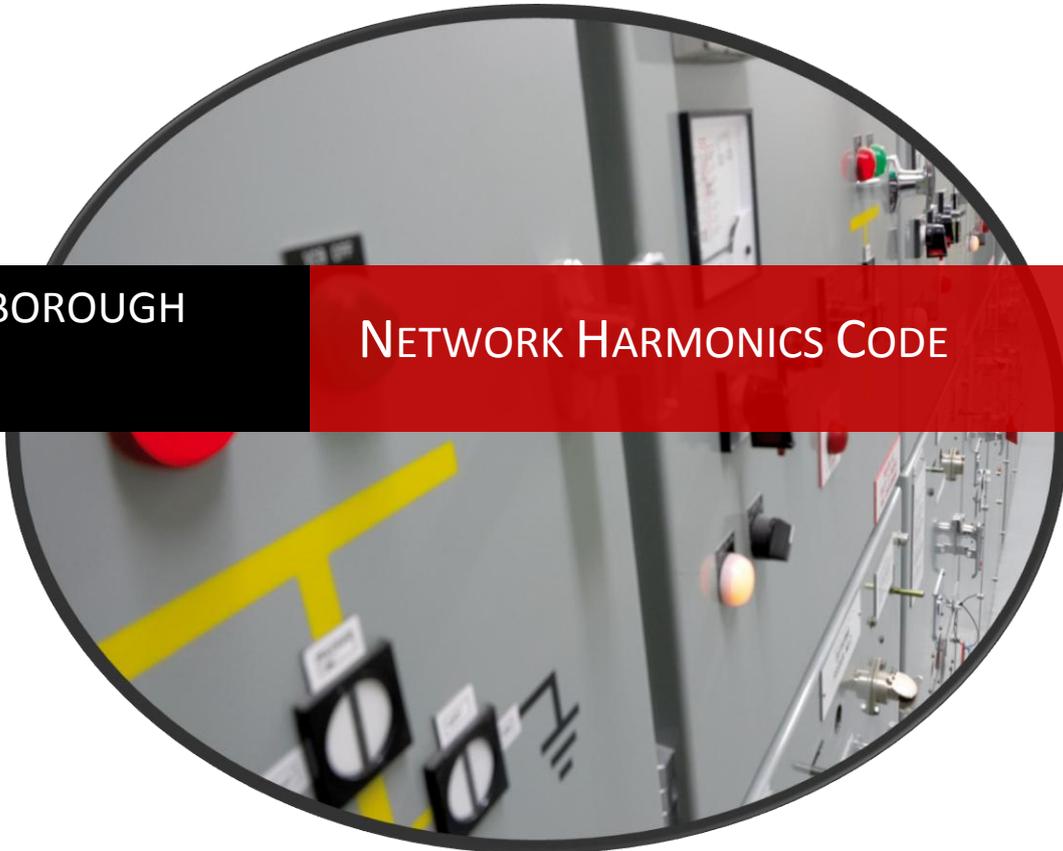MARLBOROUGH

LINES

NETWORK HARMONICS CODE

Marlborough Lines

Introduction to Harmonics

The existing electricity network has been designed and optimized to use 50Hz alternating sinusoidal voltage and current. Traditional appliances and loads such as incandescent light bulbs, electric stoves, toasters, jugs, heating, induction motors have sinusoidal current and voltages.

Harmonics are produced by equipment which switches the supply on and off quickly (generally faster than 50Hz) using power electronics.   Examples of equipment which do this are computers, televisions, variable speed drives and heat pumps.

The effect of switching the supply quickly is to generate non-sinusoidal waveforms which in turn are composed of a number of harmonic frequencies (i.e. 100,150,200,250,300….Hz). In general, the larger the power of the device, the more harmonics it is likely to produce. For this reason high powered electronic equipment such as variable speed drives or welding equipment are more likely to generate harmonics than lower powered equipment such as computers.

The presence of harmonics can result in a range of effects, from flicking lights to equipment malfunctions or failures.

As harmonics are produced by the equipment using power, i.e. within customers electrical installations, it is important that any harmonics are controlled within the installation.

This reduces the cost of controlling the harmonics, the likelihood of interference with other nearby electrical installations and the spread of the harmonics into high voltage networks.

Marlborough Lines Network works to ensure that the quality of voltage in the network is always maintained at acceptable levels. Increasingly we are encountering voltage problems that are associated with harmonics. This is due to the increasing number of electronic devices such as variable speed drives and heat pumps.

Marlborough Lines considers that it is necessary to take measures to minimize the impact of harmonic pollution on the electricity network and the electricity customers in Marlborough.

This purpose of this document is ensure that as far as practical all equipment connected to the Marlborough Lines Network is of an appropriate standard and does not cause problems for other connected equipment.

Table of Contents

1. Purpose

This code defines the harmonic current and voltage limits requirements of harmonic producing loads. The focus of the document is on variable speed drives but the limits can be applied to other types of loads as well. A customer who wishes to connect new variable speed drives or who wishes to replace/upgrade variable speed drives (VSD) is required to comply with the guidelines provided in this document.

2. Definitions and Abbreviations

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 (IL): This is the maximum current drawn by the load as defined in equation 2.

Non linear load: A load that draws a nonsinusoidal current wave when supplied by a sinusoidal voltage source.

Short circuit current (Isc): 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 (Isc/IL): 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-

$$\eta = \kappa\theta \pm 1$$

Where   k = any integer
             q = pulse number of converter

Power Factor: The ratio of power to apparent power (W/VA).

Point of common coupling (PCC): 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.

Pulse number (q): This is the number of pulses occurring within the converter dc output during each cycle of the ac input voltage.

3. Background

The existing electricity network has been designed and optimized to use 50Hz alternating sinusoidal voltage and current. Traditional appliances and loads such as incandescent light bulbs, electric stoves, toasters, jugs, heating, induction motors have sinusoidal current and voltages.

Harmonics are produced by non-linear equipment which switches the supply on and off quickly (generally faster than 50Hz) using power electronics. Examples of equipment which do this are computers, televisions, variable speed drives and heat pumps. The effect of switching the supply quickly is to generate non-sinusoidal waveforms which in turn are composed of a number of harmonic frequencies (i.e. 100,150,200,250,300….Hz). In general, the larger the power of the device, the more harmonics it is likely to produce. For this reason high powered electronic equipment such as variable speed drives or welding equipment are more likely to generate harmonics than lower powered equipment such as computers.

The presence of harmonics can result in a range of effects, from flicking lights to equipment malfunctions or failures. As harmonics are produced by the equipment using power, i.e. within customers electrical installations, it is important that any harmonics are controlled within the installation.

This reduces the cost of controlling the harmonics, the likelihood of interference with other nearby electrical installations and the spread of the harmonics into high voltage networks.

Marlborough Lines Network works to ensure that the quality of voltage in the network is always maintained at acceptable levels. Increasingly we are encountering voltage problems that are associated with harmonics. This is due to the increasing number of electronic devices such as variable speed drives and heat pumps.

This purpose of this document is ensure that as far as practical all equipment connected to the Marlborough Lines Network is of an appropriate standard and does not cause problems for other connected equipment.

This code is prepared based on the limits described in IEEE 519-1992. The Electricity Distribution Code, Essential Service Commission, Victoria, Australia, also uses these limits. NZECP36:1993 has comparable voltage distortion limits. Appendix A has been included to provide sample values for typical current distortion of single and 3 phase converters.

4. 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 Marlborough Lines Network. These limits are applicable for six pulse drives and general distortion situations. For 12 pulse drives (q = 12), the limits for the characteristics harmonics orders are increased by a factor of $\sqrt{\dfrac{q}{6}}$.

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 duration of one 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 Percent of IL

Isc/IL	<11	11≤	17≤h<23	23≤h<35	35≤	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.5	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Notes:
- All power generation equipment is limited to these values of current distortion, regardless of actual short circuit ratio or ISC/IL.
- Current distortions that result in a dc offset, e.g. half-wave converters, are not allowed.
- MLL assessment of harmonics compliance will be based on TDD limits at full load. It is not the individual harmonic components. If percent TDD is not satisfied for the given short circuit ratio, then the overall harmonics components must be reduced to a reasonable level in order to meet the TDD limits given in table 1.

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

$$I_{sc} = {kVA_{tf}}\Big/{(Z_{pu} \times \sqrt{3} \times kV_{\emptyset-\emptyset})} \text{----------------------(1)}$$

Where: kVA_{tf} is the rated transformer kVA

Zpu 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

$$I_l = {kW_{md}}\Big/{(PF \times MEFF \times \sqrt{3} \times kV_{\emptyset-\emptyset})} \text{------------------------(2)}$$

Where: kW_{md} is the name plate rating of the motor

PF is the power factor at name plate rating output

kV is the nominal voltage i.e. 0.4kV.

$MEFF$ is the motor efficiency.

Note that, in most cases, Marlborough Lines Network's short circuit ratio (Isc/IL) at the PCC will fall in the range of 20-50. This means, in most cases, Marlborough Lines Network's 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.

5. Harmonic Voltage Limits

Harmonic voltages are the result of interaction between harmonic currents and the impedances of the network. Marlborough Lines Network can, to a limited extent, control the impedances of the network to reduce total harmonic voltage distortions. This requires the installation of larger conductors and or transformers and it is generally not economic to do this simply to reduce harmonic voltages. Reducing the system impedance also increases the fault level and may increase damage during faults.

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, Marlborough Lines Network may take further steps to reduce the voltage distortion to acceptable limits.

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

Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THDv (%)
All Voltages	3.0	5.0

Note For time periods shorter than one hour, e.g. during start-ups or unusual conditions, these limits may be exceeded by 50%.

6. Additional Requirements

It is expected that the contractors and the manufacturers will make every effort 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.

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 Marlborough Lines Network's ripple signal 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%.
- In each case, all field tests shall be completed at the minimum background voltage distortion and unbalance. Increase in total current harmonic distortion shall be acceptable to Marlborough Lines Network if the background voltage distortion and unbalance is greater than 5% and 1% respectively. A re-test maybe required if the compliance can't be established.
- Installation of harmonic mitigating device and the variable speed drives must be planned in advance so that Marlborough Lines Network can properly evaluate harmonic compliance.
- On request from Marlborough Lines Network, 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.

Appendix A: Typical Loads and their Harmonic Characteristics

Type of load	Typical Current Distortion Level, THDi *	Typical Harmonic Characteristics
Single phase converter	80%	From 3rd harmonic upwards, no even harmonics
3 phase 6 Pulse converter	**28%	Odd harmonics from 5th harmonic upwards, no even or triplen harmonics
3 phase 12 pulse converter	15%	Odd harmonics from 11th order and upwards, no even or triplen harmonics

Notes:
- *THDi figure is an indication of current distortion level. It is not the Marlborough Lines Network's 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 6 pulse converter can be as high as 80%.
- Residual harmonics are ignored.

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