ALPINE ENERGY LIMITED

NETWORK HARMONIC STANDARD

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1 GENERAL

1.1 Scope

This standard defines the harmonic current and voltage limits requirements of harmonic producing loads. The focus of the document is on 6 pulse variable speed drives but the limits can be applied to other types of harmonic generating loads as well. A customer who has connection to the Alpine Energy Limited (AEL) network and who wishes to install variable speed drives (VSD), and other types of harmonic generating loads, is required to comply with the guidelines provided in this standard.

1.2 Application

Harmonics are non sinusoidal currents or voltages produced by non linear loads. Non linear loads such as Variable Speed Drive (VSD), switch mode power supply (SMPS), electronic ballasts for fluorescent lamps, welders etc. inject harmonic currents into the power distribution network. These harmonic currents couple with the system impedances creating voltage distortion at various points on the network. As a result, equipment such as computers, digital clocks, transformers, motors, cables, capacitors, electronic controls etc. connected to the same point can suddenly malfunction or even fail completely - beyond economic repair.

As harmonics are produced by the end users, it is important that these harmonics are controlled at the end user terminal. This is considered to be a good practice as by controlling the emission levels of individual sources of harmonics, the flow of harmonics into the network and its effects at the PCC is restricted. This will, in turn, limit widespread effects of harmonics in the entire network.

AEL endeavours to ensure that the quality of supply (i.e. voltage quality) in its network is maintained at acceptable levels at all times. In recent times, AEL has observed network voltage problems that are associated with harmonics. Therefore, AEL believes that it is time to act and take all the necessary measures to minimize the widespread effects of harmonic pollution. The end result will enable AEL to provide better quality voltage to all customers.

This network standard is prepared based on industry accepted recommendations, codes of practice and standards.

1.3 Referenced Documents

1.3.1 Legislation

- Electricity Act 1992
- Electricity Governance Rules 2003 and pursuant Codes of Practice
- Electricity Regulations 1997 and pursuant Codes of Practice (NZECP)
- Health and Safety in Employment (HSE) Act 1992
- NZECP 35:1993 - Power Systems Earthing
- NZECP 36:1993 - Harmonic Levels

1.3.2 Industry Standards

IEEE 519 - 1992	IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
SM-EI	Safety Manual - Electricity Industry (SM-EI) ï Parts 1 ï 3 inclusive, latest versions

AS / NZS 3000:2007	Electrical Installations (known as the Australian / New Zealand Wiring Rules)
AS/NZ 4360:2004	Risk Management

Electricity Distribution Code, Essential Services Commission, Victoria, Australia

The Essential Services Commission is the independent regulator of the energy industry in Victoria, Australia.

1.3.3 Alpine Energy Documents

TBA

1.4 Definitions

Unless stated otherwise, all words and phrases used in this document shall have the meaning defined in: -

- Electricity Act 1992
- Electricity Safety Regulations 2010
- AS/NZS 300:2007 - Electrical Installations (known as the Australian / New Zealand as Wiring Rules)
- Alpine's standard AEL.AM 05 - Definitions
- Common English language definitions

Certificate Of Compliance (Electrical)	Means a form that provides a means of compliance with Regulation 39 of the Electricity Regulations 1997.
Consumer / Customer	This term has the same definition and meaning as defined in the Electricity Act 1992, namely "*any person who is supplied, or who applies to be supplied, with electricity*."
Consumer's Installation	For the purposes of this standard Consumer's Installation means any items which are used or designed or intended for use in, or in connection with the conversion, transformation, transportation or use of electricity and which are owned by a Consumer and that form part of a system for transporting electricity between the Distributors Network and the ICP, and excludes the Distributor's equipment.
Consumer's Premises	For the purposes of this standard Consumer's Premises means the land and buildings owned or occupied by a Consumer, and any land over which the Consumer has an easement or right to pass electricity, including: - (a) The land within the boundary where the electricity is consumed; (b) The whole of the property, if the property is occupied wholly or partially by tenants or licensees of the owner or occupier; and (c) The whole of the property that has been subdivided under the Unit Titles Act 1972.
Distribution Network	Means the distribution system controlled by AEL and includes the 33 kV, 22 kV, 11 kV and LV portions of this system.
HV (High Voltage)	As defined in SM-EI and means any voltage exceeding 1000 Volts a.c. or

	1500 Volts d.c.
Installation	As defined in the Electricity Act. (a) Means all fittings: - ▪ That form part of a system for conveying electricity; and ▪ That form part of such a system at any point from the point of supply to a Consumer to any point from which electricity conveyed through that system may be consumed; and (b) Includes any fittings that are used, or designed or intended for use, by any person, or in connection with the generation of electricity for that personôs use and not for supply to any other person; but (c) Does not include any electrical appliance.
Installation Control Point (ICP)	Means a point of connection on a local network or an embedded network which the distributor nominates as the point at which a retailer will be deemed to supply electricity to a Consumer.
Load	ñLoadòmeans an Installation: - ▪ An electrical impedance connected to the network. ▪ The total electrical demand for electrical energy on AELôs network.
LV (Low Voltage)	As defined in SM-EI and means any voltage exceeding 50 Volts a.c. or 12 Volts ripple free d.c. but not exceeding 1000 Volts a.c. or 1500 Volts d.c.
Metering Equipment	Means any apparatus for the purpose of measuring the quantity of electricity transported through an ICP along with associated communications facilities to enable the transfer of metering information.
Network (The)	Means a collective term commonly used as an abbreviation to mean the whole of the electricity distribution system - i.e., high voltage or low voltage delivery systems. In this document, The Network is taken to mean AELôs network (or AELôs Works as defined in the Electrcity Act 1992)
PCC	Means Point Of Common Coupling of the Consumer. For dedicated harmonic load (supplied by one transformer), it is the nearest supply connection point to the harmonic mitigating equipment. For multiple harmonic loads (supplied by one transformer), it is the secondary of the supply transformer or a convenient point where harmonics compliance tests can be done..
Point of Connection	Means the point at which electricity may flow between the Network and the Consumerôs Installation (Connection).
Point of Supply	As defined in the Electricity Amendment Act 2001. Point of Supply in relation to a property means the point(s) on the boundary of the property at which exclusive fittings enter that property except that: a) If there are both High Voltage lines and a Transformer owned by the electricity distributor on the property, the Point of Supply is the point at which electricity from the Transformer enters exclusive fittings; or b) If there are non-exclusive fittings on the property, the Point of Supply is the point at which those fittings become exclusive fittings; or c) If the exclusive fittings on the property are owned by a Consumer that is a tenant or licensee of the owner or occupier of the property, the Point

	of Supply is the point at which those exclusive fittings enter the area leased or licensed by the owner; or d) If there is a specific agreement that any other point on the property is the Point of Supply, the Point of Supply is the agreed point.
Rural	Means Areas zoned rural in the Local Authority District Plan.
Harmonics	A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency. For example, 5th harmonic frequency has 5 times the fundamental frequency i.e. 250 Hz.
Distortion	It is the deviation of 50 Hz sine wave due to harmonic components.
Maximum Load Current (I_L)	This is the maximum current drawn by the load as defined in equation 2.
Non linear load	A load that draws a non-sinusoidal current wave when supplied by a sinusoidal voltage source.
Short circuit current (I_{sc})	It is the maximum short circuit current available at the transformer secondary determined by the transformer rated kVA and the per unit impedance of the transformer at its rated kVA.
Short circuit ratio (I_{sc}/I_L)	The ratio of available short circuit current at the point of common coupling (PCC) and the maximum load current.
Total Demand Distortion (TDD)	It is the total root mean square harmonic current distortion, in percent of the maximum load current.
Total Harmonic Distortion-Current (THDi)	It is the square root of the sum of the squares of the root mean square (rms) values of harmonic currents, divided by the rms value of the fundamental current.
Total Harmonic Distortion-Voltage (THDv):	It is the square root of the sum of the squares of the root mean square (rms) values of harmonic voltages, divided by the rms value of the fundamental voltage.
Characteristic Harmonic	It is the harmonic produced by the equipment in the course of its normal operation. For example, the characteristic harmonics of six pulse VSD are- 5th, 7th, 11th, 13th etc. The characteristic harmonics are derived using the following equation: $h=kq\pm1$ where: k=any integer q=pulse number of converter
Power Factor	The ratio of real power to apparent power (W/VA).
Pulse number (q)	This is the number of pulses occurring within the converter dc output during each cycle of the ac input voltage

1.5 Health and Safety Hazard Identification and Management

Contractors and Service Providers to AEL shall obey the requirements of AEL standard Health and safety Requirements.

A systematic method of identifying all hazards shall be applied to all projects and worksites, generally as required by *Safety Manual – Electricity Industry* (SM-EI) Parts 1, 2 & 3. Appropriate hazard mitigation methods shall then be implemented before work commences.

This process is particularly important when selecting materials and equipment for use on AEL electricity network.

Particular attention shall be given to the ability to apply effective worksite earthing equipment and any equipotential bonding requirements, to comply with all SM-EI earthing requirements.

Personnel shall use personal protective equipment (PPE) as per the requirements of: -

- AEL standard *Selection Use and Maintenance of Safety Equipment*. This standard outlines where and when staff, contractors and Service Providers alike should be wearing personal protective equipment (PPE).
- *Safety Manual – Electricity Industry* (SM-EI) ï Parts 1 ï 3 inclusive.

When working with materials such as insulating oils, gases and other hazardous substances the requirements of Section 7 of the SM-EI shall be adhered to.

1.6 Environmental Considerations

TBA.

1.7 Risk Identification and Management

A systematic method of identifying all risks shall be applied to all design, construction and maintenance projects undertaken on the AEL network, generally as required by *Risk Management Standard /NZ/ISO 13000:2009.* Appropriate risk mitigation or reduction methods shall then be implemented before work commences on any network asset.

1.8 Copyright

1.9 Enquiries Regarding this Document

Contact Person: Network Manager
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Timaru 7940

Phone (03) 687 4300
Fax (03) 684 8261

2 HARMONIC CURRENT LIMITS

Harmonic current distortion limits are defined in Table 1 below. By limiting the harmonic injections from individual harmonic loads, unacceptable voltage distortions at a PCC can be controlled effectively for normal system characteristics. This also means other sensitive equipment connected in the vicinity will operate free of harmonic pollution.

Table 1 sets the maximum allowable current distortions for a customer who wishes to connect any harmonic loads to the AEL network. These limits are applicable for six pulse drives and general distortion situations. For 12 pulse drives (q=12), the limits for the characteristic harmonics orders are increased by a factor of $\sqrt{q/6}$. This increase is possible if the amplitudes of the non characteristic and even harmonics are less than 25% of the limits specified in Table 1. The limits are applicable if the equipment is operating for more than one hour per day. For shorter periods (a maximum of 1 hour per day), during start-ups or unusual conditions, the limits may be exceeded by up to 50%.

Table 1: Maximum Harmonic Current Distortion in % of maximum load current.

I_{sc} / I_L	< 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	TDD
< 20	4	2	1.5	0.6	0.3	**5**
20-50	7	3.5	2.5	1	0.5	**8**
50-100	10	4.5	4	1.5	0.7	**12**
100-1000	12	5.5	5	2	1	**15**
> 1000	15	7	6	2.5	1.4	**20**

The value of short circuit current (Isc) can be calculated using the following formula:

$$I_{sc} = kVA_{TF}/(Z_{pu} x \sqrt{3} x kV_{\phi\text{-}\phi}) \text{----------(1)}$$

Where kVA_{TF} is the rated transformer kVA, Z_{pu} is the per unit impedance of the transformer at rated kVA, kV is the nominal voltage i.e. 0.4kV.

The value of maximum load current (IL) can be calculated using the following formula:-

$$I_L = kW_{max\ demand}/(PF \times MEFF \times \sqrt{3} \times kV_{\phi\text{-}\phi}) \text{----------(2)}$$

Where kV is the nominal phase to phase voltage i.e. 0.4kV, kW is the name plate rating of the motor, PF is the power factor at rated load and MEFF is the motor efficiency.

Note that, in most cases, AELôs short circuit ratio (I_{sc}/I_L) at the PCC will fall in the range of 20-50. This means, in most cases, AELôs TDD limit will be 8%. Equation 1 and 2 can be used to calculate the short circuit ratio and the TDD limit for a given load.

3 HARMONIC VOLTAGE LIMITS

Harmonic voltages are the result of interaction between harmonic currents and the impedances of the network. AEL can, to a certain extent, control the impedances of the network to reduce total harmonic voltage distortions. However, this is not always feasible due to economics or network configurations during outages or peak load. If the sources of harmonic generation are restricted to limits as specified in Table 1 above, it is expected that the harmonic voltages at various nodes on the network will stay within reasonable limits as specified in Table 2. When the harmonic voltage distortion level is more than as specified in Table 2, AEL will take every necessary step to reduce THDv to an acceptable limit. For example, immediate investigation within the AEL Network to identify loads operating with current distortion above the specified limits or, if possible, changing the network configurations where appropriate.

The limits in Table 2 are used by AEL to gauge harmonic voltage distortion lasting longer than one hour. For shorter periods, during start-ups or unusual conditions, these limits may be exceeded by 50%.

Table 2: Maximum Voltage Distortion Limits in % of nominal fundamental frequency voltage.

Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THDv (%)
Vrms ≤ 66 kV	3.0	5.0

4 ADDITIONAL REQUIREMENTS

It is expected that the contractors and the manufacturers will make every endeavour to maintain a high standard of installation and performance of their respective equipment. All VSDs above 20 kW (combined rating of all VSDs at an installation) shall meet this standard.

Where an existing VSDôs without harmonic filters are replaced, the new VSD shall comply with this standard if it has a rating of 20 kW or more, OR if the VSD to be replaced is less than 20 kW but contributes to a combined rating of the installation of more than 20 kW.

The following requirements are additional to the limits described in Table 1.

- Equipment shall not resonate with the distribution network.
- Equipment shall not operate with unreasonably low leading PF at reduced load. At reduced load, high leading VAr can result in supply resonances which can amplify the harmonic currents and voltages at various nodes. Therefore it is expected that the amount of leading VAr at reduced load or no load shall not be excessive.
- Equipment shall not interfere with AELôs ripple signal (317 Hz) for tariff and load control.
- Equipment shall meet the total current harmonic distortion limit as per Table 1 at full load with voltage background distortion of no more than 5% and voltage unbalance of no more than 1%.
- Increase in total current harmonic distortion shall be acceptable to AEL if the background voltage distortion and unbalance is greater than 5% and 1% respectively.
- In each case, all field tests shall be completed prior to the start of the irrigation season. This will ensure optimum performance of equipment at the minimum background voltage distortion and unbalance.
- Installation of harmonic mitigating device and the variable speed drives must be planned in advance so that AEL can properly evaluate harmonic compliance.
- On request from AEL, harmonic performance of the equipment shall be demonstrated to show that it meets the appropriate compliance limit.

Failure to meet any part of this standard may result in either disconnection of supply or delayed connection.

5 DOCUMENT REVIEW HISTORY:

Version Number	Reviewed By.	Review Date	Reason
1	WT Rawlins	March 2011	Introduction of standard to manage increasing harmonic levels on networks as a result of variable speed drives and other harmonic generating loads.
2	WT Rawlins	May 2011	Change name of standard by removing ñRuralò to broaden application of the standard. Correcting spelling mistakes.

6 ALPINE STANDARD - DOCUMENT CHANGE REQUEST

Memo To: **Network Manager.**
Alpine Energy Limited
42 Meadows Road
Washdyke, Timaru.

Change Details:
(Attach separate sheets as necessary).

Paragraphs Affected:

Priority: **Urgent** (Within 1 week) ☐ **Routine** (Within 12 months) ☐ **Low** (Next Review) ☐

Submitted By (Print Name) **Date**

Document Change Request - Acknowledgement

Dear é é é é é é é é é é é

Thank you for your suggestion regarding changes to the above mentioned document.

Your request has been noted and added to our works program. Should we require any additional information regarding your notification then we will be in contact with you.

Thank you for your contribution to improving the quality of AELôs documentation.

Regards,

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Network Manager **Date**

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Appendix A. Typical Converter Loads and their harmonic characteristics

Converter type	Typical current distortion level THDi *	Typical Harmonic Characteristics
Single phase	80%	Odd harmonics from 3rd harmonic upwards, no even harmonics
3 Phase 6 Pulse	28% **	Odd harmonics from 5th harmonic upwards, no even or triplen harmonics
3 Phase 12 Pulse	15%	Odd harmonics from 11th harmonic upwards, no even or triplen harmonics

Notes: * THDi figure is an indication of current distortion level. It is not AELs limits or may not be true for a specific equipment. (to be checked with manufacturer)

** This level of distortion is achievable with a large inductor for current smoothing. With no inductance, typical THDi for a 6-pulse converter can be as high as 80%

Residual harmonics are ignored.

Triplen harmonics (odd multiples of three) are additive in the neutral conductor and can quickly cause overheating.

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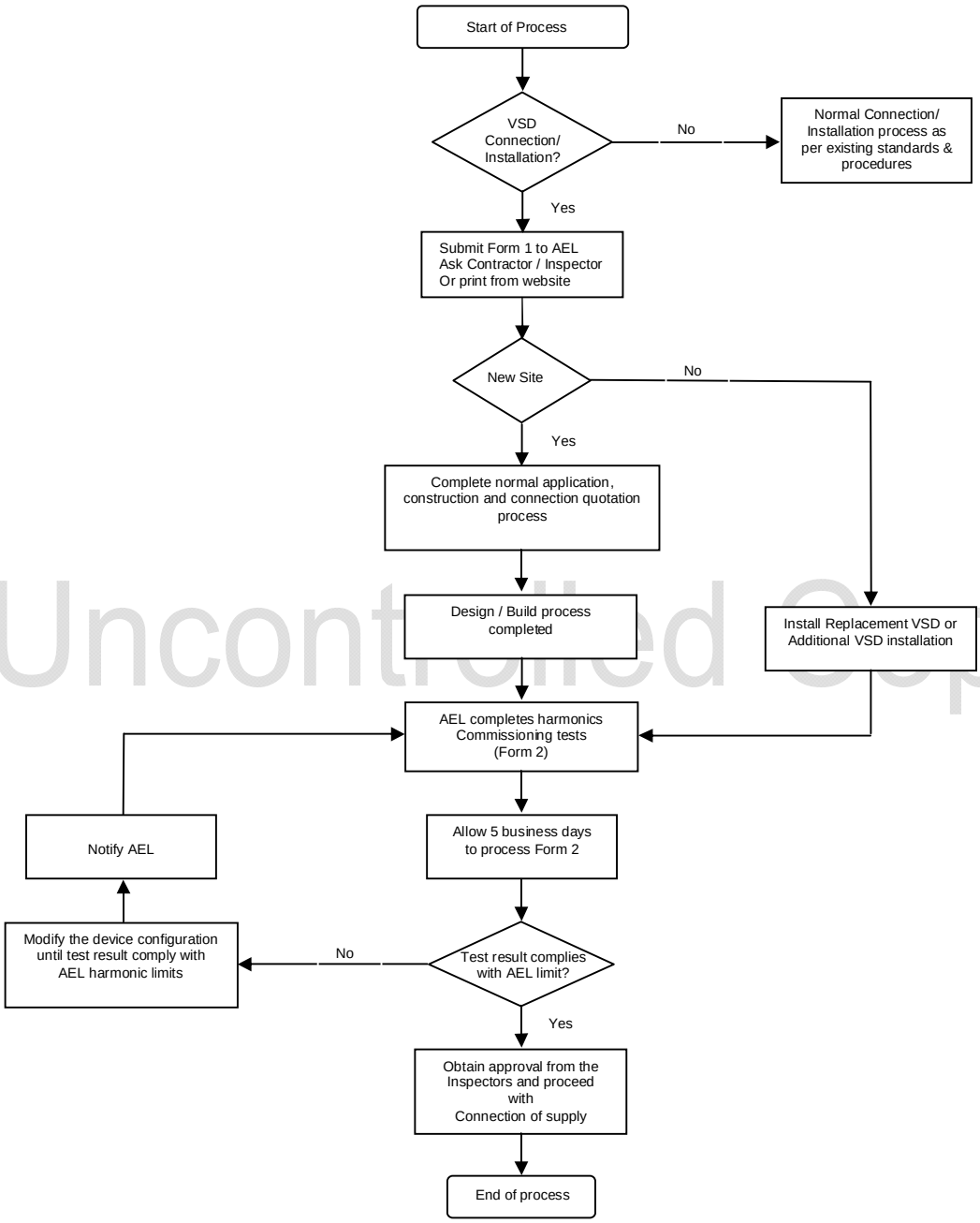
Appendix B. External process for the Implementation of the Rural Network Harmonic Standard



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Appendix C. Form1: Manufacturer's Harmonics data

Harmonic emission certificate from the equipment manufacturer is to be submitted to AEL in the following format (Leave blanks if the information is not yet available):

Equipment Data
Manufacturer:é é é é é é é é é é é é é é .
No of VSDôs:é é é é é é é é é é é é é é ..
VSD Rating:é é é é é é é é é é é é é é é
Motor Rating:é é é é é é é é é é é é é é ..
Pulse Number:é é é é é é é é é é é é é é .

Site Data
Site Address:é é é é é é é é é é é é é é é
Customer Name:é é é é é é é é é é é é é ..
Customer Address:é é é é é é é é é é é é ...
é é é é é é é é é é é é é é é é é é é ..
é é é é é é é é é é é é é é é é é é é ..

Harmonic Spectrum	
Background Voltage Distortion (Assumed)	
Voltage Unbalance (Assumed)	

Harmonic No	Frequency (Hz)	Current Magnitude (A)
1	50	
3	150	
5	250	
7	350	
9	450	
11	550	
13	650	
15	750	
17	850	
19	950	
21	1050	
23	1150	
25	1250	
27	1350	
29	1450	
31	1550	

Notes/Comments:

Date:

Contractors Signature

Appendix D. Form 2: Commissioning Test Data

Commissioning test data will be collected by the AEL inspector in the following format (Leave blanks if the information is not yet available):

Equipment Data
Manufacturer:é é é é é é é é é é é é é é .
No of VSDôs:é é é é é é é é é é é é é é ..
VSD Rating:é é é é é é é é é é é é é é é
Motor Rating:é é é é é é é é é é é é é é ..
Pulse Number:é é é é é é é é é é é é é é .

Site Data
Site Address:é é é é é é é é é é é é é é é
Customer Name:é é é é é é é é é é é é é ..
Customer Address:é é é é é é é é é é é é ...
é é é é é é é é é é é é é é é é é é é ..
é é é é é é é é é é é é é é é é é é é ..

Installation Data	
Voltage Levelsé é é é é é é é é é é .	Substation/Feederé é é é é é é é é é é é .
Existing / Newé é é é é é é é é é é .	Transformeré é é é é é é é é é é é é .. Ser No. /kVA

Pre-Commissioning Test		
I_{sc}		
I_L		
I_{sc}/I_L		
Voltage Unbalance		
THD_V	R	
	Y	
	B	

Post Commissioning Test							
Harmonic Load	THDi			THD_V			TPF/DPF
	R	Y	B	R	Y	B	
100%							
75%							
50%							
25%							
0%							

Approved

Yes

No

Notes/Comments:

Date:

Inspector Nameé é é é é é é

Inspector Signatureé é é é é ..