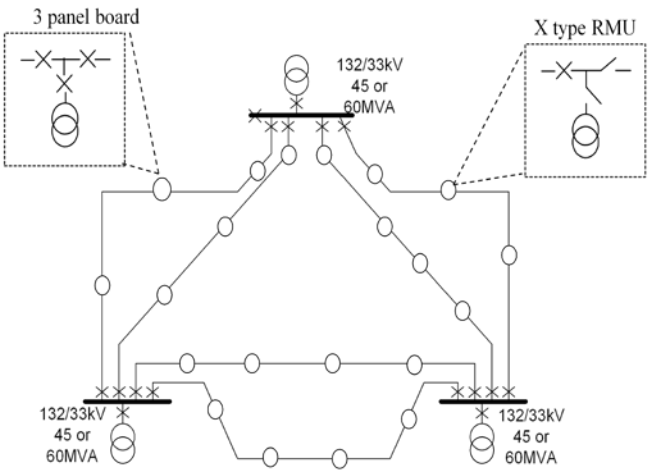
The benefits of uniformity can be applied to any network configuration however when a uniform network is configured to operate in an interconnected manner then the benefits can be multiplied. Interconnection in this context means the circuits of each voltage layer run from one infeeding substation to another substation and are predominately operated with all intermediate switches in the circuit 'closed' position.

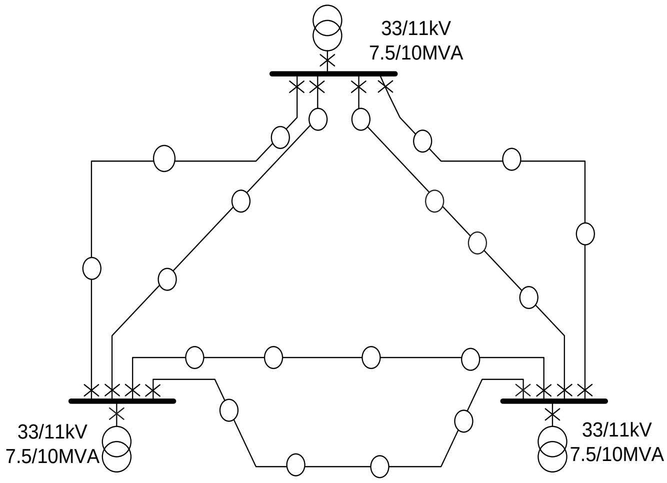
In the early development of the cable network at each voltage level, it was important to install uniform sized cables rather than employ tapered networks, in order to establish the grid or lattice interconnected network for the future, facilitating the connection of additional transformers due to load growth.

Equally during the depressions of the 1980's and more recently, as load centres move, then underutilised transformers can simply be unplugged and re-established closer to the new load with minimal network alteration.

By operating interconnected networks between in feeding substations it is possible to increase the utilisation factor of high value (and cost) transformers. By operating smaller than industry standard transformers in this manner it is possible to reduce the physical foot print and therefore cost of associated plant and civil accommodation.

In an ideal network, utilisation factors of up to 85% are possible. However in order to operate the equipment on the Manweb Network safely within its design fault level parameters then it is normal to operate via interconnected cables up to 4* 60MVA Grid Transformers, or 5 * 7.5MVA primary transformers. This still achieves utilisation factors of 75% and 80% respectively but maintains fault level within the design criteria of 750MVA and 250MVA. It is equally permissible to interconnect secondary substations via the LV network, with the limiting factor that no lv circuit can be controlled by more than 3 fuses from separate substations. Beneath ground LV link boxes are used extensively on the LV network to split up the LV interconnected network to achieve this requirement.





With higher utilisation factors incremental load growth can be absorbed more efficiently before reinforcement is triggered. When the group load reaches its maximum then a further transformer can be simply added or ‘plugged in’ to the network or the transformer group can be reconfigured by the movement of network split points.

Ring Main Units (RMU’s) were originally installed at the primary substations and secondary substations along the interconnectors between infeeding substations. These RMU’s comprise of 2 ring switches and a circuit breaker or fused switch in a single unit of switchgear.

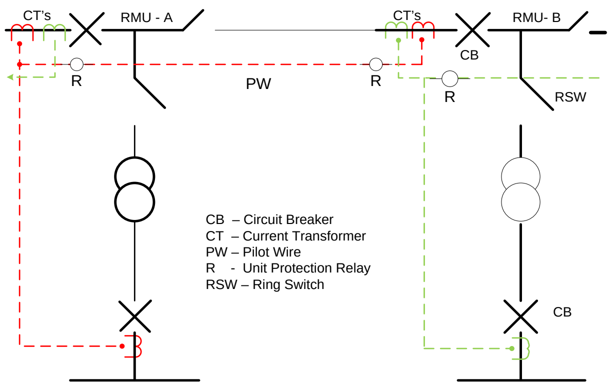
In the Urban network design the RMU is configured as an ‘X-type’ and is illustrated above, with one ring switch connected to local transformer, the other ring switch and the circuit breaker being connected to the incoming and outgoing cables along the interconnector. At 33kV suitable RMU’s are no longer manufactured therefore the design and application has evolved to comprise of a 3 panel switchboard again illustrated above.

There is a Circuit Breaker on the lower voltage side of the transformer.

Unit Protection

Unit protection in its simplest form utilises the *Merz Price* principle, which effectively checks that load current entering a protected zone is equal to the load current leaving the protected zone. As long as this is the case then the protection remains in balance and does not operate. Should a fault develop in the protected zone then the current entering the protected zone will be the sum of the load current plus the fault current, the current leaving the protected zone will be the load current only, therefore the protection becomes out of balance and will operate a protection relay, which in turn will operate the controlling circuit breakers for the protected zone, and the circuit will be safely disconnected from service.

Unit protection as applied to the SP Manweb network interconnected distribution network, whilst generally based on the basic principle above is more sophisticated and has been developed to protect substation, transformers and its feeding cables. A simplified representation of unit or ‘zone’ of protection as applied to the SP Manweb Urban network is illustrated in the figures below.



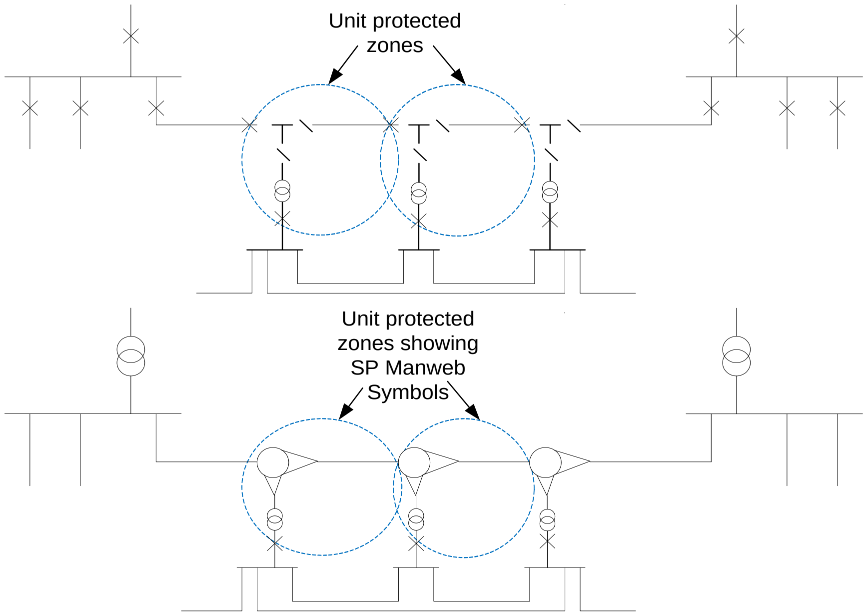
A simplistic illustration of unit protection as applied to the SP Manweb urban network is shown opposite purely to illustrate the additional components required over and above those employed in traditional network designs.

At RMU-A Current transformers (CT's) are installed and connected locally to summate the current on the incoming cable and the outgoing load of the locally connected transformer; this current is in effect balanced against the outgoing current at the remote end of the circuit at the adjacent RMU-B.

The summated output of the pair of CT's at RMU A and the output of the CT's at remote RMU B are connected via communication cables commonly referred to as 'Pilot Wires' run alongside the main distribution cable between substations - illustrated by the red section of the drawing above.

Under normal circumstances the load current entering the unit protected zone at RMU B will balance with the load current of the local transformer at RMU-A together with the outgoing load current along the remainder of the interconnector, and the protection relays connected to the pilot wires will remain stable.

If a fault occurs within the unit protected zone on the distribution cable between the two RMU's or on locally connected transformer at RMU A, then the normal load current entering and leaving the protected zone will be incremented by the fault current entering the protected Zones at RMU A and RMU B, and will not balance. Therefore the protection relays connected to the pilot wires will operate, and cause the controlling circuit breakers to operate and remove the faulted zone. The protection relays connected into Pilot Wires are powered by DC battery systems.



By overlapping unit protected zones along the interconnector, a fault or outage in any given unit protected zone can be occur without disconnecting customers, as these supplies will be maintained by the adjacent network via the interconnecting cables from neighbouring substations. In the more traditional 'Y' type networks used elsewhere in SP Manweb on semi urban and rural networks and the wider GB electricity network as a whole, a similar fault will result in loss of supplies to the entire customer base connected to the interconnector, or radially operated circuit, with as a consequence a poorer customer performance.

Unit Protection on interconnected networks as applied to SP Manweb networks operating at 33kV is generally comprised of 'Translay' Protection and at 11kV, 'Solkor' Protection. Whilst their operation can be traced back to the fundamental principles outlined above each of these protection schemes are much more sophisticated and reference to manufactures literature, or support documentation should be made if a detailed understanding of the individual protection scheme is required.

Performance

It has already been stated that the Customer Performance of the SP Manweb network as a whole is second only to that of Central London. (UKPN LPN), with customers in SP Manweb likely to see a power interruption once in every 2 years, lasting typically 63 minutes, and customers in Central London once in every 3 years lasting a similar duration. It is also true that with an average of 53 customers interrupted per fault on SP Manweb network; this is the lowest number of customers impacted by a fault (and therefore the best performance) on any electricity network in Great Britain (Data taken from Ofgem - Electricity Distribution Annual Report for 2010-11)

	2010/11 - CUSTOMER INTERRUPTIONS PER 100 CUSTOMERS:		2010/11 - CUSTOMER MINUTES LOST	
DNO	Target	Performance	Target	Performance
LPN	33.4	24.4	41	42.4
SPMW	45.6	39.3	61.1	47.5
ENWL	52.9	47.8	55.6	47.3
SPD	60.1	50.7	65.5	49.4
SWales	79.5	58.4	44.6	32.4
SWest	73.6	61.5	51	42.6
EMID	75.7	61.7	69	54.9
SSES	73.8	63.6	69.1	64.1
NPGN	68.3	65.2	71.3	71.1
NPGY	75.3	69.9	76	68.2
SSEH	77	74	75.1	78.4
SPN	85	76.9	87.6	73.2

Table ranked on CI performance

The statistics above relate to total network performance for individual Distribution Network Operators.

Looking at the SP Manweb values in more detail it is clear that they are a combination of both our urban and rural networks performance, which due to the prominence of the west coast weather systems is exposed to extremes in weather conditions and consequently a greater fault rate than that experienced by the relatively benign urban networks.

As described above the design of the SP Manweb urban network is such that for any 33 kV or HV network fault the CI's should be zero, as the faulted circuit is protected by unit protection and customer supplies are maintained by the wider interconnected network. In reality there are interruptions to customer's supplies on these networks due to a combination factors, such as:-

- Second circuit faults occurring simultaneously with the first circuit fault leaving sections of network stranded or islanded.
- Failures of unit protection systems to operate correctly due to faulty relays or faulty/damaged pilot cables.
- Failures of circuit breakers to operate correctly
- 'Designed in' customer losses such as radially fed HV customers or IDNO's, or elements of radial networks embedded within the urban network
- Failures on the fringe of the urban areas where the overall circuit can be configured using a mixture of Urban X-type and Semi Rural Y-Type network
- More recently developments in organised 3rd party interference/intervention – Metal theft

For faults on LV interconnected networks then for the majority of fault conditions only a small percentage of the customers connected to the LV cable circuit will be interrupted as fuses at one end of the circuit only will trip to remove the fault, with supplies to the remaining customers connected to the LV circuit maintained from the remote ends of the 2 way or 3 way interconnected circuit.

The Central London electricity system of LPN consists entirely of underground urban networks, and is operated in an interconnected mode, therefore it is appropriate to compare the SPM urban network directly with the performance of LPN as a whole, in order to demonstrate the performance advantage of the SP Manweb urban network design.

By extracting the customer performance for the SP Manweb urban networks for the same reporting year as shown above (2010/11), the CI per 100 customers is 13.22 and the CML per 100 customers is performance is 22.0 minutes, this equates to customers connected to the SP Manweb urban networks likely to see a power interruption once in every 8 years, some 2.5 times better performance than that of LPN network, with the interruptions affecting less customers per fault and lasting on average for shorter periods.

This SP Manweb urban network has demonstrated consistently over time its frontier network performance in terms of CI and CML

Network Design and Efficiency Reviews

The SP Manweb Urban network is unique in design and delivers frontier network and customer performance as discussed in the previous sections, a heritage as an organisation that SP Energy Networks is rightly proud of. However it is recognised both within SP Energy Networks and the wider industry that this network has greater complexity, involves more components and is more expensive to construct and maintain than the recognised industry network design, (Y Type).

This is something that SP Energy Networks is continually aware of and has reviewed and evaluated on a number of occasions both internally and externally by engaging independent consultants, in order that we can consider if it remains viable to continue to propagate the SP Manweb urban networks 'X type', and to consider alternative network designs and solutions.

These reviews were conducted as follows

External : -

- Merz and Mclellan 1998
- ABB 2000

Internal :

- Martin Deehan 1998
- Jane Wilkie 2006.

The engineering aspects of these reviews remain unchanged over time and common threads of these reviews can be summarised as follows:

- Urban LV interconnected networks should if designed and operated correctly provide better performance than traditional radial networks but are expensive as they are generally longer networks
- Urban 11kV interconnected network design delivers frontier customer performance, but at a cost premium over traditional radial networks with or without automation. However it's not cost effective/or desirable to convert wholesale to 'Y-type' networks
- It is considered that urban 33kV interconnected network provides little or no customer performance benefit and is significantly more expensive than traditional dual radial transformers operated in parallel configurations, due to additional switchgear requirements. (*Author Comment - whilst the benefits of a development of a dual radial transformer solution may be true for green field developments, the various reports have failed to recommend substantial proposals of how we would complete a migration from the existing interconnected network. Both in terms of the additional network reinforcement, or the more onerous task of acquiring suitable 'larger' sites for the development of additional urban substations. Analysis of SP Manweb 33KV customer performance indicates major contributors to CI/CML are from faults affecting rural radial primary transformers or radial urban transformers. Occasional malfunctioning equipment on the SP Manweb urban network does incur customer interruptions; however this is the exception rather than the rule.)*
- The SP Manweb urban 33kV and 11kV cable networks utilise standardised and uniform cable sizes. Migration to industry designs would in many locations leave stranded assets as the cable sizes and rating would be inadequate.

- The SP Manweb urban networks utilisation factor is very much higher than for traditional networks, implying that our network is working harder in our SP Manweb area, leaving less spare capacity than on traditional networks. *(Author comment - through the introduction of the UK network Load Measure, we will reduce our trigger point for reinforcement by 20%. We will also continue our programme to uprate our high voltage network from 6.6kV to 11Kv, releasing latent capacity in our HV cable networks throughout ED1).*
- The SP Manweb urban network represents the most cost effective network, both in cost per kVA of capacity and maximum demand. However, the incremental cost of SP Manweb's urban network arrangement is approximately 30% more expensive in terms of total cost per unit of network capacity.
- No reports deal adequately with the consequential reinforcement of Bulk Supply points as a consequence of breaking up 33kV network, and reducing the currently high utilisation factor of Grid transformers at Bulk Supply Points.

In summary the advantage of the SP Urban Network is confirmed as offering frontier CI performance over that of traditional radial networks. The network design is also inherently "smart" as the network is designed to accept power flowing in either direction, and alternative paths are available when there is a fault. The network is more ready to facilitate customer uptake of low carbon technologies and the associated costs are lower as reinforcement is facilitated in the main by 'plug in' substations and minimal cable lying.

The disadvantage of the SPM Urban Network design is that it is more expensive to build, as it requires more switchgear and unit protection which in turn requires a means of reliable communication network between substation sites and a more robust building construction.

The design reviews have confirmed that the size and complexity of the existing network does not allow wholesale change to the network design in urban areas, without a major impact on the performance of the network to existing customers and significant capital spend.

Whilst savings could be made by developing less complicated 'Y-Type' networks these savings would be offset by additional capital expenditure and future operating costs required to supplement the existing transformer capacity within the network as a whole, as current high utilisation factors on which the network was fundamentally designed over the last 60 years or so would be brought down to the industry norm of 50%

Internal estimates based on the last five years of data supplied to Ofgem through the quality of supply reporting scheme indicate that for the 11kV network alone should it be converted to 'Y-Type' network, the result would see an additional 104,000 or 7% of our customers experience a power cut each year.

We believe that this would be unacceptable to our customers who, through stakeholder engagement across the Manweb licence area (including an event held in Liverpool) have told us they want to experience less power cuts.

We therefore have no feasible alternative when replacing existing assets in interconnected areas other than to replace like for like, and to maintain the existing network arrangements.

However we recognise that it is more cost effective to build new networks using a more traditional design, and therefore when SPEN, or an Independent Connection provider (ICP) are designing new networks or connections on our network , we will build a non-interconnected design where possible, provided this will not impact or compromise on existing customer performance.

Key Costs in ED1 to maintain the SP Manweb Urban Networks

SP Manweb have outlined in its RIIO- ED1 submission a number of areas of expenditure specifically related to the continued successful operation and integrity of the urban network, over and above expenditure for the areas of its more traditionally designed networks.

Specific details are contained in the relevant CV tables, however key activities and threads are itemised below :-

- Ongoing maintenance of substation environment to provide a safe, watertight environment for X Type substations, this will not only ensure safe operation of primary equipment but will safeguard the integrity of the associated unit protection equipment.
- Ongoing maintenance and repair of the 11kV and 33kV network communications system (Pilot Wires), without which the integrity of the associated unit protection systems will deteriorate, with significant reduction in performance of the protection systems and consequential decrease in customer performance.
- Maintenance and inspection of LV link Boxes (including confirming network configuration of the internal switching points) utilised in the operation and control of LV interconnected network.
- Ongoing maintenance of 33kV RMU's used extensively on X-type interconnected 33kV networks
- Replacement of 25 'end of life'HI5, 33KV RMU's with 3 panel switchboards (33KV RMU's are now out of production).
- Ongoing maintenance of secondary substation (11 or 6kV/LV substation) battery systems associated with X-type networks – Simple Y-type secondary substations are generally battery free.
- Continue our 6.6kV network updating programme to 11kV to release more capacity from the current interconnected cable networks.
- Continue to install remote control facilities (SACDA) on Urban Networks as part of Asset modernisations schemes to allow better monitoring of interconnected network performance

A summary of our key costs and investments for the ED1 period can be found in our 2015-2023 Business Plan – Expenditure Chapter.