VIEW POINT

MANAGING COMPLEX LOW-VOLTAGE NETWORKS IN A FLEXI GRID

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Those who are interested in the Smart or Flexi Grid are likely to have come across a whole spate of articles on this topic, recently. These have set out the benefits, risks, and concerns around the implementation of the smart grid and its various systems. However, little has been written about managing these complex low-voltage (LV) networks, particularly the matrix or mesh type arrangement of the smart grid. Such networks have multiple routing options, through LV switches such as link boxes, allowing operators to reconfigure the grid at LV to supply properties from different substations. Most of these switches are manual and have no remote recording (e.g. telemetry), so temporary switching can go unrecorded. This is particularly true for countries such as the UK, where the smart grid is also called the Distribution System Operator (DSO).

A low-voltage network, where voltages are less than 1,000 V is a part of any electric power distribution system which carries electric energy from distribution transformers to electricity meters of end customers[1] . In the UK, there is a much higher percentage of LV networks compared to countries such as the US, and this presents particular issues listed in the next section of this point of view. Left unaddressed, some of the problems that could emerge, include phase imbalance, voltage, frequency and waveform issues, and increased outages. This is turn, will result in customer and network interruptions, and thermal issues. There would also be concerns related to regulations, commercial models and societal rules that have yet to be resolved.

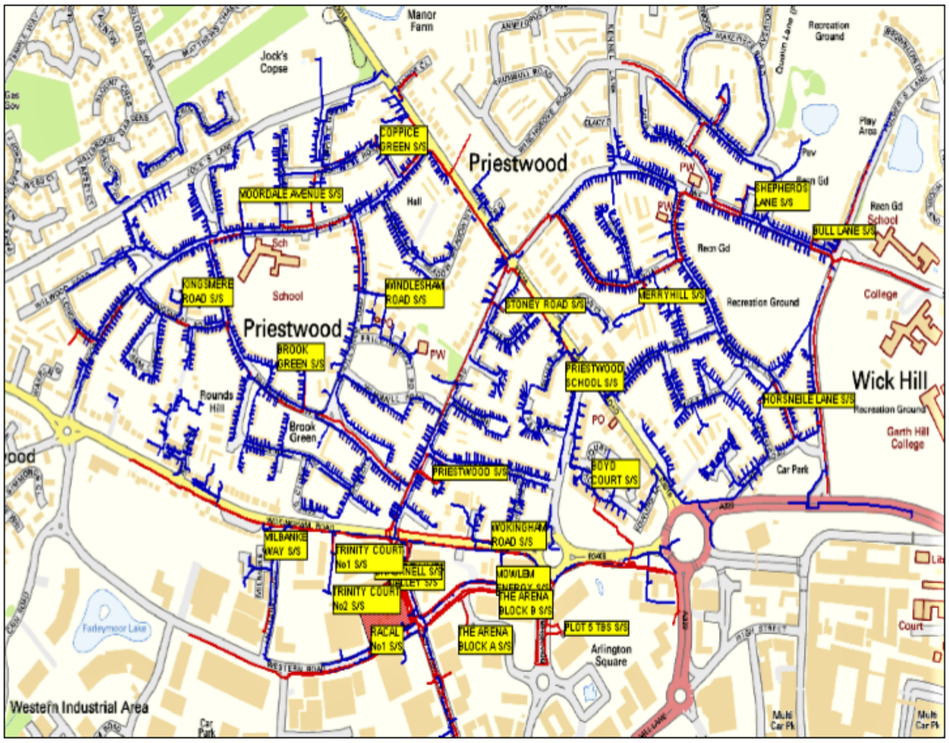
[1] https://en.wikipedia.org/wiki/Low-voltage_network

Technical challenges related to large, complex low-voltage (LV) networks

- Many of the assets are underground, and this means that both specifications and conditions are uncertain
- Switching options through localized switches, such as link boxes, (switches housed in underground chambers: see photo opposite), is system flexibility that is difficult to exploit at present, as such switches are manual
- Poor management of the records of LV networks (e.g. updates to maps and schematics), with emergency repairs and local switching, are often unrecorded
- Connectivity of premises is frequently uncertain, both in terms of the location of the connection point(s), and the routing of cables
- Due to regulatory models in the UK, and some other countries, the actual power usage at individual premises is unknown to the network operator
- Details of small Distributed Energy Resources (DERs) and Flexible Demands (FDs) from electric vehicles and heat pumps at individual premises is often unavailable to the network operator
- The phase used for single-phase connections at properties (both domestic and industrial) is generally unknown

Typical low-voltage layout

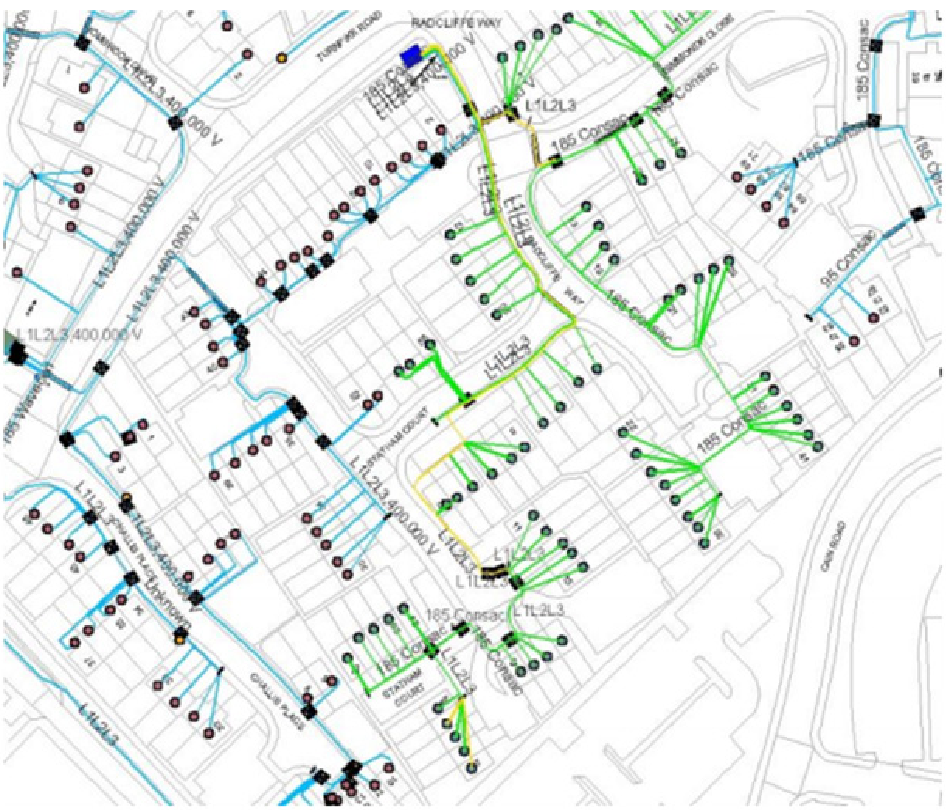
The map below, taken from the Ofgem Innovation project New Thames Valley Vision (managed by SSE), shows a typical LV layout.



Source: Low Voltage Network Modelling and Analysis Environment by Southern Electric Power Distribution 2013– Page 16

Circuit analysis

The amber color signifies a feeder exceeding capacity for a short period.



Source: New Thames Valley Vision, Page 22

The role of data in managing complex low voltage networks

In terms of the data, a combination of an IT analysis and physical survey can resolve issues related to connectivity and specification. Data are often more easily available than it might seem when one is just looking at core systems. For example, the core asset management software may say that a cable is of a specification and age, but there would seem no way to validate this unless the cable is exposed. However, often there is dispersed information about the asset, such as forms completed during repairs. This generally has location and details of the asset and often has been transposed into a digital form, such as a spreadsheet. Geospatial analysis tools coupled with artificial intelligence can show where data aligns and can be flagged as high quality, or where there is misalignment, and hence needs additional work. Coupling this data with other data, such as historic mapping (e.g. what was built when) can further reinforce the quality of the data. Such analysis can deliver far greater confidence in large part of the network and highlight areas where there may be concerns overcapacity. Data held by others in the industry, such as suppliers, can fill gaps in other data, such as Distributed Energy Resources (DER) and Flexible Demands (FD). Any new facilities are reported to the supplier by the installer, however often the network operator is not informed of the installation of small equipment: there are plans to move the registration to a web-based facility, which should improve these records.

New information can also help to plug the data quality gap, for instance, data coming from smart meters. The latest research by UK Network Operators shows that the profiles of the supply at these meters are almost unique (almost like an electrical fingerprint). With a few reference points, obtained by a selective site survey, AI can be used to work out the connectivity of the meter on the network, such as which substations and feeders supply the meter. It is even possible to work out the phase the meter is connected to, subject to a couple of reference sites. For above-ground assets, tools such as computer vision and LiDAR are a great help in not just validating the position of assets but also, when coupled with AI, they enable asset identification. All these details massively improve both the designed (i.e. normally open switch positions) and Operational (i.e. temporary changes to switch positions) connectivity models, which are the base to Distribution System Operator working.

Whilst such data improvements provide a great base for technical operation of flexible markets, they must be coupled with process improvements to ensure that data is accurately maintained in the future. Mobility tools can be a great help in simplifying the task of updating asset information from the field. Such tools must not only be simple in operation, so as not to burden field staff but must also be fully functional when off-line, especially as many locations on networks have limited internet connectivity. Mobility tools that are map-based greatly aid the operations of network field staff. However, the most vital element is culture, making sure staff understand how important it is to record changes, especially to local switching such as link boxes.

But these improvements only provide the base for the working of Distribution System Operators (DSO), and new tools will be needed. The market must be open to all, so the systems used for DER and FD actors must be based on open technology, such as browsers. These tools must allow actors to register their resources, make offers, bids, participate in peer-to-peer trading, and confirm the dispatch of agreed flexibility, all in a secure manner. They must be coupled with commercial tools that will securely manage all contracts and payments. These Facilitation tools should also interface with the DSO, who will need a tool that can coordinate the network. This Coordination tool will need facilities to forecast the near future, estimating demands and supplies at a very granular level. Power System Analysis will then be needed to place these forecasts on the network model, highlighting constraints that are likely to occur. The Coordination tool can then be used to request from the Facilitation market tool DERs or FDs at specific locations and times of the constraint. The market can respond with bids and offers to meet the requirement. The DSO would then have the flexibility to select the appropriate resources and be informed when the requirement is dispatched.

Coupled with these new tools should be a wealth of new sensors, instrumentation, and controls that monitor and control the network at increasingly granular levels. Instrumentation and controls will likely be on some form of private secured network and linked to Active Network Management (ANM) tools that will ensure network capacity is not exceeded at any time. Due to last-minute changes (i.e. more or less wind than expected, unplanned outages, etc.), the ANM may countermand what was previously agreed on the flexibility market, and commercial mechanism will need to be in place to manage such changes. These ANM and Flexibility tools will make use of a plethora of new sensors, many of which will communicate over new public networks, such as those being established for the Internet of Things (IoT). The use of LV Automation tools will also increase, indeed some equipment is already being deployed to a limited degree. Over time, the most abundant type of control will be that managing the charging of Electric Vehicles (EVs), which may also export energy back to the grid when it is not required for the running of the vehicle (Vehicle to Grid, or V2G). These metered controls must have a communication network that is both widespread and secure.

In some countries, such as the UK, regulations may also need amendment. Here, the network operator does not bill the customer, instead, retailers (suppliers) buy services from generators, transmission, and distribution operators, and others, such as meter reading services, and then charge the consumer based on their usage.

Consumers are free to choose the supplier they want, independent of the place where they live. However, if the DSO pays for DERs or gives discounts to FDs, how is this managed by way of commercials and regulations? As has been described above, 'Power Systems Analysis' assess the physics of a network and understand capacities and constraints. Projects are now underway to assess the relationship between physics and economics: this is sometimes referred to as 'Power System Economics'. However, this may be an oversimplification, as people are not always motivated by money alone, so other factors, such as convenience, must be considered in such research. How will such findings be incorporated into the regulation?

The complexity and localized constraints on these LV networks mean that it will not always be possible to meet all requests. The networks will, therefore, move from an 'on-demand' facility to one that is 'rationed', albeit in a limited form, in that an electric vehicle user will not always be able to charge her car when desired, or a DER supplier may not always be able to export to the grid. This is a fundamental change in the way these networks will interface with customers, and such changes cannot be managed by companies on their own. It will need significant input from governments, regulators, legal and commercial specialists, engineers, but above all society.

Distribution System Operators or the Flexi Grid presents many challenges around the world, but these complex LV networks compound the risks. It will require new systems, new instrumentation, new communication and security networks, new commercial and regulatory models, new processes and ways of working, but above all a change in the way we all use the electricity network.

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Mike has over 30 years of experience in the utility industry. His expertise is in operations, strategy, asset management, design, delivery, site, IT, finance, contracts, procurement, business development, business processes, manufacturing, R&D, and teamwork.

At Infosys, Mike works with a large UK-based client on a network project, including a major innovation project that will trial the IT systems that will be needed for DSO operation. He is also assisting in several global initiatives.

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