GREEN Grid

Report

Managing fuse protection in low-voltage networks with distributed generation

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Notices

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1 Introduction

1.1 Overview

New Zealand's (NZ's) uptake of inverter-based solar photovoltaic energy systems can affect fused protection in its 400 V low-voltage (LV) networks. This paper proposes some basic rules that can be applied generally to avoid problems with fuse protection in such networks. NZ's low-voltage domestic and residential electricity distribution networks typically follow a radial topology beyond the distribution transformer, with a multiple earthed neutral (MEN) earthing system and individual phases connecting residences and premises of small businesses. Most solar photovoltaic (PV) based inverter energy systems (IESs) are installed on north-facing rooftops at suburban residences. The inverters are connected to the main supply into each installation connection point (ICP), usually installed wherever the main circuit board is located. Electricity is exported to the distribution network from behind the domestic metering equipment. Increasing PV uptake in NZ is affecting power flows in its distribution networks [1]. New types of fault can occur under these new conditions, in networks that were designed originally for unidirectional power flow. As such, it is important to maintain a properly discriminated protection scheme that ensures fuses operate as they should.

Problems with protection systems in high-voltage (>1 kV) distribution systems hosting high penetrations of IESs have been studied in significant depth [2]. Specific consideration of the behaviour of fuses at the low-voltage level has been uncommon to date, and this paper addresses the management of fuse-based protection in low-voltage networks with high penetration of IESs. Of particular importance is the relationship between fuses and the conductors they protect, and the purpose of developing this method is to ensure that the phenomenon of conductor "burndown" or "burnout" can be avoided with certainty [3].

A previous study investigated the interaction of inverter undervoltage cut-out with network undervoltage due to faults [4]. It was found that the inverter's response was dependent on fault resistance, and that for moderately high fault resistances, voltages could be maintained above the lower threshold for inverter disconnection. As a consequence, the possibility of fuse protection blinding could not be discounted. Because inverter undervoltage cut-out is a secondary effect of fault conditions, the undervoltage disconnection feature cannot be relied upon to act as a primary protection mechanism for the cable in the event of fuse blinding. Hence some further checks are required to ensure that cables will not carry excessive current owing to the presence of IESs in a LV network.

The rest of the introduction highlights familiar fuse protection problems. The method formulates mitigation strategies, giving recommendations embodied in formulae that can be used with contemporary cable fuse protection standards. The results section presents tables derived from the method, firstly based on the theoretical limits from the standard, and secondly based on an example fuse protection policy of one particular NZ Electricity Distribution Business (EDB). Worked design examples are presented, before a summary discussion of the whole approach.

1.2 LV network fuse protection

Protection in power systems is aimed at protecting equipment against damage. Almost universally, the type of protection at the level at which IESs are connected is overcurrent protection, and is meant to disconnect before affected equipment can overheat. Typically, inverse definite minimum time (IDMT) overcurrent relays or fuses are used. Trip times can be anywhere between a fraction of a second, and tens of seconds, depending on the fault current. Low current faults are allowed to persist for some time, while high current faults are cleared quickly. This characteristic also allows discrimination, such that the fuse closest to the fault will trip, clearing the fault faster than fuses further away from the fault.

In low-voltage electricity distribution networks, fuses protect cables and overhead lines from carrying excessive current for too long. Fuses are rated to protect the conductor while avoiding blowing under load. Overcurrent in cables and lines may damage the insulation, or the conductor itself, resulting in costly replacement of sections of conductor. With roof-top photovoltaic (PV) Inverter Energy Systems (IESs) becoming more common in low-voltage distribution networks, it is important that fuse protection functions properly to protect conductors in the event of a fault.

1.3 Protecting cables with fuses

This section outlines the approach to cable fused protection, explaining what is demanded by standards to meet minimum protection criteria. AS/NZS 3008.1.2-2017 (Electrical installations - Selection of cables) Section 2.3a lays out the method for selecting a minimum cable size based on current-carrying capacity considerations. It introduces the current for which the circuit is designed, I_B, which can be, for example, the maximum demand. It also introduces the continuous current carrying capacity of the circuit, I_Z, determined after applying relevant de-rating factors from tables in that standard. The standard asserts that the design current, I_B, shall be no greater than the continuous current carrying capacity of the conductor, I_Z, i.e.,

$$I_B \leq I_Z \tag{1}$$

To protect the cable from overload current, AS/NZS 3008.1.2-2017 2.3a refers to the method outlined in AS/NZS 3000-2017 (Electrical installations - Known as the Australian/New Zealand Wiring Rules) (AS/NZS 3000) section 2.5.3 "Protection against overload current". Section 2.5.3.1 introduces a nominal current for the protective device, I_N, and additionally the current ensuring effective operation of the protective device, I_2. The AS/NZS 3000 then goes on to state the two conditions to be satisfied when protecting a conductor against overcurrent as,

$$I_B \leq I_N \leq I_Z \tag{2}$$

$$I_2 \leq 1.45 I_Z \tag{3}$$

In the case where a fuse acts as the protection device, I_2 is the fusing current in conventional time for fuses, which is $1.6I_N$ for fuses complying with the IEC 60269 series. To satisfy this condition specific to fuses, equation 3 above becomes,

$$I_B \le I_N \le 0.9I_Z \tag{4}$$

In other words, the nominal fuse current must be less than or equal to 90 percent of the rated cable current, and the normal load current must be less than this.

Most EDBs have their own fuse scheduling, largely based on this approach. However, the maximum continuous current carrying capacities of cables in those schedules vary with the installation conditions of their respective networks, e.g., due to the ambient temperatures of surrounding air or soil. Due to this variation in scheduling, there may be greater or lesser margin to accommodate overcurrent.

1.4 Types of protection problems arising from PV

The contribution of IESs to protection issues depends strongly on whether they keep supplying current under fault conditions.

IESs have automated subsystems for under-voltage cut-out - activating when the network voltage collapses, and anti-islanding, when the network disappears from the perspective of the IES. There are two thresholds for under-voltage cut-out; 200 V (the prevailing legal requirement in NZ according to the Electricity (Safety) Regulations 2010, from AS 4777.3:2005) and 180 V (from AS/NZS 4777.2:2015) [5] [6] [7]. In NZ at the time of writing, inverter energy systems must comply with AS 4777.3:2005 [8]. Clause 7.4 says that if the system voltage goes below 200 volts for longer than a second, then the IES must disconnect within a further one second. This gives a maximum disconnection time of two seconds, while maintaining a minimum trip delay time of one second to allow ride-through for brief transients. The threshold will reduce to 180V when the 2015 standard is fully adopted.

When a fault occurs in an electricity network, a high current will flow from the source, and the voltage on the line may or may not drop below the threshold at which IESs should disconnect. The amount of current contributed by an inverter rated up to 10 kVA is typically around 1.2 times the rated current output [9]. In aggregate, these inverters can produce fault current contributions comparable to the nominal current rating of the conductor [10]. The IES contribution is limited to 1.2 times the rated current for 2 seconds if the under-voltage condition is met, otherwise the contribution will persist.

If fault currents are high and under-voltage conditions are met, the IES contribution, being close to normal operating currents, will be relatively small. If fault currents are low, system studies show that under-voltage conditions will not be met, and the persisting IES current contribution can lead to two issues. At the electricity distribution level, these two issues are sympathetic tripping, and protection blinding.

1.4.1 Sympathetic tripping

Sympathetic tripping is unwanted disconnection of generation on healthy feeders, as a consequence of a fault on a nearby feeder. This has three sub-categories:

1. When the unwanted disconnection is via a fuse blowing or overcurrent relay operation, as shown in Figure 1a. This sort of disconnection requires human intervention to restore power.

2. When there is an unwanted operation of a protection device (i.e. a fuse blowing) downstream of a fault on a feeder. While this does not result in more customers being disconnected, it does make the fault recovery more complicated. This situation is shown in Figure 1b.

3. When distributed generation on healthy feeders is disconnected due to abnormal voltage conditions. This type of disconnection is automatically restored when voltage levels return to normal. This sort of disconnection is of little consequence.

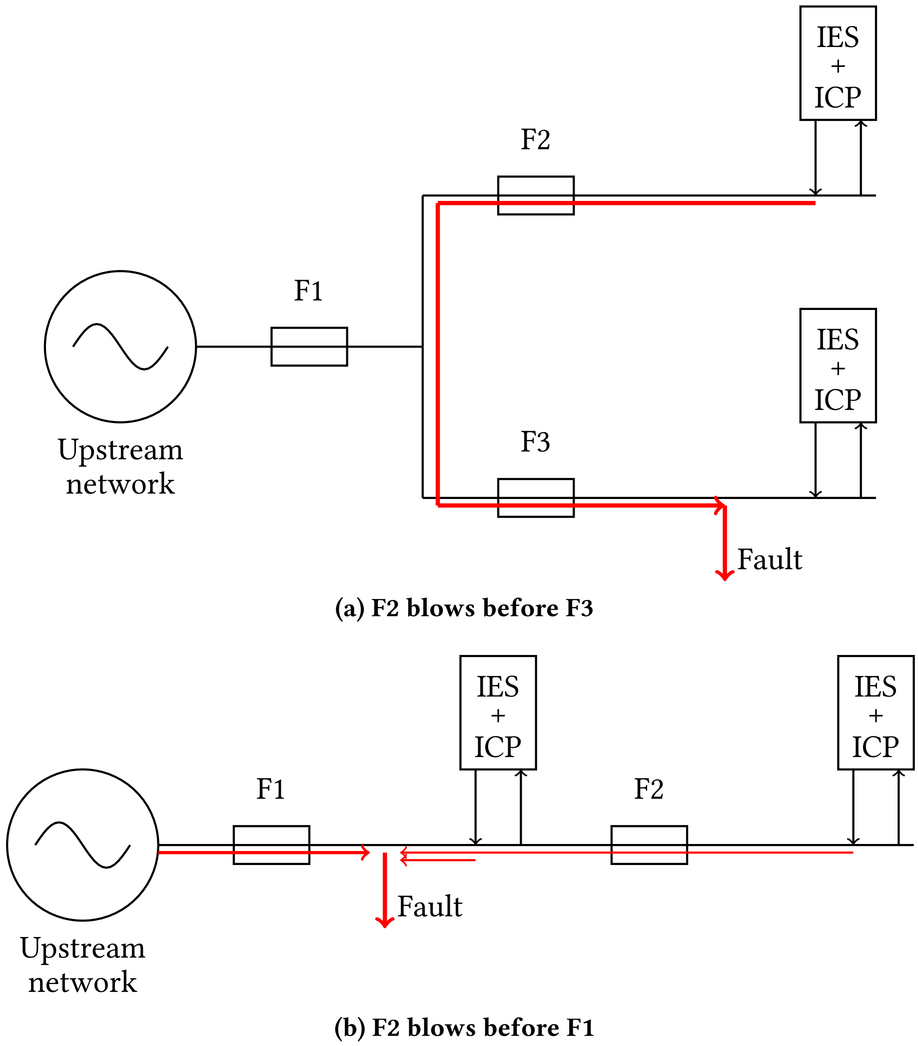

Figure 1: Two causes of sympathetic tripping in LV networks

1.4.2 Protection blinding

Also known as protection under-reach, this is defined as when distributed generation on a faulted feeder provides a high enough proportion of the fault current that the appropriate feeder fuse does not clear a fault, and part of the faulted feeder carries a current that could damage the feeder. For this to occur, two conditions must be met. Firstly, the voltage at the IESs on the faulted feeder must remain at or above the minimum voltage threshold (200 or 180 volts), such that they remain connected and contributing to the fault current.

Secondly, the current flow at the fault must be high enough that the cable is likely to be damaged. The fault resistance has two bounds - an upper bound above which currents (including the IES contribution) are insufficiently high to damage the cable, and a lower bound, below which fuse protection operates (even though IESs contribute to the fault current). IESs may disconnect due to under-voltage, but it is dependent on the under-voltage condition being reached, and so the worst-case current contribution may not be reliably diminished. This situation is illustrated in Figure 2.

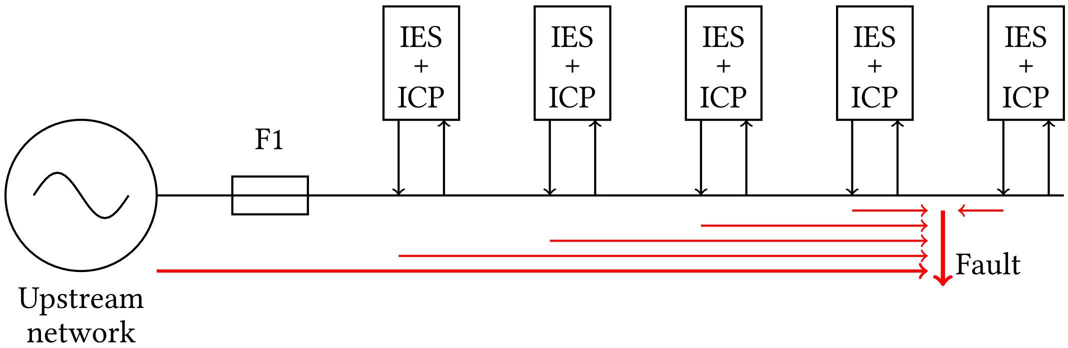

Figure 2: Fuse blinding, where the current through F1 is less than the current through the fault

1.5 Previous work

Previous studies have identified sympathetic tripping as a problem that can be caused by increased IES penetration [11] [12]. The same studies identified fuse blinding as another problem, but did not suggest ways of assessing and mitigating the potential for fuse blinding when significant numbers of IESs are installed on LV feeders. In the next section, two basic rules are described that eliminate sympathetic tripping, and minimise problems arising due to fuse blinding.

2 Method

2.1 Minimising and eliminating protection problems

Electrical networks are constrained by voltage limits and current carrying capacity. As far as LV protection systems are concerned, it is a cable's current carrying capacity that determines the upper limit of its allowable over-current. Any current carrying capacity between a circuit's design current, I_B and its maximum continuous capacity, I_Z, can be viewed as Extra Current Capacity, or simply, ECC, which can be exploited to work out how much additional IES-sourced current can be accommodated, whilst avoiding problems with protection systems.

Hosting capacity describes how many kilowatts of distributed generation can be accommodated on a LV network. Hosting capacities in LV networks are usually found based on constraints of voltage and current [13], but only in a way that addresses the question of what can be accommodated on a network within voltage and current limits, without consideration of constraints afforded by protection systems.

Since these existing ideas about hosting capacities are already established in the literature, it makes sense to introduce the notion of a Protection-Based Hosting Capacity (PBHC), as distinct from existing definitions of hosting capacity. We propose that ECC can be quantified from first principles using existing network protection design rules, in such a way that PBHC can be easily determined. PBHC can be found for any network where cable and fuse sizes are known, thus avoiding any instance of sympathetic tripping and mitigating the effects of fuse-blinding. In this method, two rules are identified that can be used to determine how much ECC there is available in a network, and what the PBHC is.

PBHC in this method is always calculated at 100 % penetration of DG on the low-voltage network.

2.2 To avoid sympathetic tripping

Avoiding sympathetic tripping of the first two kinds described in Section 1.4.1 requires that the affected fuse (F2 in Figures 1a and 1b) does not blow at the level of fault current that the IES can provide through that fuse (less the current consumed by the ICP loads). Given that this current is just 1.2 times the IES rating, a sensible fuse rating would be higher than this current. This leads to the following recommendation:

Recommendation 1 (R1): All fuses should be rated at greater than 1.2 times the combined nominal current output rating of downstream connected IESs.

This can be written as,

$$I_N \geq 1.2 I_K \tag{5}$$

where I_K is the combined nominal output current rating of downstream connected IESs.

2.3 To mitigate the effects of protection blinding

It is possible that cable current at the end of the feeder may exceed fuse rated current by up to 1.2 times the maximum combined rating of IESs on each particular single phase of that feeder. Therefore:

Recommendation 2 (R2): Fuses should be rated no greater than the cable rating minus 1.2 times the combined IES current ratings on the protected feeder.

The worst-case unmitigated fault current, I_F, due to fuse blinding that can flow in a conductor is simply nominal current rating of the upstream fuse, I_N, plus the sum of IES fault currents, $1.2 I_K$,

$$I_F \leq I_N + 1.2 I_K. \tag{6}$$

The current at the fault should be less than the maximum current carrying capacity of the cable, thus,

$$I_F \leq I_Z \tag{7}$$

with inequality 6 implying

$$I_N \leq I_Z - 1.2 I_K \tag{8}$$

which embodies Recommendation 2.

2.4 A general method for using extra current capacity to avoid fuse protection problems

It is practical to determine how many volt-amperes (VAs) of IES can be installed downstream of a fuse in an LV feeder, while avoiding fuse protection problems. The rated current of all the IESs on a single phase is the total nominal VA rating of those systems, S_K, divided by the nominal phase-to-neutral voltage, U_n,

$$I_K = \frac{S_K}{U_n}. \tag{9}$$

Recommendation 1 can be re-stated by combining equations 5 and 9 to give,

$$S_K \leq \frac{I_N \times U_n}{1.2}. \tag{10}$$

Recommendation 2 can be re-stated by rearranging equation 8 to give

$$1.2 I_K \leq I_Z - I_N \tag{11}$$

which simply states that the sum of fault currents due to IESs downstream of the fuse shall be no greater than the continuous current carrying capacity of the conductor minus the fuse nominal current.

Equations 5 and 11 can be combined to give,

$$S_K \leq \frac{(I_Z - I_N) \times U_n}{1.2}. \tag{12}$$

The maximum total IES VA rating allowed on a single phase is therefore the minimum of equation 10 and equation 12, in other words,

$$H_{max} \leq min\left\{\frac{I_N \times U_n}{1.2}, \frac{(I_Z - I_N) \times U_n}{1.2}\right\} \tag{13}$$

where S_K has been replaced by H_{max} to denote the maximum allowable total IES power on a single phase.

This definition is purely a function of a fuse's nominal current I_N, and the cable's maximum continuous current carrying capacity. This definition can be used directly in conjunction with the AS/NZS 3008.1.2-2017, where I_Z corresponds to the de-rated value of cable current carrying capacity.

3 Results

3.1 Tables derived from AS/NZS 3008.1.2-2017

Equation 13 is significant because it enables the population of tables for various combinations of cable sizes and fuse sizes that show the per-phase H_{max} for a feeder downstream of a fuse, so that neither fuse sympathetic tripping can occur, nor can fuse blinding endanger cables. This is done for the case of both copper and aluminium three or four core cross-linked polyethylene (XLPE) insulated cables, buried direct, whose current carrying capacities are found in AS/NZS 3008.1.2:2017 Table 14, columns 23 and 24, respectively. It should be noted that I_Z has not been thermally re-rated, and that it is a requirement of the standard to adjust the rating depending on installation conditions, as per AS/NZS 3008.1.2:2017 section 2.3 clause (d). H_{max} for copper conductor cables are shown in Table 1, while those for aluminium conductor cables are shown in Table 2.

H_{max} is given on a per phase basis, as a single fuse protects a single phase of a feeder. All the tables presented in this document have been calculated with the phase-neutral voltage U_n = 230 V. Where dashes appear in the tables, it means that the inequality in equation 4 has been violated, meaning those values are unacceptable for a normal protection design.

Table 1: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for copper conductor cables, three or four core, XLPE insulated and buried direct. Based on AS/NZS 3008.1.2:2017 Table 14, column 23.

Cable		Fuse rating I_N (A)									
Copper		63	100	125	160	200	250	315	355	400	500
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)									
16	118	10.5	3.5	-	-	-	-	-	-	-	-
25	153	12.1	10.2	5.4	-	-	-	-	-	-	-
35	184	12.1	16.1	11.3	4.6	-	-	-	-	-	-
50	218	12.1	19.2	17.8	11.1	-	-	-	-	-	-
70	269	12.1	19.2	24.0	20.9	13.2	-	-	-	-	-
95	323	12.1	19.2	24.0	30.7	23.6	14.0	-	-	-	-
120	368	12.1	19.2	24.0	30.7	32.2	22.6	10.2	-	-	-
150	412	12.1	19.2	24.0	30.7	38.3	31.1	18.6	10.9	-	-
185	465	12.1	19.2	24.0	30.7	38.3	41.2	28.8	21.1	12.5	-
240	539	12.1	19.2	24.0	30.7	38.3	47.9	42.9	35.3	26.6	-
300	607	12.1	19.2	24.0	30.7	38.3	47.9	56.0	48.3	39.7	20.5
400	685	12.1	19.2	24.0	30.7	38.3	47.9	60.4	63.3	54.6	35.5

Table 2: Feeder single-phase hosting capacity (H_{max}), in kW per phase, for aluminium conductor cables, three or four core, XLPE insulated and buried direct. Based on AS/NZS 3008.1.2:2017 Table 14, column 24.

Cable		Fuse rating I_N (A)								
Aluminium		63	100	125	160	200	250	315	355	400
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)								
16	91	5.4	-	-	-	-	-	-	-	-
25	119	10.7	3.6	-	-	-	-	-	-	-
35	142	12.1	8.1	3.3	-	-	-	-	-	-
50	170	12.1	13.4	8.6	-	-	-	-	-	-
70	209	12.1	19.2	16.1	9.4	-	-	-	-	-
95	250	12.1	19.2	24.0	17.3	9.6	-	-	-	-
120	286	12.1	19.2	24.0	24.2	16.5	6.9	-	-	-
150	320	12.1	19.2	24.0	30.7	23	13.4	-	-	-
185	364	12.1	19.2	24.0	30.7	31.4	21.9	9.4	0	0
240	423	12.1	19.2	24.0	30.7	38.3	33.2	20.7	13.0	0
300	477	12.1	19.2	24.0	30.7	38.3	43.5	31.1	23.4	14.8
400	546	12.1	19.2	24.0	30.7	38.3	47.9	44.3	36.6	28.0

3.2 Tables derived from a NZ local electricity distribution utility

The following tables were derived from the cable and fuse combination policy of an NZ electricity distribution utility. The key difference is a much more conservative cable current rating I_Z, which significantly restricts the hosting capacity. Of note is the significant variation in available capacity for hosting IESs compared to the capacities derived from standards in Tables 1 and 2. This is mostly due to the restricted variety of cables and fuse sizes; some combinations have significantly diminished hosting capacity compared to others. For this series of tables, there is also the trend that copper conductors appear to have more hosting capacity than aluminium conductors for the same fuse ratings.

Table 3: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for copper conductor cables, four core, XLPE insulated and buried direct. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Cu XLPE buried		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	179	15.1	10.4	3.6	-	-	-
95	215	19.2	17.3	10.5	-	-	-
120	244	19.2	22.8	16.1	8.4	-	-
185	309	19.2	24.0	28.6	20.9	11.3	-
300	403	19.2	24.0	30.7	38.3	29.3	16.9

Table 4: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for aluminium conductor cables, four core, XLPE insulated and buried direct. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Al XLPE buried		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	140	7.7	2.9	-	-	-	-
95	167	12.8	8.1	-	-	-	-
120	192	17.6	12.8	6.1	-	-	-
185	249	19.2	23.8	17.1	9.4	-	-
300	365	19.2	24.0	30.7	31.6	22.0	9.6

3.3 Worked examples

3.3.1 Example 1: Assessment of an existing network

A feeder is composed of a 185 mm^2 buried aluminium XLPE cable, with 9 ICPs per phase, and a 160 A fuse protecting the cable. What is the maximum IES size per ICP that can be hosted on the feeder at 100 % penetration, without affecting fuse performance?

From Table 2, H_{max} is 30.7 kVA. Since the number of ICPs on the feeder is 9, then the maximum permissible IES size at each ICP is,

$$\frac{30.7 \text{ kW}}{9 \text{ ICPs}} = 3.4 \text{ kVA}. \tag{14}$$

3.3.2 Example 2: Design of a new network

A new subdivision consisting of 45 ICPs is to be built. A covenant specifies each ICP will have 2 kW PV IES systems connected. A colleague's modelling suggests the peak load will average to 4.9 kW at each ICP. From Table 1, find the cable and fuse combination for the job.

On a per-phase basis, the peak current for the subdivision will be,

$$\frac{15 \text{ ICPs} \times 4.9 \text{ kW}}{230 \text{ V}} = 320 \text{ A}, \tag{15}$$

So a suitable fuse size will be 355 A. The total IES power rating for the feeder will be,

$$15 \text{ ICPs} \times 2 \text{ kW} = 30 \text{ kW}. \tag{16}$$

Looking at Table 1, the smallest cable size for a 355 A fuse that will accommodate the 30 kW of IES power is a 240 mm^2 Cu cable.

4 Conclusion

It is shown how fuse coordination can be preserved in LV networks with high penetrations of IES, so that cables are still protected. Recommendations are made to help combat sympathetic tripping and blinding of fuse protection systems. In particular, sympathetic tripping can be avoided if fuses are rated greater than 1.2 times the combined nominal current output rating of downstream connected IESs. In addition, to mitigate effects of protection-blinding, fuses should be rated no greater than the cable rating minus 1.2 times the combined IES current ratings on the protected feeder. Equations were derived that embodied these recommendations, and tables were drawn up to show the available hosting capacity for various combinations of fuses and cable sizes. Lastly, some design examples were given to show the methodology working in practice.

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5 Appendix A: Further tables

Table 5: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for copper conductor cables, four core, XLPE insulated and ducted. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Cu XLPE ducted		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	165	12.5	7.7	-	-	-	-
95	199	19.0	14.2	7.5	-	-	-
120	231	19.2	20.3	13.6	5.9	-	-
185	297	19.2	24.0	26.3	18.6	9.0	-
300	396	19.2	24.0	30.7	37.6	28.0	15.5

Table 6: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for copper conductor cables, four core, PVC insulated and buried direct. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Cu PVC buried		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	160	11.5	6.7	-	-	-	-
95	192	17.6	12.8	6.1	-	-	-
120	219	19.2	18.0	11.3	-	-	-
185	277	19.2	24.0	22.4	14.8	-	-
300	360	19.2	24.0	30.7	30.7	21.1	8.6

Table 7: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for copper conductor cables, four core, PVC insulated and ducted. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Cu PVC ducted		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	149	9.4	4.6	-	-	-	-
95	183	15.9	11.1	4.4	-	-	-
120	208	19.2	15.9	9.2	-	-	-
185	267	19.2	24.0	20.5	12.8	-	-
300	354	19.2	24.0	30.7	29.5	19.9	7.5

Table 8: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for aluminium conductor cables, four core, XLPE insulated and ducted. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Al XLPE ducted		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	129	5.6	-	-	-	-	-
95	155	10.5	5.8	-	-	-	-
120	181	15.5	10.7	4.0	-	-	-
185	233	19.2	20.7	14.0	6.3	-	-
300	314	19.2	24.0	29.5	21.9	12.3	-

Table 9: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, four core, PVC insulated and buried direct. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Al PVC buried		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	124	4.6	-	-	-	-	-
95	149	9.4	4.6	-	-	-	-
120	153	10.2	5.4	-	-	-	-
185	196	18.4	13.6	6.9	-	-	-
300	283	19.2	24.0	23.6	15.9	6.3	-

Table 10: Feeder single-phase hosting capacity (H_{max}), in kVA per phase, for aluminium conductor cables, four core, PVC insulated and ducted. Based on fuse protection policy from a NZ electricity distribution utility.

Cable		Fuse rating I_N (A)					
Al PVC ducted		100	125	160	200	250	315
Size (mm^2)	I_Z (A)	Feeder H_{max} (kVA per phase)					
70	115	2.9	-	-	-	-	-
95	140	7.7	2.9	-	-	-	-
120	160	11.5	6.7	-	-	-	-
185	206	19.2	15.5	8.8	-	-	-
300	277	19.2	24.0	22.4	14.8	-	-