CITY OF LETHBRIDGE ELECTRIC	ENGINEERING STANDARDS

POWER QUALITY

SPECIFICATIONS AND GUIDELINES

FOR CUSTOMERS

The City of Lethbridge acknowledges the use of other utility industry and industry committee developed documents as the framework and sources in producing this technical guideline.

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GENERAL OVERVIEW

1.1 WHAT DOES THIS SPECIFICATION MEAN

Due to the increase in harmonic loads, utilities across Canada are implementing power quality limits to protect customer and utility equipment.

The purpose of this document is to explain the harmonic limits and voltage flicker limits the customer must meet, the commissioning process for the specification, and the procedure that takes place to mitigate customer complaints. The limits that are described in this document reflect industry standards.

1.2 ADHERING TO THE GUIDELINES

To maintain a high quality of electrical utility service, all new customers and all existing customers connected to the City of Lethbridge power system are required to adhere to the specifications and guidelines in this document. If a customer exceeds these limits it is probable that the customer will have to be disconnected from the City Of Lethbridge power system. The conditions that determine whether a customer will be connected are listed below. The criterion for stage 1 and stage 2 are outlined in Section 3.

The City of Lethbridge will be able to connect the customer if the customer has:

- completed all steps in stage one.
- completed all steps in stage two.
- does not produce harmonics and does not have to be evaluated under any of the stages of acceptance.

The customer cannot be connected to the power system if the customer has been:

- rejected under any of the stages.

A customer may be disconnected from the power system if:

- the customer exceeds the limits described in the specifications; and
- other customers and/or utility equipment is being adversely affected.

1.3 WHAT IS THE CONNECTION PROCESS?

Found below is a brief description of the stages of the process that harmonic producing customers must follow in order to be connected to the City of Lethbridge power system. A detailed description of this process is found in Section 3.

Step 1: A new customer, consultant, or Energy Service Provider contacts a designer at the City of Lethbridge for connection of a new service or an upgrade.

Step 2: The designer gives the customer, consultant, or Energy Service Provider the power quality specifications and informs the engineer that a customer has been given the document.

Step 3: The engineer contacts the customer and the two parties discuss the customer's operation and the specifications.

Step 4: If required, the engineer administers the specifications.

Step 5: The customer submits a report, which demonstrates that it will adhere to the specifications.

Step 6: The engineer reviews the report and confirms all electrical utility standards are met.

Step 7: The customer is connected to the power system.

POWER QUALITY LIMITS

2.1 HARMONIC CURRENT DISTORTION LIMITS

All City of Lethbridge customers that are connected to the City of Lethbridge Power distribution system are responsible for complying with the harmonic current limits, at the point of common coupling, that have been stipulated by the City of Lethbridge.

The current harmonics created by the customer cannot exceed the limits that are outlined in Tables 2.1 and 2.2, at the point of common connection (PCC). These limits are applied to each phase current individually and are expressed as a percentage of the customer's maximum demand load current.

Table 2.1 Harmonic Current Distortion Limits

69kV and Below						
I_{SC}/I_L	h<11	11≤h<17	17≤h<23	23≤h<35	35≤h	**THD**
<20 See Note 4	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

1 See Section 4 for explanations of the symbols.
2 The symbol "h" is for odd harmonics only.
3 Triplen harmonics are limited to 1/3 of the limits for odd-order harmonics.
4 All power generation equipment applications are limited to these values of current distortion regardless of the actual short circuit ratio I_{SC}/I_L.

Table 2.2 Harmonic Current Distortion Limits

138kV						
I_{SC}/I_L	h<11	11≤h<17	17≤h<23	23≤h<35	35≤h	**THD**
<20 See Note 4	2.0	1.0	0.75	0.3	0.15	2.5
20 – 50	3.5	1.75	1.25	0.5	0.25	4.0
50 – 100	5.0	2.25	2.0	1.25	0.35	6.0
100 – 1000	6.0	2.75	2.5	1.0	0.5	7.5
> 1000	7.5	3.5	3.0	1.25	0.7	10.0

• All of the information found in the notes below Table 2.1 also pertain to Table 2.2

2.2 HARMONIC VOLTAGE DISTORTION LIMITS

The City of Lethbridge has the responsibility to supply voltage at the PCC that does not exceed the distortion limits listed in the table below.

Table 2.3 Harmonic Voltage Distortion Limits		
Bus Voltage at PCC (V_n)	**Voltage IHD (%)**	**Voltage THD (%)**
$V_n \leq 69kV$	3.0	5.0
$V_n = 138kV$	1.5	2.5

The above information, as with all information found in this document, should be verified with the City of Lethbridge.

2.3 SHORT DURATION HARMONIC LIMITS

The harmonic limits listed in the tables in Sections 2.1 and 2.2 refer to steady state conditions. However, due to the time-varying nature of harmonics and certain facility operations, such as start-up, harmonics may exceed the limits given in the previously mentioned tables. The table below shows the acceptable limits for harmonic bursts.

Table 2.4 Short Duration Voltage and Current Harmonic Levels		
Acceptable Harmonic Distortion Levels (THD and IHD)	**Maximum Duration of a Single Harmonic Burst in a 24 Hour Period ($T_{maximum}$)**	**Total Duration of All Harmonic Bursts in a 24 Hour Period (T_{total})**
3.0 X Steady State Limit	1 sec < $T_{maximum}$< 5 sec	15 sec < T_{total} < 60 sec
2.0 X Steady State Limit	5 sec < $T_{maximum}$< 10 min	60 sec < T_{total} < 40 min
1.5 X Steady State Limit	10 min < $T_{maximum}$< 30 min	40 min < T_{total} < 120 min
1.0 X Steady State Limit	30 min < $T_{maximum}$	120 min < T_{total}

• The limits mentioned in the table above are allowed *only* if the other customers are not adversely affected by the harmonic bursts.

2.4 EVALUATING CONCERNS FOR HARMONIC FILTERS AND POWER FACTOR CORRECTION

Power factor correction capacitors and harmonic filters at customer facilities may absorb harmonic currents from the system or magnify harmonic currents created by the customer load equipment. These installations should be coordinated with the City of Lethbridge.

It is not the purpose of these guidelines to penalize customers for harmonic currents that are absorbed from the power system. More detailed evaluation is necessary to assess the impact of a customer that is applying either harmonic filters or power factor correction capacitors.

Please note that the harmonic filters or power factor correction capacitors applied in customer facilities should be designed assuming background voltage distortion levels as specified in Table 2.3

2.5 FLICKER LIMITS FOR MOTOR STARTING AND CYCLICAL LOADS

The voltage flicker limits for customers connected to the City of Lethbridge power system are shown in the figure below. In the case where there is a single customer on a transformer, the voltage fluctuations may not exceed the limits in Figure 2.1 on the utility side of the transformer. If there is more than one customer connected to a transformer, the voltage fluctuations may not exceed the limits found in Figure 2.1 on the customer side of the transformer.

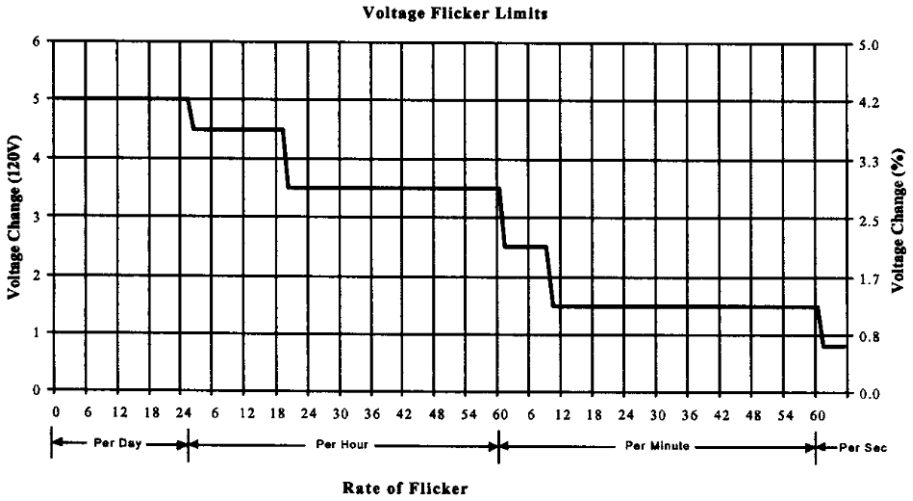


Figure 2.1Voltage Flicker Limits

2.6 GENERAL FLICKER LIMITS

Customers that have loads with random fluctuation characteristics will be evaluated according to the procedures in IEC 1000-4-15. The weighting curves for 60Hz, 120 volt systems will be used. A customer with fluctuating loads should not result in Pst value exceeding 1.0 at the 99% probability level recorded during an interval of at least one week.

COMMISSIONING PROCESS & GUIDELINES

3.0 CRITERIA FOR STAGED ACCEPTANCE OF NEW INSTALLATION

Only harmonic-producing customers are required to be evaluated under staged acceptance. The commissioning process for applying the Power Quality Specifications is a cooperative effort between the customer and the utility. Each party will provide the relevant information necessary to determine the impact on the power system. Refer to Figure 3.2 for the commissioning process and Figure 3.3 for the staged acceptance process.

3.1 STAGE 1 - AUTOMATIC ACCEPTANCE

Customers that have a small amount of harmonic load may be allowed to connect to the system without detailed evaluation. In order to be automatically accepted the customer must satisfy the following two criteria.

Criterion 1: The first requirement is that the customer shall satisfy

$S_{Dw} / S_{SC} < 0.1\%$

S_{Dw} is the amount of weighted disturbing load within the customer's facility and is calculated by using the following:

$$S_{Dw} = \sum_{i} (S_{Di} \times W_i)$$

Where:

S_{Di} = power rating for an individual disturbing load (kVA)
W_i = weighting factor for the disturbing load (pu)
S_{SC} = actual three phase short capacity at the PCC

The weighting factors for various types of loads are given in Figure 3.1. If the type of load is unknown, a weighting factor of 1.0 should be used.

Criterion 2: The second requirement is the customer's capacitors cannot cause a harmonic resonance.

The parallel resonant frequency, h_r, only needs to be checked out for the two harmonic orders that are adjacent to h_r. The following equation may be used to calculate h_r, if all capacitors are connected to the same busbar.

$$h_r = \sqrt{(MVA_{SC})/(MVAR_{cap})}$$

Since MVA_{sc} and $MVAR_{cap}$ may change with loading, this criterion must satisfy all system conditions.

3.2 STAGE 2 - EVALUATION OF HARMONIC EMISSIONS

In order to be accepted at Stage 2, the customer must adhere to the City of Lethbridge Harmonic Specification by performing a detailed harmonic analysis and submitting a report to the City of Lethbridge. If the harmonic distortion exceeds the limits in the specification, then the customer must install harmonic control equipment to remedy the situation.

3.3 INFORMATION REQUIREMENTS

Table 3.1 Responsibilities to Supply Information	
Customer will supply the following information	A single line diagram, a list of linear load and nonlinear loads, a list of transformers, and a list of capacitors and filters.
The City of Lethbridge will supply information pertaining to	PCC location, fault current at PCC, and supply system impedance.

3.4 WEIGHTING FACTORS FOR DIFFERENT TYPES OF HARMONIC PRODUCING LOADS

The following figure shows various weighting factors.

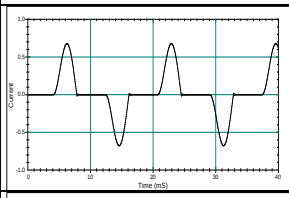
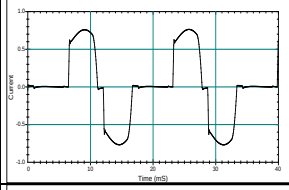
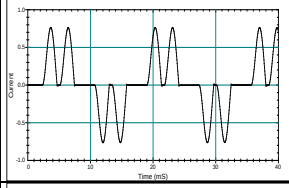
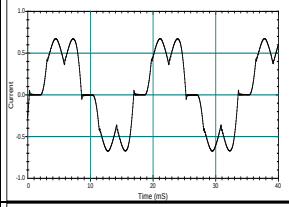
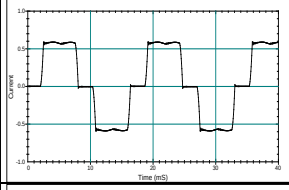
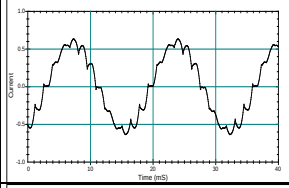
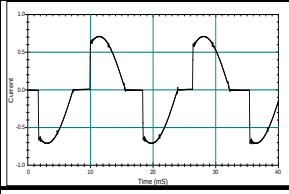
Type of Load	Typical Waveform	Current Distortion	Weighting Factor (W_i)
Single Phase Power Supply		80% (high 3rd)	2.5
Semiconverter		high 2nd,3rd, 4th at partial loads	2.5
6 Pulse Converter, capacitive smoothing, no series inductance		80%	2.0
6 Pulse Converter, capacitive smoothing with series inductance > 3%, or dc drive		40%	1.0
6 Pulse Converter with large inductor for current smoothing		28%	0.8
12 Pulse Converter		15%	0.5
ac Voltage Regulator		varies with firing angle	0.7
Fluorescent Lighting		17%	0.5

Figure 3.1 Weighting Factors

3.5 THE COMMISSIONING PROCESS

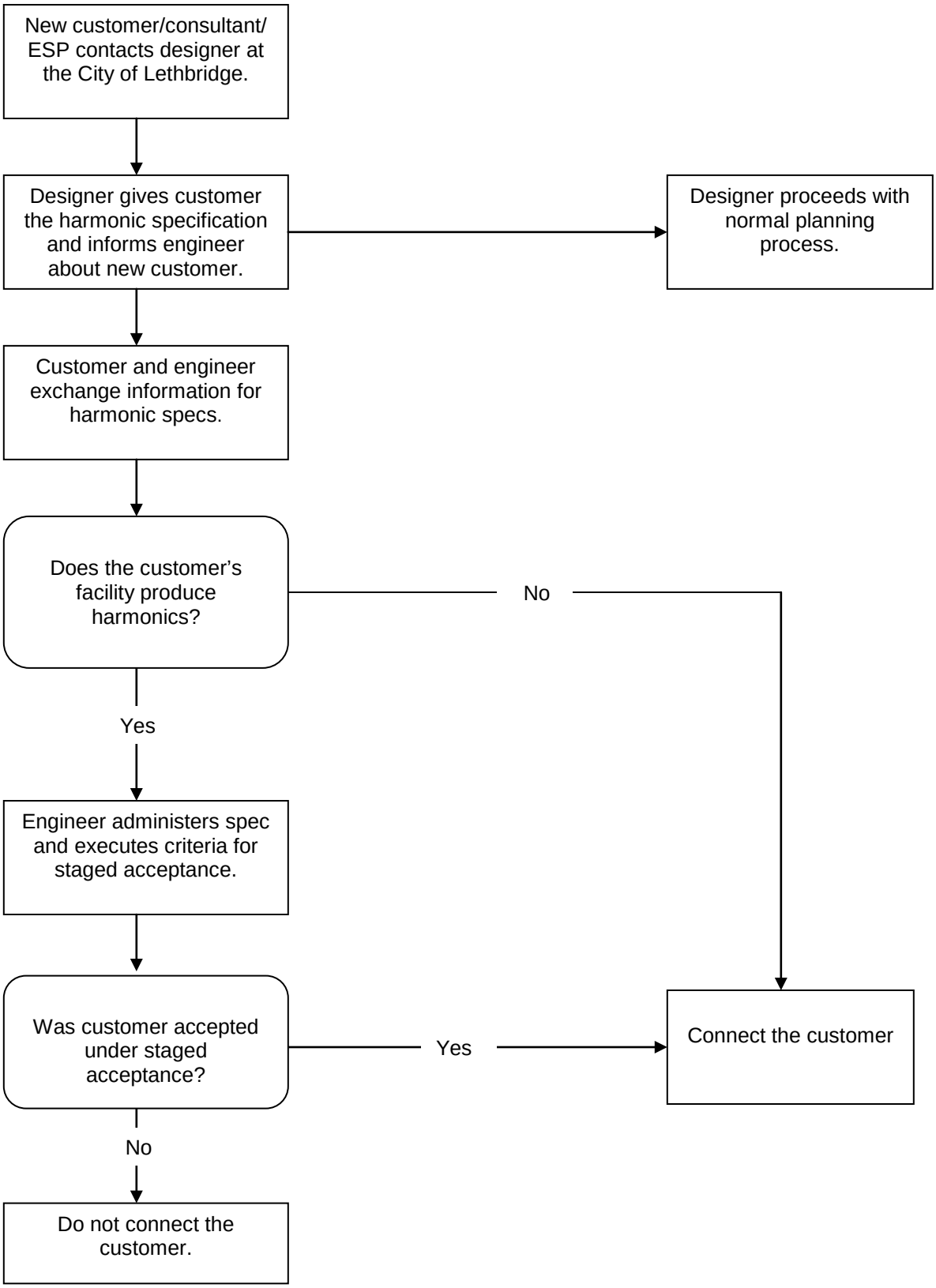


Figure 3.2 Commissioning Process

3.6 STAGED ACCEPTANCE

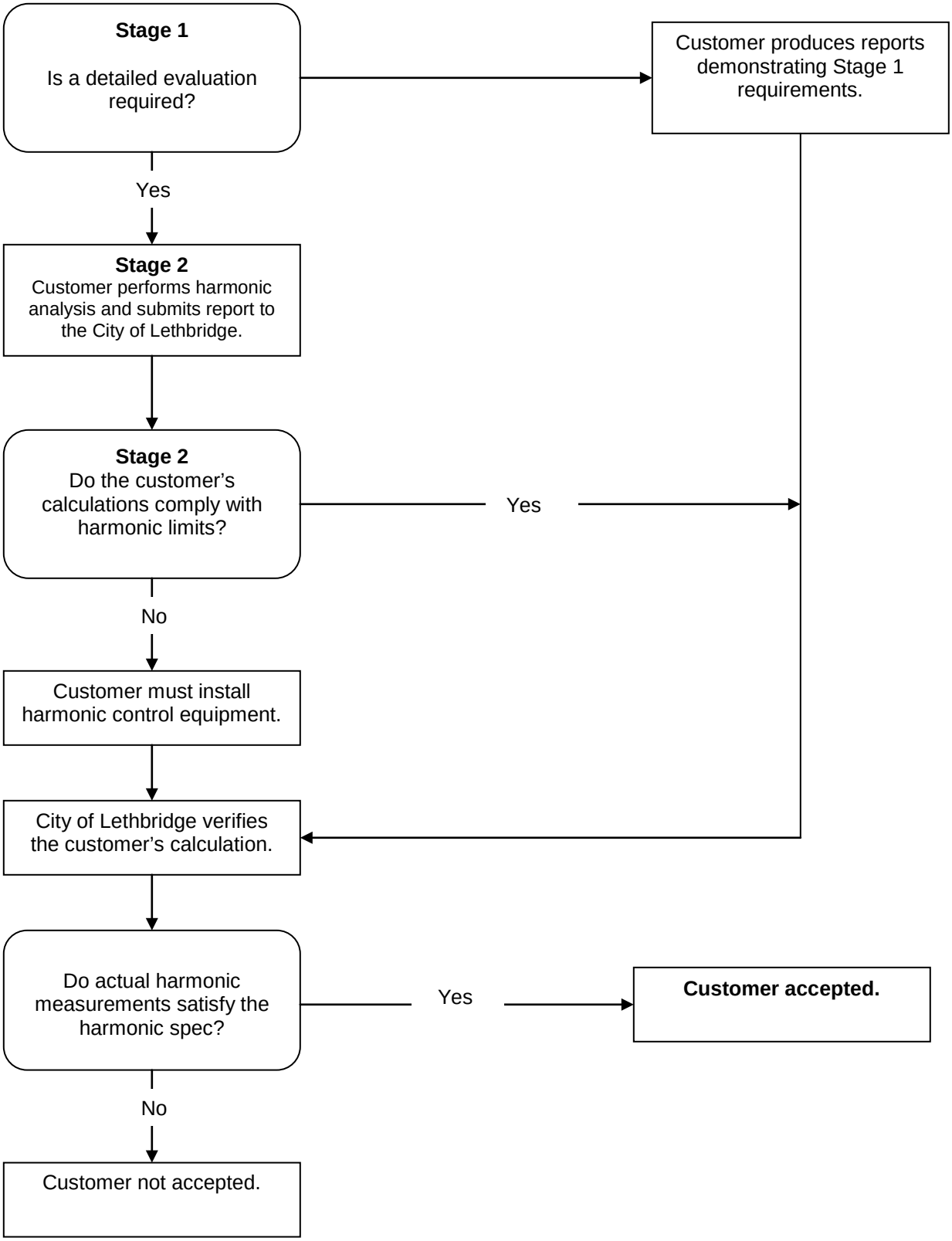


Figure 3.3 Staged Acceptance

SYMBOLS AND DEFINITIONS

4.1 SYMBOLS

h	Harmonic order (2, 3, 4, 5,...)
h_r	Parallel resonant frequency as a multiple of the fundamental frequency.
I_h	Magnitude of individual harmonic components (rms amps).
I_L	Maximum demand load current (fundamental frequency component) at PCC (rms amps). (Calculated as the average of the maximum monthly demand currents for the previous 12 months or estimated based on predicted load profiles.)
I_{sc}	Actual system short circuit current at PCC under normal circumstances.
MVA_{sc}	System short circuit MVA at the capacitor bus.
$MVAR_{cap}$	MVAR rating of capacitor bank.
P_{st}	Short-term flicker assessed in a 10 minute interval.
V_h	Magnitude of individual harmonic components (rms volts).
V_n	Nominal system rms voltage (rms volts).

4.2 DEFINITIONS

Harmonic: A harmonic is a sinusoidal component of a periodic wave form having a frequency that is an integral multiple of the 60 Hz fundamental frequency. For example, the second, third, and fourth order harmonics have frequencies of 120, 180, and 240 Hz respectively.

IHD: Individual harmonic distortion (IHD) is the magnitude of distortion at each individual harmonic. The IHD can be expressed in both voltage and current as a percentage of the fundamental component.

PCC: Point of common coupling (PCC) is the location on the CITY OF LETHBRIDGE power system that is electrically closest to the specified customer and is common to other City of Lethbridge customers.

THD: Total harmonic distortion (THD)

Voltage: $$THD = \frac{\sqrt{\sum_{h=2}^{50} V_h^2}}{V_n} X(100\%)$$

Current: $$THD = \frac{\sqrt{\sum_{h=2}^{50} I_h^2}}{I_L} X(100\%)$$

REFERENCES

1. Allard, G. et al, "*New Hydro-Quebec Guide for Limiting Harmonic Current Emissions at the Distribution Level: Principles and Applications*." CEA Distribution Planning Conference #16, 1996.

2. "*Guide and Requirements for Harmonic Control for Customers Supplied at a Voltage Level from 69kV to 287 kV*." British Columbia Hydro, June 1994.

3. "*Guide for Applying Harmonic Limits on Power Systems*," IEEE Std 519a/D5, May 1996.

4. Nesbitt, R., "*City of Calgary Electric System Standard for Voltage Flicker*," ENMAX Power Corporation, October 1989.

5. "*Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*," IEEE Std 519-1992, April 1996.