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ENA Paper: Analysis of P2 Class B Security of Supply

Executive Summary

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Background

The purpose of this ENA Paper is to inform the discussion on proposed changes to minimum levels of security of supply for specific parts of a distribution network.

Distribution Network Operators (DNOs)[1] are mandated to design their networks to at least a level of security of supply compliant with the level set in ENA Engineering Recommendation (EREC) P2. The current version of EREC P2 is Issue 7, i.e. EREC P2/7.

EREC P2 (commonly abbreviated to 'P2') stipulates minimum restoration times for loss of supplies following an outage on the network, i.e. how quickly customer supplies must be restored. The requirements in P2 have been the subject of review in recent years, led by the ENA P2 Working Group (under the auspices of the Distribution Code Review Panel, DCRP). In 2015/16, a review of P2 undertaken by Imperial College London (ICL) (with assistance from DNV.GL and NERA)[2] indicated that existing networks might be able to accommodate demand growth, in the short term, by relaxing restoration times required in P2 up to the point where reinforcement becomes economically justified. In March 2020[3] the ENA P2 Working Group completed an analysis which considered the societal, economic and environmental impact of reductions in security of supply at a GB level. The findings from the analysis included the following:

- For demand groups supplied by Primary Substations and Bulk Supply Points (Class of Supply C and D) it was concluded that the security of supply requirements for these network types should remain as specified in P2/7.

- For demand groups supplied by HV feeders (Class of Supply B) the impact of reducing redundancy was less pronounced and it was concluded that there might be situations where the reinforcement savings available outweigh the increase in the societal costs of interruptions. It was recommended that further work was needed to consider network security for HV feeders to a fuller extent.

The above findings and conclusions were reported to representatives of BEIS and Ofgem, where they were fundamentally accepted. Ofgem agreed with DNO members of the ENA that work to review security of HV feeders should commence with an expectation that a reduction in the security of supply level requirement would be appropriate for some HV feeders.

The DNO members of the ENA P2 Working Group have undertaken further analysis on demand groups supplied by HV feeders (Class of Supply B) to determine:

i. Which HV feeders could be planned with a lower minimum security of supply level; and

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[1] The term 'DNO' used in this ENA Paper also includes Independent Distribution Network Operator (IDNO).

[2] DNV GL, Imperial Consulting (Imperial) and NERA Economic Consulting, Engineering Recommendation P2 Review Workstream 2.7: Alignment of Security of Supply Standard in Distribution Networks with Other Codes and Schemes, 20 November 2015.

[3] ENA Paper: *P2/8 High-level Analysis*, 2020.

ii. What the lower minimum security of supply level should be.

The findings and conclusions from the HV feeder analysis are outlined in this ENA Paper.

Overview of Class of Supply B HV feeders

The majority of HV feeders in GB are operated as 'radial' circuits, i.e. a circuit with a single point of supply, with connection to alternative points of supply used to maintain customer supplies during planned circuit outage or to restore customer supplies during unplanned circuit outages. The analysis in this Paper focuses on these 'radial' circuits only.

Analysis of all DNO HV feeder data[4] for 2019/20 was undertaken which determined that there are approximately 32,000 HV feeders in GB. HV feeders comprise a mixture of both underground circuits (cables installed in the ground) and overhead circuits (conductors installed on poles) in both urban and rural areas. The vast majority of HV feeders may be categorised as underground circuits:

- Approximately 23,000 HV feeders are predominately underground (≤20% overhead).
- Approximately 9,000 HV feeders are predominately overhead (>20% overhead).

In addition to the analysis of this HV feeder data, a further large representative sample of DNO data was collated to study the maximum demand on HV feeders. This data showed that 82% of HV feeders have a maximum demand in the range 0 - 4MW. The predominant maximum demand on an HV feeder is in the range of 1.5 - 2MW.

Security of supply level for Class of Supply B

For HV feeders (Class of Supply B), P2 stipulates the following minimum requirements for a first circuit outage, e.g. a circuit fault:

Existing EREC P2/7 minimum requirements for HV feeders
Demand to be restored within 3 hours (MW) = **Group Demand (MW) – 1MW**

In considering lower minimum levels of security for Class of Supply B, the P2 Working Group reviewed the main factors that affect the security of supply of HV feeders. In the study, these factors were identified as; fault rate/length of circuit, speed of supply restoration following a fault, the demand profile and presence of an alternative circuit to supply customers. To analyse the impact of reducing security levels for HV feeders a coefficient was applied to the minimum requirements as follows:

[4] Data used was taken from the DNO Quality of Supply (QoS) HV Disaggregation reporting packs.

Using a coefficient to study impact of reducing EREC P2/7 minimum requirements for HV feeders
Demand to be restored within 3 hours (MW) = **0.9xGroup Demand (MW) – 1MW**

A coefficient of 0.9 translates as an increase of 11% of the permitted Group Demand that could be accommodated on an existing P2/7 compliant HV feeder. For example, an existing HV feeder with a maximum demand of 1.8MW requires a minimum of 0.8MW to be restored within 3 hours, under P2/7. Applying a coefficient of 0.9, the HV feeder maximum demand can be increased to 2MW, whilst the same minimum restoration of 0.8MW applies within 3 hours.

Assessing the impact of lowering Class of Supply B requirements

To assess the impact for customers of lowering the security of supply requirements the concept of expected energy not supplied (EENS) is used. This is a widely applied metric when assessing network outage risk and it represents the probabilistic calculation of energy that would not be supplied to customers as a consequence of a network outage. This Paper applies the following equation to determine the EENS for a HV feeder per annum:

EENS = Group Demand (MW) x Restoration time (hr) x Fault rate (f/a/km) x HV feeder length (km) x Load probability (%)

As there are two predominant stages of supply restoration following a fault outage – network reconfiguration (switching) stage and fault repair stage – the EENS for each stage has been calculated and the sum used to represent the total EENS for the HV feeder. The values that have been applied for the parameters are as follows:

- Group Demand

  Group Demands in the range 1.5 – 4MW have been considered, as this range represents the majority of HV feeder demands.

- Restoration time

  A switching restoration time of 3 hours and a repair time of 9 hours have been applied. 3 hours relates to the present EREC P2 requirement, whilst 9 hours was established by the P2 Working Group as being a typical value.

- Fault rate

  The fault rate per km for 32,000 GB HV feeders has been calculated for the two generic types of HV feeder, i.e. HV underground cable feeder and HV overhead line feeder, and the weighted average has been calculated as 0.09. It was noted that there is not a significant difference between the fault rates of HV underground cable feeders and HV overhead line feeders.

- HV feeder length

  Various lengths of HV feeder have been considered in the range 0 - 50km. The average length of a HV feeder is 5.08km.

- Load probability

A load duration curve (LDC) has been used to take into account the fact that load (or demand) on a HV feeder is not constant and changes over time. An LDC is a static representation of a time-dependent load – it depicts the duration for which the load will remain above certain values, i.e. % demand vs. % time. For a HV feeder, the area under a LDC represents the total energy supplied via that feeder, to consumers, per annum; this can be used to calculate an average value for the HV feeder load. When the transfer capacity associated with an alternative supply circuit is known, then the probability that there is insufficient transfer capacity to supply the load normally supplied by the faulty feeder whilst the repair is being carried can be determined. This Paper uses a simplified piecewise linear LDC. Over 40 LDCs from a range of HV feeders were studied to determine a range of representative LDCs for HV feeders.

The EENS for a HV feeder was determined in two scenarios:

a) A group of customers (demand) supplied by a HV feeder with a security of supply level compliant with the minimum requirements of P2/7; and

b) The same group of customers (demand) supplied by a HV feeder with the same characteristics to that used in a) above, i.e. length, fault rate, LDC etc., but with a security of supply level compliant with the proposed reduction in minimum requirements, i.e. with a coefficient of 0.9 applied.

The difference in EENS between scenarios a) and b) was analysed and used to calculate the increase in average minutes off supply per annum that a customer[5], connected to a circuit that was complaint with P2/7, would experience if they were supplied by a circuit compliant with the proposed reduction in minimum requirements. It is this increase in 'average minutes without a supply' that has been the focus of this Paper.

In respect of what would be an acceptable limit, the P2 Working Group agreed to base the analysis on the assumption that an 'average increase without a supply' of 10 minutes per year for a customer is reasonable. This is on the assumption that a limited number of customers would be affected (because only specific HV feeders would meet the criteria) which in turn would have limited impact on the overall customer minutes lost (CML)[6] for GB, i.e. 1.8% increase if all of the potential 1.2 million customers were affected by the proposed change. There are approximately 30 million customers in GB. To set this additional 10 minutes that a customer would be without a supply into context, the existing average time without supply due to a fault affecting a Primary Substation or Bulk Supply Point is approximately 15 minutes, the existing average time without supply due to a HV fault is approximately 60 minutes and the average time without supply due to a LV fault is approximately 150 minutes[7].

Findings

[5] The 'average minutes off supply per annum that a customer experiences' in this context is specific to the group of customers being considered. It is not necessarily the same as the customer minutes lost (CML) which is a weighted average for all customers across a network (see footnote 6)

[6] CML = sum of the customer minutes lost for all restoration stages / total number of connected customers

[7] Based on data from the National Fault and Interruption Reporting Scheme (NaFIRS) within the last 4 years.

The application of a coefficient of 0.9 to the calculation of the minimum demand to be restored for a first circuit outage of a HV feeder (Class of Supply B), a study of the increase in EENS and the average time a customer would be off supply has been undertaken, using the following parameters:

i. Group Demand = 1.5MW (lower limit of the predominant HV feeder Group Demand);

ii. Fault rate = 0.09 faults / annum / km;

iii. Switching time = 3 hours;

iv. Fault repair time = 9 hours; and

v. The representative LDC.

Using these parameters it has been determined, to ensure that the average additional minutes a customer supplied from a HV feeder would be off supply per year is no greater than 10 minutes, that the proposed lower security of supply level should only be applied to HV feeders that are 1km long or less.

Benefit and Impact

Reducing the redundancy of HV feeders would mean power outages experienced by customers would on average last longer. Previous stakeholder engagement by DNOs, as part of their RIIO-ED1 and DCRP stakeholder engagement activities, has clearly demonstrated that GB customers do not support a reduction in supply security.

A reduction in security of supply levels conflicts with DNOs' focus to continually improve their 'customer minutes lost' objectives.

A reduction in security of supply levels also conflicts with DNOs' focus to reduce network losses. Those parts of the network with lower levels of supply security will have increased asset utilisation, i.e. equipment operating with more current passing through it, and a consequential increase in network technical losses.

The main benefit of reducing the minimum security of supply level is facilitating an increase in network capacity that can be 'released' for normal network configuration, as opposed to network capacity being reserved for use in outage scenarios. In the proposal, up to an 11% increase in customer demand could be accommodated on specified HV feeders without incurring upgrading costs. Theoretically this would facilitate the connection of low carbon technology with their associated increase in network demand. Determining the extent of cost savings on HV feeder upgrades is complex as a number of factors determine whether and when reinforcement may be required (e.g. the location, magnitude and timing of future load growth, the diversity between the new and existing feeder load, the capacity of existing HV feeder and the HV feeder topology) – such factors may be generalised if the proposed security of supply criteria is applied nationwide, but for HV feeders of interest, specific data and analysis would be needed to determine a meaningful value for any cost saving. The potential cost saving for a HV feeder, if facilitated by the proposed reduction in security of supply level, could be significant as a HV feeder reinforcement scheme typically costs in the region of £100k[8].

There are approximately 3,600 HV feeders in GB which are up to 1km in length which supply a total of 1.2 million customers.

On the basis that the maximum length of HV feeder is 1km for the application of the proposed '0.9 coefficient', the expected increase in customer minutes lost (CML) for HV faults is 1.8%. To put this increase into context, in 2017/18 the HV CML value was 22.3 – this may have increased to 22.7 if all 1km HV feeders had been planned to just comply with the proposed lower security of supply level.

Simplifying the 0.9 coefficient

The P2 Working Group considered the practical application of a co-efficient to the calculation of the minimum demand to be restored following an outage, from a network planning perspective. Applying a '0.9 coefficient' approach can mean that the size of the demand which is permitted to remain off-supply following an outage is dependent on the Group Demand; this can change over time, which could have implications for the network topology. To avoid these practical difficulties, the '0.9 coefficient' approach has been converted to an equivalent alternative representation. Using a Group Demand of 2MW to represent the most common HV feeder load, the "0.9 x 2MW – 1MW" approach equates to "Group Demand – 1.2MW" approach, such that the simplified requirement becomes:

Proposed EREC P2 requirements for HV feeders
Demand to be restored within 3 hours (MW) = **Group Demand (MW) – 1.2MW**

Recommendations

It is recommended that:

i. P2/7 is amended with the inclusion of a note to indicate that the minimum demand to be restored within three hours can be reduced for specific HV feeders within Class of Supply B; and

EREP 130[9] is amended to convey that for HV feeders up to 1km in length, the demand that shall be restored within 3 hours is Group Demand minus 1.2MW. A summary of the assumptions and exclusions for this criteria should be included as well as the treatment of the Class of Supply A/B boundary.

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[8] Indicative cost of a reinforcement scheme addressing security of supply on a HV feeder based on GB DNO data for the current price control period (ED1).

[9] ENA EREP 130, Issue 3, Guidance on the application of Engineering Recommendation P2, Security of Supply