REFCL Compliance Maintained Planning Report Kilmore South (KMS) Zone Substation

AMS – Electricity Distribution Network

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1 Project overview

The Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016 came into effect on 1 May 2016 amending the *Electricity Safety (Bushfire Mitigation) Regulations 2013* (the **Regulations**). These Regulations specify the Required Capacity for Rapid Earth Fault Current Limiter performance. The Regulations also specify the 22 zone substations on AusNet Services' network that must comply with the Regulations.

The *Electricity Safety Amendment (Bushfire Mitigation Civil Penalties Scheme) Act 2017* (the **Act**) sets out the significant financial penalties enforceable for non-compliance. Refer to Appendix A for further information.

Kilmore South (**KMS**) zone substation (**ZSS**) was included in Tranche 1 of the AusNet Services REFCL Program. This report investigates and seeks funding for the most prudent and efficient approach to maintain compliance with the Regulations at KMS during the 2022-26 regulatory control period.

KMS has one Arc Suppression Coil (**ASC**) which was installed as part of the initial REFCL trial. The KMS ASC has a lower capacity than the current standard ASC, with a capacitive current limit of 80 Amperes (A). In 2025, the ASC limit is forecast to be exceeded. This report has reviewed options considered by AusNet Services to manage the capacitance growth.

The preferred option, which is the option found to be the most economically efficient and technically feasible, recommends that a larger ASC be installed at KMS. The new ASC will be the standard size, which is expected to provide a capacitive current limit of 120A given the known damping characteristics of the KMS network, and new associated control equipment. The total cost for this option is $3.7 million. This option does not require any technical exemptions from the *Electricity Safety Act 1998* and Regulations.

2 Background

2.1 Purpose of this report

This report investigates any constraints that are forecast to occur at KMS, identifies and assesses potential options, and seeks funding for the preferred option. KMS is included in Schedule 1 of the *Electricity Safety (Bushfire Mitigation) Regulations 2013*, and must meet the Required Capacity defined in the Regulations.

The constraints investigated include:

- Forecast demand;
- Network constraints; and
- Capacitive current and compliance with the Regulations.

The following sections of this report describe the compliance obligations, the technologies available to achieve those obligations, constraints at the zone substation and options to mitigate any issues.

2.2 Compliance obligations

The Victorian Government has mandated, through the Regulations, that electricity distribution companies increase safety standards on specific components of their networks to reduce bushfire risk. The Regulations set challenging performance standards (the **Required Capacity)** for 22 of AusNet Services' zone substations. The dates for compliance are separated into three tranches based on a prioritising points system, and occur on 1 May 2019, 1 May 2021 and 1 May 2023. In addition, the Victorian Government has enforced timely compliance of the Regulations by introducing significant financial penalties though the *Electricity Safety Amendment (Bushfire Mitigation Civil Penalties Scheme) Act 2017* (the **Act**).

Distribution businesses have found that the Required Capacity can only be met by installing Rapid Earth Fault Current Limiters (**REFCLs**) in zone substations. In addition, the Victorian Government's Powerline Bushfire Safety Program also identified REFCLs as the preferred solution for meeting the Required Capacity[1].

The Act provides for the Governor-in Council to grant exemptions and for a Major Electricity Company to request the modification of due dates and periods.

Details of the Act, the Regulations and the penalties are in Appendix A.

2.3 REFCL technology

There are various types of technology that fall under the REFCL umbrella, however the only type of REFCL currently considered suitable by the Victorian Electric Supply Industry (VESI) for bushfire safety is known as the Ground Fault Neutraliser (GFN), a proprietary product by Swedish Neutral. Presently, the GFN is the only device that can meet the performance criteria of the Regulations. All references to REFCLs in the remainder of this document are referring to the GFN type.

REFCLs are comprised of the following key components:

- Arc Suppression Coil (**ASC**) – which is a large inductor that compensates for the capacitive current during an earth fault;

[1] REFCL fact sheet 2016 111216, Introducing best knowledge and technology, Powerline Bushfire Safety program, Dec 2016

- Residual Current Compensator (**RCC**) – also referred to as the inverter, which is located in the zone substation control building or switchroom. It is used to reduce fault current by compensating for the active current during an earth fault; and
- Control Panels and software, which control the equipment.

2.4 REFCL constraints

The REFCL's ability to successfully detect, manage and locate phase to earth (also referred to as ground) faults on the 22kV network[2] is dependent on a complex combination of network conditions which, when correctly managed, allow continued operation of the REFCL protection in compliance with the Required Capacity.

The following network conditions and physical constraints impact the continued correct operation of the REFCL and its ability to continue meeting the Required Capacity:

Network damping factor

The network damping factor is defined as the ratio of the resistive current losses to the capacitive current (I_R/I_C) measured across the zero-sequence network. A higher damping factor is undesirable as it limits the ability of the REFCL to detect a high impedance fault, and thus operate in the time required to comply with the Required Capacity. The higher the damping factor the lower the capacitive current limit of the ASC.

Network topology

Most modern residential developments are constructed using underground cables which have a higher capacitance than overhead lines. As the 22kV network grows due to increased demand, new customer connections and overhead conductor to underground cable conversions, the additional cable installations will increase the total capacitive current on the network. If the network capacitive current exceeds the capacitive current limit of the ASC, network investment is required to maintain compliance with the Regulations.

Capacitive current limit of the ASC

There are two capacitive current limits:

- **Per ASC:** The typical configuration for REFCLs is one ASC per supply transformer and therefore per bus. The limit of an ASC is dependent on the damping characteristics of the network. However, the actual damping characteristics specific to the network can only be measured once a GFN installation is operating. For planning purposes, a typical rating of 100A is used. In the case of KMS, this zone substation was the trial site for the REFCL in 2015, and a smaller capacity ASC was installed with a capacitive current limit of 80A.
- **Per feeder:** To enable differentiation of the feeder experiencing a fault, the maximum capacitive current that is allowable per individual feeder is 80A.

Software limitations

Currently, Swedish Neutral (manufacturer of the GFN) has not deployed a software solution that will allow the use of three GFNs at one zone substation.

2.5 Prudent and efficient investment

AusNet Services has taken the approach of incremental funding requests to maintain compliance with the Regulation to ensure minimal long term cost to customers. This is prudent and efficient as it enables:

- Minimum works to be carried out just in time to maintain compliance with the Regulation until 2026.

[2] SWER, which operates at 12.7kV, is excluded from the Required Capacity and is subject to its own requirements.

- Planning to be based on the most up-to-date network growth and capacitive current information and
- Application of the latest development in REFCL technology in this rapidly developing field. For example, should Swedish Neutral deploy a software solution that enables the use of three REFCLs at a zone substation, it may enable deferral of a new zone substation.

3 KMS zone substation overview

Kilmore South (**KMS**) zone substation (**ZSS**) is located in the town of Kilmore, approximately 75km north of Melbourne. This zone substation was established in the 1980s and supplies the town of Kilmore and surrounding areas including Broadford, Wandong and Strath Creek.

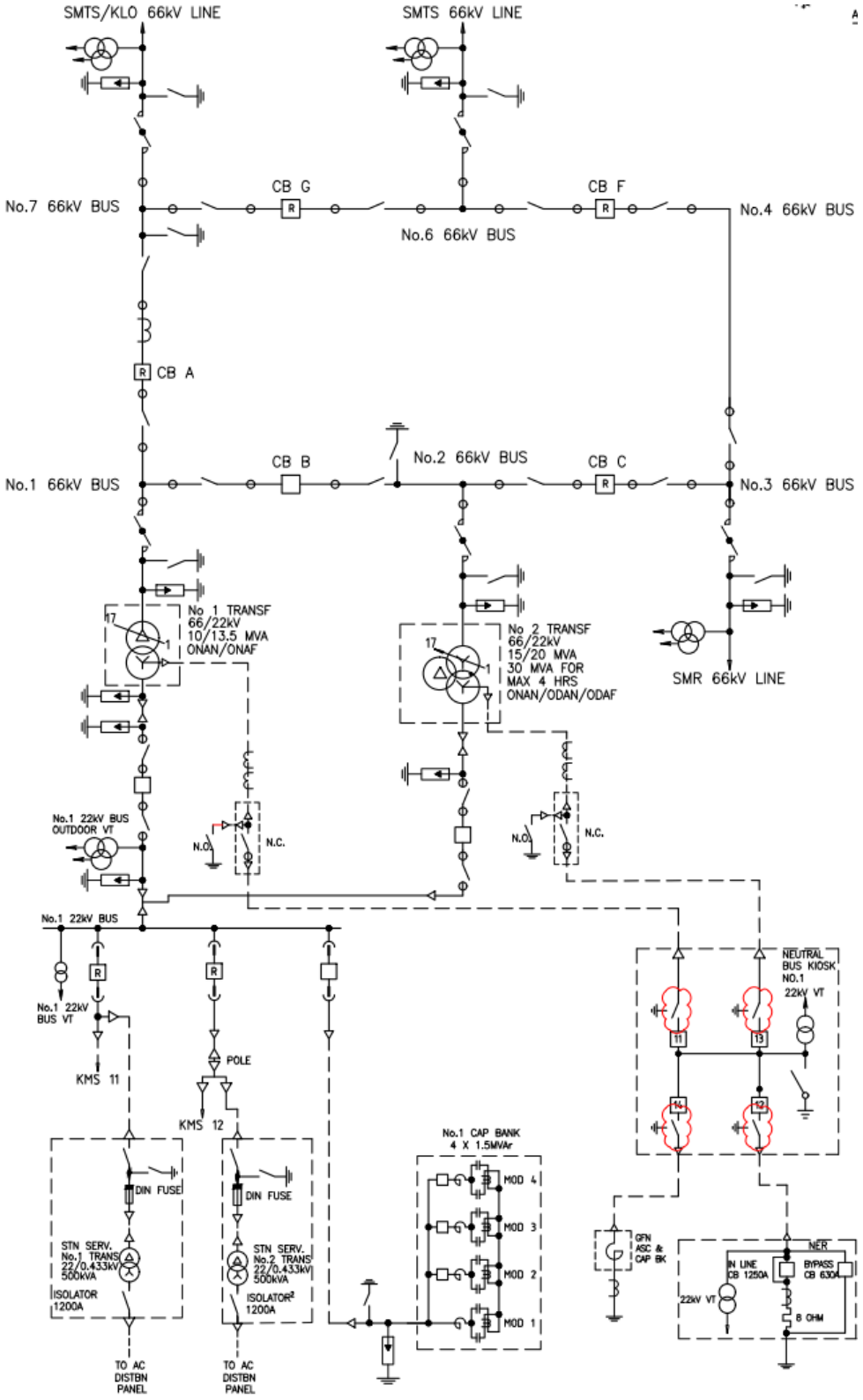
The station supplies 8,495 customers by means of two medium voltage (15/20 and 10/13.5 MVA) transformers on different vector groups and two distribution feeders. The transformers operate with Transformer 2 normally supplying the load and Transformer 1 as back up.

The feeders cover a total route length of 250km. The 22kV network includes 22 automatic switchable sections.

The Single Line Diagram (**SLD**) and an aerial view layout of the 22kV feeders originating from the KMS ZSS are included in Figure 3.1 and Figure 3.2 respectively.

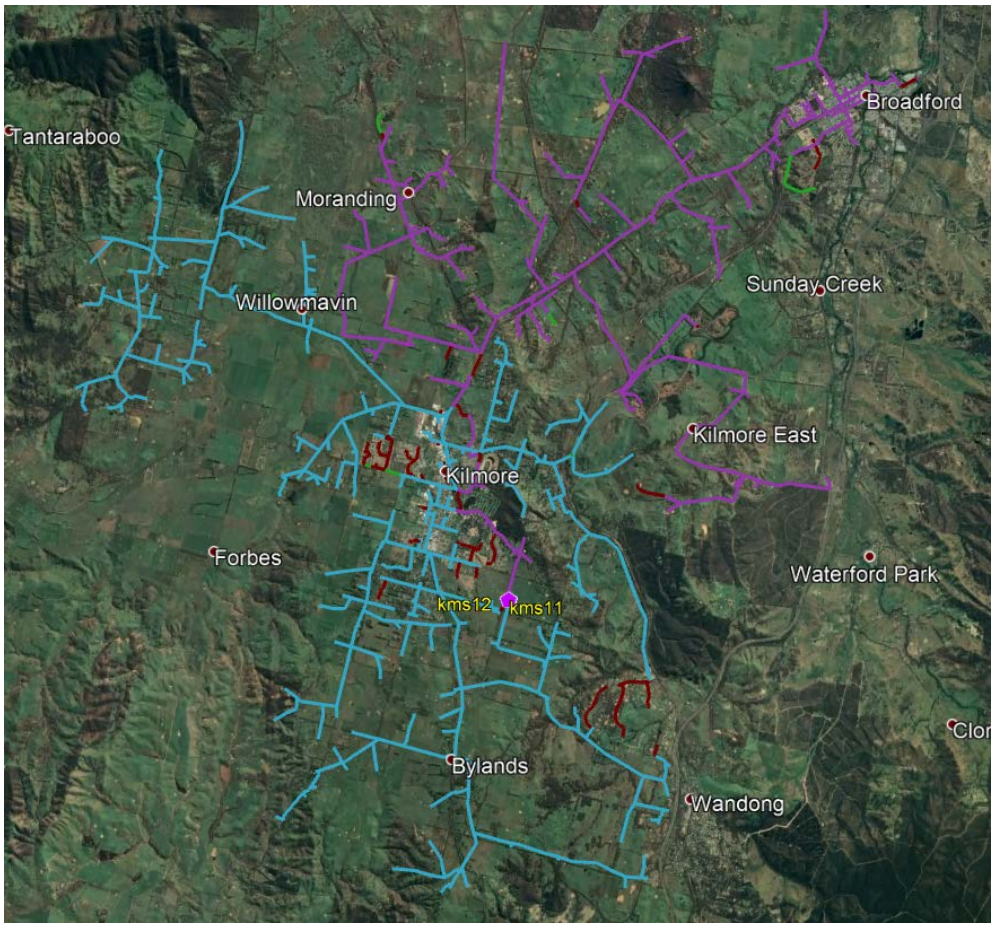
KMS ZSS was included in Tranche 1 of the AusNet Services REFCL Program and has one REFCL installed with an ASC capacity of 80A.

Figure 3.1 KMS ZSS Single Line Diagram



Source: AusNet Services

Figure 3.2 KMS ZSS Aerial Layout (underground conductor is shown in dark maroon)



3.1 Network forecast

This section discusses the demand and capacitive current forecasts to identify if either attribute is exceeding the capacity of the substation and when it is expected to occur. This will identify the need and drive the type and timing of any intervention or investment that may be required.

3.1.1 Demand forecast

Table 3.1 below shows the KMS maximum demand forecast (MVA) between 2020 and 2026. By 2026, the summer demand is expected to increase by approximately 3.5 MVA. The demand does not exceed the short term cyclic capacity of either transformer.

Table 3.1 Maximum Demand (MVA) Forecast for KMS – 2020 to 2026

	2020	2021	2022	2023	2024	2025	2026
KMS Winter (50POE)	8.7	8.7	8.8	8.8	8.9	8.9	8.9
KMS Summer (50POE)	13.3	13.7	14.2	14.8	15.4	16.0	16.7
KMS Winter (10POE)	9.2	9.3	9.3	9.4	9.4	9.4	9.5
KMS Summer (10POE)	13.7	14.1	14.5	15.1	15.8	16.5	17.2
KMS Consolidated Forecast[3]	13.4	13.8	14.3	14.9	15.5	16.2	16.9

[3] The forecast is the weighted sum of the summer forecasts, calculated as 30% of the 10POE summer forecast plus 70% of the 50POE summer forecast

3.1.2 Capacitance forecast

The network capacitance forecast was developed based on the characteristics of each zone substation supply area, the standard topology of cables installed for underground residential developments (**URDs**) and other known network augmentation.

Since the growth in capacitance is strongly related to the growth of URD, the forecast was made in 5 year increments as the timing of growth on an annual basis is not certain. The growth is expected to be a step function of new URDs that are being established, rather than a smooth and gradual increase each year. However, the capacitive current growth has been extrapolated to create an indicative annual trend, as shown below, to provide indicative timing of when intervention is likely to be required.

As stated in section 2.4, the ASC limit is dependent on the damping characteristics of the network that the individual zone substation supplies, including the effect of earth resistivity in the zone substation supply area and pollution (salt) on insulators.

As a Tranche 1 site, the network damping at KMS is known. KMS currently has one ASC installed, for both transformers, with a capacitive current limit of 80A. Table 3.2 shows that the capacitive current limit is forecast to be exceeded from 2025.

Table 3.2 KMS capacitive current forecast

	2020	2021	2022	2023	2024	2025	2026
KMS capacitive current	64	68	71	75	78	82	86
ASC Limit	80	80	80	80	80	80	80
Excess capacitive current	0	0	0	0	0	2	6

Assuming a constant growth in damping as the network capacitance grows, no issues with sensitivity are expected within the forecast period (2026).

3.2 Identified need

As shown in section 3.1, due to expected growth in AusNet Services' network, additional works will be required to maintain compliance with the Required Capacity in the Regulations during the 2022-2026 regulatory control period.

The forecast of continued residential growth and network augmentation in the KMS supply area, particularly URDs which increase the capacitive current on the network, means that the capacitive current capacity of the REFCL at KMS may be exceeded in 2025.

As the demand growth is not found to be a constraint for the zone substation, AusNet Services needs to identify the most economic option to address the capacitive current constraint that will affect compliance with the Regulations in the 2022-2026 regulatory control period.

4 Options analysis

The options identified below are based on the best knowledge currently available on the network, including ASC limit and forecast capacitive current growth.

AusNet Services has identified two options that could maintain compliance with the Regulations. These are summarised in Table 4.1 and the credible option is discussed in further detail in Section 4.1.

Table 4.1 Options Reviewed

Option	Discussion	Credible
Option 1 - Business as Usual	The Business as Usual option maintains the status quo at KMS which will entail no additional investment at KMS to manage the impact of the capacitive current. Once the capacitance exceeds 80A, the KMS REFCL will no longer able to reliably tune and detect faults on the KMS network. The KMS network would need to be resistively earthed. The community served by the KMS zone substation would be exposed to increased risk of fire starts from 22kV phase-to-earth faults, and AusNet Services will be subject to penalties under the Act. On this basis, Option 1 is not a credible option.	N
Option 2 – Upgrade Arc Suppression Coil	This option proposes to upgrade the existing ASC to allow an increase of the current limit from 80A to a limit of 120A. This is a credible option and is discussed further in section 4.1	Y
Option 3 - Install second REFCL	KMS has space for a second REFCL and the technology allows for two REFCLs at a single zone substation. However, the cost of a new REFCL is $4.3 million which is significantly higher than the cost of upgrading the existing ASC and the forecast capacitance does not warrant the additional capacity of a second REFCL at this stage.	N

4.1 Option 2 – Upgrade Arc Suppression Coil

As illustrated in section 3.1, the Arc Suppression Coil is forecast to exceed allowable limits by 2025 due to increasing capacitive current. The existing ASC was installed as part of the initial REFCL trail and has a lower capacity than the current standard ASC. Since a REFCL is already operational at KMS, the network damping is known and an upgrade to the standard sized ASC will provide a capacity increase to 120A. This will be meet the performance criteria set out in the Regulations.

The new ASC will require an upgrade of the inverter and other control equipment. Therefore, a new control room building will be required. Associated secondary modifications and civil works will also be required. Capex for this option is $3.7 million. This upgrade will ensure AusNet Services can achieve the requirements of the Regulations throughout the 2022-2026 regulatory control period. No negative social impact is expected as all works are within the existing zone substation boundary.

4.2 Option Summary

The preferred option is summarised below.

Option	Technical feasibility	Estimated Cost (real $ 2020)	Regulatory feasibility	Social impact	Preferred
Option 2 – Upgrade Arc Suppression Coil	Yes	$3.7 M	Yes	No	Yes

5 Recommendation

It is recommended that Option 2 is approved. Following approval, AusNet Services will procure and install the larger (current standard) ASC at KMS to account for the increasing capacitive current at the site. The high-level scope is summarised below:

- Replace non-standard ASC with the new standard ASC, install a larger inverter and complete required civil works; and
- Install one new REFCL control room and perform associated secondary modifications.

The estimated capital cost for the ASC and associated works is $3.7 million.

6 Appendix A

6.1 The Regulation stipulates the requirements

AusNet Services' network's geographical location means that it is exposed to extreme bushfire risk. These conditions warrant significant investment to mitigate the risk of bushfires that may occur following earth faults on the distribution network.

The Victorian Bushfire Royal Commission, established in 2009, made several recommendations with respect to fires initiated from electricity distribution networks. Subsequently, the Victorian Government established the Powerline Bushfire Safety Taskforce (**PBST**) to investigate new cost efficient and effective technologies and operational practices to reduce catastrophic bushfire risk.

The PBST identified Rapid Earth Fault Current Limiters (**REFCLs**) installed in zone substations as an efficient and effective technology.

The *Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016* (**Amended Bushfire Mitigation Regulations**), which came into operation on 1 May 2016, set out new requirements for major electricity companies including the requirement for Polyphase Electric Lines (defined as multiphase distribution between 1 kV and 22 kV) at selected zone substations to have the following abilities:

- to reduce the voltage on the faulted conductor for high impedance faults to 250 volts within 2 seconds
- to reduce the voltage on the faulted conductor for low impedance faults to
    i. 1900 volts within 85 milliseconds; and
    ii. 750 volts within 500 milliseconds; and
    iii. 250 volts within 2 seconds; and
- Demonstrate during diagnostic tests for high impedance faults to limit
    i. Fault current to 0.5 amps or less; and
    ii. The thermal energy on the electric line to that resulting from a maximum I^2t value of 0.10 A^2s;

The Amended Bushfire Mitigation Regulations define the low and high impedance faults as follows:

- High impedance = a resistance value in ohms that is twice the nominal phase-to-ground voltage. This is equal to 25.4 kilohms or a fault current of 0.5 amps on a 22 kV network.
- Low impedance = resistance value in Ohms that is the nominal phase-to-ground network voltage divided by 31.75. This is equal to 400 Ohms or a fault current of 31.75 Amps on a 22 kV network.

6.2 The Act stipulates non-compliance penalties

The penalties for not complying with the requirements set out in the Regulations are set out in the *Electricity Safety Act 1998* (the **Act**). The Act states that there will be a fine of up to $2 million for each point less than the prescribed number of points that must be achieved at each of the three specified dates and an ongoing fine of $5,500 per day that compliance is not achieved.

The detail of the fines is set out in Clause 120M (3) which states a major electricity company is liable to pay:

a *if subsection (1)(a) or (b) [(1)(a) - A major electricity company must ensure that for the initial period, a sufficient number of zone substations in its supply network are*

complying substations so that the total number of allocated substation points prescribed in respect of all of the complying substations is not less than 30 (the period 1 minimum points); and (1)(b) for the intermediate period, a sufficient number of zone substations I its supply network are complying substations so that the total number of allocated substation points prescribed in respect of all of the complying substation is not less than 55 (the period 2 minimum points)] is contravened, a pecuniary penalty not exceeding $2 000 000 for every point forming the difference between the total number of allocated substation points prescribed in respect of all of the complying substations and, as the case require:

i *the period 1 minimum points; or*

ii *the period 2 minimum points; and*

b *if subsection (1)(c) [on or after 1 May 2023, of if Energy Safe Victoria specifies a later date under section 120X, that date, all zone substations in its supply network are complying substations] is contravened, a pecuniary penalty not exceeding $2 000 000 for every allocated substation point prescribed in respect of each zone substation that is not a complying substation; and*

c *if there is a continuing contravention of subsection (1)(a), (b) or (c), a pecuniary penalty that is a daily amount not exceeding $5500 for each day that contravention continues after service on the major electricity company by Energy Safe Victoria of notice of that contravention.*

6.3 Exemptions and time extensions

Electricity businesses can seek an exemption from both the Act and Regulations.

Exemption from the Act can be sought under section 120W of the Act from the requirements under section 120M of the Act. An exemption requires the Director of ESV to consult with the Minister for Energy, Environment & Climate Change and Governor in Council approval. The process can take up to 6 months or longer depending on the complexity of the exemption.

Clause 13 of the Regulations allows for the electricity businesses to apply for exemptions from complying with the requirements of (7)(1)(ha) and (7)(1)(hb).

13 Exemptions

2 *Energy Safe Victoria may, in writing, exempt a specified operator or major electricity company from any of the requirements of these Regulations.*

3 *An exemption under subregulation (1) may specify conditions to which the exemption is subject.*

Time extension requests under S120X of the Act can be made to the Director of Energy Safe Victoria clearly stating the reasons for the request.