Rural Network Harmonics Standard

Contents

1. Introduction

Harmonics are non sinusoidal currents or voltages produced by non linear loads. Non linear loads such as Variable Speed Drives (VSD), switch mode power supplies (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 is restricted at the Point of Common Coupling. This will, in turn, limit widespread effects of harmonics in the entire network.

MainPower endeavours to ensure that the quality of voltage in the network is always maintained at an acceptable level at all times. In recent times, MainPower has observed network voltage problems that are associated with harmonics. Therefore, MainPower 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 MainPower to provide better quality voltage to all customers.

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

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

2. Purpose

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 loads as well. Customers with existing variable speed drives or customers who wish to connect new or replace/upgrade variable speed drives to MainPower's distribution network are required to comply with the guidelines provided in this document.

3. Definitions

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 in section 5.

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 (THD_I): 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 (THD_V): 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 a six pulse VSD are- 5th, 7th, 11th, 13th etc. The characteristic harmonics are derived using the following equation-

$h = kq \pm 1$

Where k = any integer and q = pulse number of converter

Power Factor: The ratio of real 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.

4. References

IEEE 519-1992

"IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems". This is the most widely accepted recommendations for harmonic currents and voltages.

Electricity Distribution Code, Essential Services Commission, Victoria, Australia

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

New Zealand Electrical Code of Practice for Harmonic Levels, NZECP36: 1993

This code of practice is prepared by the Ministry of Commerce and is pursuant to the Limitations of Harmonics Levels Notice 198

5. 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 MainPower 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 $\sqrt{\frac{q}{6}}$. 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

I_{sc}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤h	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.
- MainPower 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:

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

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-

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

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

6. Harmonic Voltage Limits

Harmonic voltages are the result of interaction between harmonic currents and the impedances of the network. MainPower 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, MainPower will take every necessary step to reduce THDv to an acceptable limit. For example, immediate investigation within the MainPower 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 MainPower 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≤66kV	3.0	5.0

7. 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.

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

a) Equipment shall not resonate with the distribution network.
b) 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.
c) Equipment shall not interfere with MainPower's ripple signal for tariff and load control.
d) 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%.
e) 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 MainPower 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.
f) Installation of harmonic mitigating device and the variable speed drives must be planned in advance so that MainPower can properly evaluate harmonic compliance.
g) On request from MainPower, harmonic performance of the equipment shall be demonstrated to show that it meets the appropriate compliance limit.

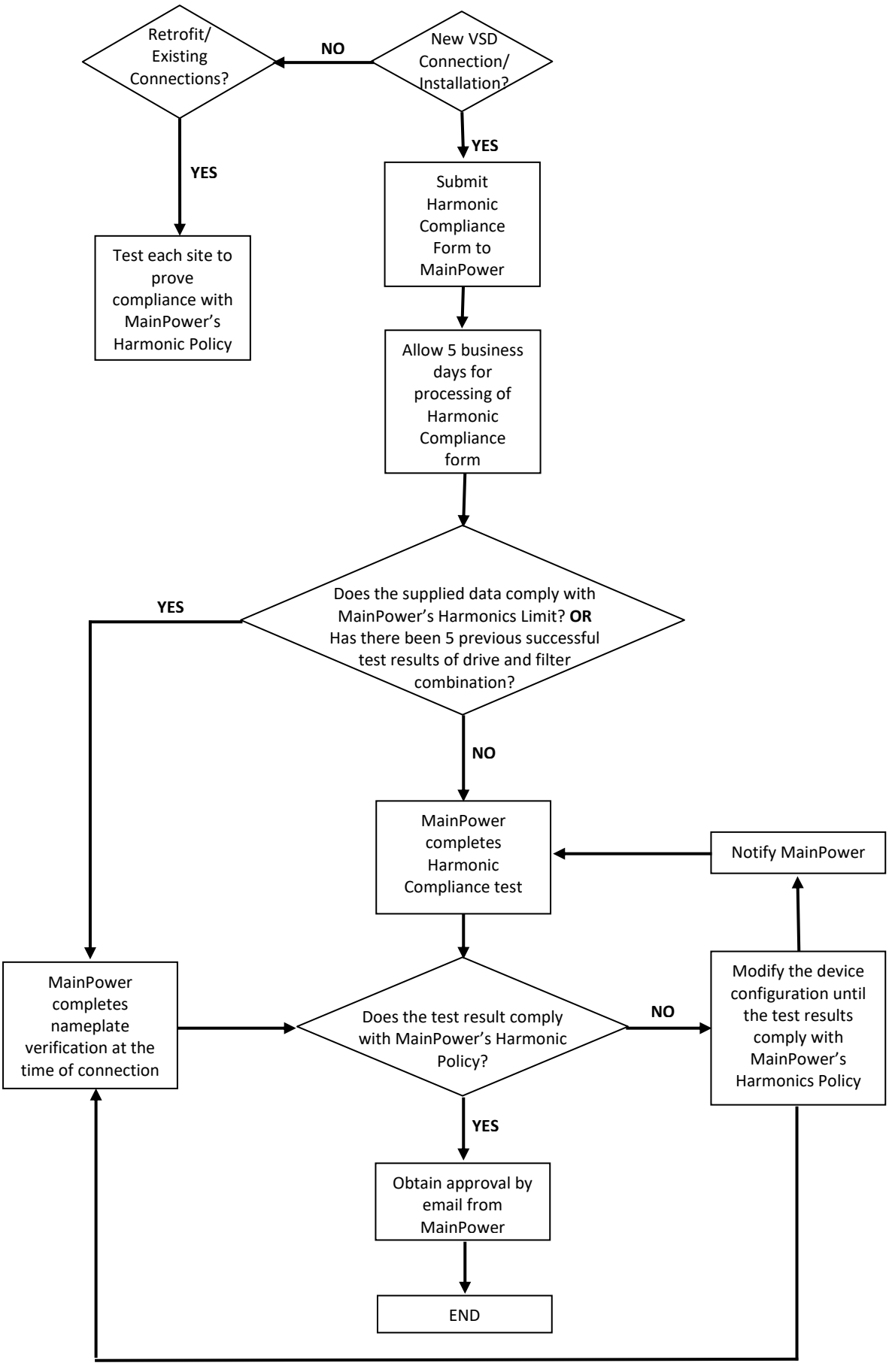
8. Responsibilities

It is the responsibility of the customer or their delegated installer to ensure compliance with this standard for all installations on the MainPower network. MainPower can be engaged for testing purposes only.

9. Document History and Version Control

Version #	Date Approved	Approved By	Brief Description
1.0	06.09.16	Stuart Wilson	Initial Document

Appendix A: Network Harmonics Standard Flow Chart



Appendix B: Harmonics Compliance Form

Please submit this compliance form to MainPower in advance of the date of testing (three weeks) to be eligible for a waiver of Harmonic testing requirements.

Load Data

Site Number:						
ICP Number:						
Voltage Levels:	U_1:		U_2:		U_3:	
Ratio:	I_{sc}:		I_L:		I_{sc}/I_L:	

Required Data:

Customer Name:			
Customer Address:			
Contractor's Name:			
Existing/New:			
Number of VSD's:			
Pulse Number:		**Filter Manufacturer:**	
VSD Manufacturer:		**Filter Model:**	
VSD Model:		**Filter Rating (kW/Amps):**	
VSD Rating (kW/Amps):		**Filter Type:**	Active / Passive
Motor Rating (kW/Amps):		**Pump Type:**	Surface / Sub

Harmonic Data

	Manufacturer/Supplier/Contractor			*Installation Test Results*		
Background Voltage Distortion						
Voltage Unbalance						
THD_i at Full Load (%)						
TPF/DPF at Full Load						
THD_i at 75% Load (%)						
TPF/DPF at 75% Load						

Manufacturer/Supplier/Contractor Declaration:

We certify that the total harmonic current distortion at full load at the PCC will be compliant as per the information given above and MainPower's harmonics policy. We understand that failing to comply as per the above and MainPower's policy may result in instant disconnection or delayed connection.

_____ _____

(Manufacturer/Supplier/Contractor) (Date)

Office Use:

Accepted ☐ Not Accepted ☐	Notes:	Date: Inspector Signature: