Executive Summary

This report presents the results of the Noise Assessment Study required for Solar Facilities under Ontario Regulation 359/09 and 521/10, as part of the Renewable Energy Approval (REA) Process. Northland Power Solar North Burgess L.P. ("Northland") is proposing to develop a 10 megawatt (MW) solar photovoltaic (PV) project titled North Burgess Solar Project (the "Project"). The Project will be located on approximately 40 hectares of land near Narrow Locks Road in the Township of Tay Valley within the Lanark County, Ontario.

This Draft Noise Assessment Study Report has been prepared based on the document entitled "Basic Comprehensive Certificates of Approval (Air) – User Guide" by the Ontario Ministry of the Environment (MOE, 2004). The sound pressure levels at the points of reception (POR[1]) have been estimated using ISO 9613-2, implemented in the CADNA-A computer code. The performance limits used for verification of compliance correspond to the values for rural areas (45-dBA for day time and 40-dBA for night time). The results presented in this report are based on the best available information at this time. It is the intention that, in the detailed engineering phase of the project, certified noise data based on final plans and designs will confirm the conclusions of this noise impact Assessment study.

The results obtained in this study show that the sound pressure levels at POR will not exceed MOE requirements for rural areas. Any noise issues that might arise during commissioning will be manageable and will be resolved by implementing typical remediation measures such as acoustical barriers and enclosures. It is our intention to verify by field measurements taken on completion of installation and during commissioning that the noise levels at the POR resulting from the Project's operation are within the limits set by the MOE (45-dBA for day time and 40-dBA for night time

[1] "Point of reception" in the context of this study is equivalent to "noise receptor" as defined in Ontario Regulation 521/10.

Project Report

August 25, 2011

Northland Power Inc.
North Burgess Solar Project

Draft Noise Assessment Study Report

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1. Introduction

1.1 Project Description

Northland Power Solar North Burgess L.P. ("Northland") is proposing to develop a 10-megawatt (MW) solar photovoltaic (PV) project titled North Burgess Solar Project (the "Project"). The Project Location[2] is situated on approximately 40 hectares of land near Narrow Locks Road in the Township of Tay Valley within the Lanark County, Ontario.

The proposed Project is a renewable energy generation facility which will use solar photovoltaic technology to generate electricity. Electricity generated by solar photovoltaic panels will be converted from Direct Current (DC) to Alternating Current (AC) by inverter clusters which will also step-up the voltage to 27.6-kV. A main transformer, located in the substation, will step up the voltage from the clusters to 44-kV prior to being sent to the existing local distribution line. In order to meet the Ontario Power Authority (OPA)'s Feed-In-Tariff (FIT) Program requirements, a specific percentage of equipment will be manufactured in Ontario.

The construction of the Project will begin once the Renewable Energy Approval (REA) has been obtained and a power purchase agreement is finalized with the OPA. The construction period is estimated to be approximately 6 months. Operationally, the anticipated lifespan of the Project will be 30 years.

1.2 Renewable Energy Approval Legislative Requirements

Ontario Regulation 359/09 and 521/10, made under the Environmental Protection Act identify the Renewable Energy Approval (REA) requirements for green energy projects in Ontario. As per Section 4 of the Ontario Regulation 359/09 and its amendment (Ontario Regulation 521/10), ground mounted solar facilities with a name plate capacity greater than 12 kilowatts (kW) are classified as a Class 3 solar facility, and therefore, require an REA.

Section 13 of the Ontario Regulation 359/09 requires proponents of Class 3 solar facilities to complete a Noise Study Report in accordance with Appendix A of the publication "Basic Comprehensive Certificates of Approval (Air) – User Guide, 2004" by the Ministry of the Environment (MOE, 2004).

The Noise Study Report is to include a general description of the facility, sources and points of reception (POR[1]), Assessment of compliance, as well as all the supporting information relevant to the Project. A draft of the Noise Study Report must be made available to the public, the local municipality and identified Aboriginal communities, at least 60 days prior to the final public consultation meeting in accordance with Ontario Regulation 359/09 and 521/10.

2. Facility Description

The Project will utilize photovoltaic (PV) panels installed on fixed racking structures mounted on the ground. The PV panels generate DC electricity which will be converted to AC electricity by inverters. The Project layout is based on 7 inverter clusters each one containing two inverters and one

[1] "Project Location" means, when used in relation to a renewable energy project, a part of land and all or part of any building or structure in, on or over which a person is engaging in or proposes to engage in the project and any air space in which a person is engaging in or proposed to engage in the project" [Ontario Regulation 359/09, s. 1 (1)].

medium-voltage (27.6-kV) transformer, and one 10-MVA/44-kV substation transformer. The 27.6-kV power, collected from the inverter clusters, will be stepped-up to 44-kV by the substation transformer prior to being sent to the existing local distribution line.

Since the panels will be ground-mounted and the total nameplate capacity is over 12-kW, the Project is considered to be a Class 3 Solar Facility, according to the classification presented in Ontario Regulation 521/10.

Table 2.1 General Project Description

Project Description	Ground-mounted Solar PV, Class 3
System Nameplate Capacity	10-MW AC
Local Distribution Company	Hydro One Networks Inc.

2.1 Project Location

The Project will be located on privately owned lands totalling approximately 40-ha. The Project Location is zoned rural in the zoning by law for Tay Valley Township (02-121 Schedules A1, December 2008). Figure 2.1 shows the site layout plan while the zoning designation plan (Figure A.1) and area location plan (Figure A.2) drawings are included in Appendix A. There are 125 points of reception located within 1.2-km from the Project Site[3] boundary.

For modeling purposes, the vegetation that blocks some of the POR from the sources has not been incorporated.

2.2 Acoustical Environment

The Project will be surrounded by farmland, with some forested areas to the west and southwest. The background noise levels are expected to be typical of rural areas, classified as a Class 3 based on Publication NPC-232 by the MOE. Some traffic noise is expected from RR 14 to the east, Stanley Road to the south and from Scotch Line RR-10 to the northwest, mainly during day hours. There are no airports within 5-km of the Project Location. Perth is the nearest urban center and it is located about 10-km northeast of the proposed location. There are no large industrial facilities within 5-km of the Project Location.

2.3 Life of Project

The expected life of the Project is 30 years. At that time (or earlier if the 20-yr power purchase agreement is not extended), the Project will be decommissioned or refurbished depending on market conditions and/or technological changes.

2.4 Operating Hours

Solar PV facilities produce electricity during the day hours, when the sun's rays are collected by the panels. After sunset the facility will not receive solar radiation to generate any electricity. Under these conditions the inverters will not produce any noise and the transformers will be energized, but not in operation (no fans).

[3] Project Site is the complete area owned by the Project but not necessary occupied by the Project infrastructure.

Figure 2.1 Site Layout Plan

Inert Figure 2.1 in original size and orientation.

Back of figure

2.5 Approach to the Study

The sound pressure levels at the POR were predicted using procedures from ISO 9613-2, which is a widely used and generally accepted standard for the evaluation of noise impact in environmental Assessments. The sound power level for the inverters was provided by the manufacturer while the sound power level for the transformers was estimated. The software package CADNA-A, which implements ISO-9613-2, was used to predict the noise levels at the closest POR. This numerical modeling software is able to simulate sound sources as well as sound mitigation measures taking into account atmospheric and ground attenuation. The height contours for the site were taken from the Ontario Base Maps (OBM).

3. Noise Sources

The main sources of noise from the Project will be seven inverter clusters, each one containing two inverters and one medium-voltage transformer, and a substation containing the main step-up transformer. Northland provided a layout of the solar PV facility (see Figure 2.1). The coordinates of each noise source are presented in Table B.1 of Appendix B.

All noise sources were modeled as non-directional point sources.

Switchgear and a small step-down transformer used for lighting, located at the substation, do not emit any significant noise and consequently have not been considered as sources of noise.

Two operational scenarios were accessed in the study; day time operation (all inverters and transformers in operation) and night time operation (energized transformers).

3.1 Substation Transformer

A 10-MVA step-up transformer that will step-up the 27.6-kV power to 44-kV, required by the local distribution company, will be located in the substation. Since the transformer make and model have not been selected at this point, the sound power levels resulting from the operation of the transformer were evaluated using data from NEMA TR 1-1993 (R2000). This standard provides maximum sound level values for transformers, and manufacturers routinely meet this specification. Hence, the results based on NEMA may slightly overestimate the impact on POR since the actual transformer is expected to be quieter.

The NEMA levels were then converted into frequency spectra using empirical correlations for transformer noise (Crocker, 2007). This calculation is available in Figure B.2 of Appendix B.

Power transformers are considered by the MOE to be tonal noise sources. A 5-dB penalty was added to the sound power spectrum, as recommended by Publication NPC-104, “Sound Level Adjustments” for tonality. Table B.2 in Appendix B shows the frequency spectrum used to model the substation transformer.

3.2 Inverter Clusters

At this stage of the Project, Northland is planning to use inverters manufactured by SMA. Seven inverter clusters will be installed as part of the Project. Each cluster comprises of two SMA Sunny Central 800CP inverters and one medium voltage transformer. A schematic layout with approximate dimensions of such cluster is available in Figure 3.1. The cluster components listed above were modeled as point sources shown in Figure 3.2.

The installed capacity of each Sunny Central 800CP inverter is 800-kW. SMA provided third-octave noise data for the Sunny Central 800CP inverter (Figure B.1 of Appendix B). The provided third octave spectrum was converted to a full octave spectrum and the contribution from two inverters was combined into a single sound power spectrum for use with CADNA-A model (calculations are available in Figure B.3 of Appendix B). A 5-dBA penalty was added to the frequency spectrum, as stipulated in Publication NPC-104, "Sound Level Adjustments," to allow for tonality. The frequency spectrum used to model combined noise emission from the two inverters located next to each other within the same cluster is shown in Table B.2 of Appendix B.

A 1.6-MVA transformer used to step-up the 360-V power from the inverters to 27.6-kV will be located in proximity to the inverters. Since the transformer make and model have not been selected at this point, the sound power levels resulting from the operation of the transformer were evaluated using data from NEMA TR 1-1993 (R2000). The NEMA levels were then converted into frequency spectrum using empirical correlations for transformer noise (Crocker, 2007). This calculation is available in Figure B.4 of Appendix B. Power transformers are considered by the MOE to be tonal noise sources. A 5-dB penalty was added to the sound power spectrum, as recommended by Publication NPC-104, "Sound Level Adjustments" for tonality. Table B.2 in Appendix B shows the frequency spectrum used to model the transformers located in the clusters.

Note also that at night time the facility will not operate. Under these conditions the inverters do not produce noise. The transformers (at the substation and clusters) are energized and make some magnetostrictive noise at a reduced level, but no cooling fans are in operation. To simulate night time operation it was assumed that only the transformers would emit noise at the same sound power level as during day time.

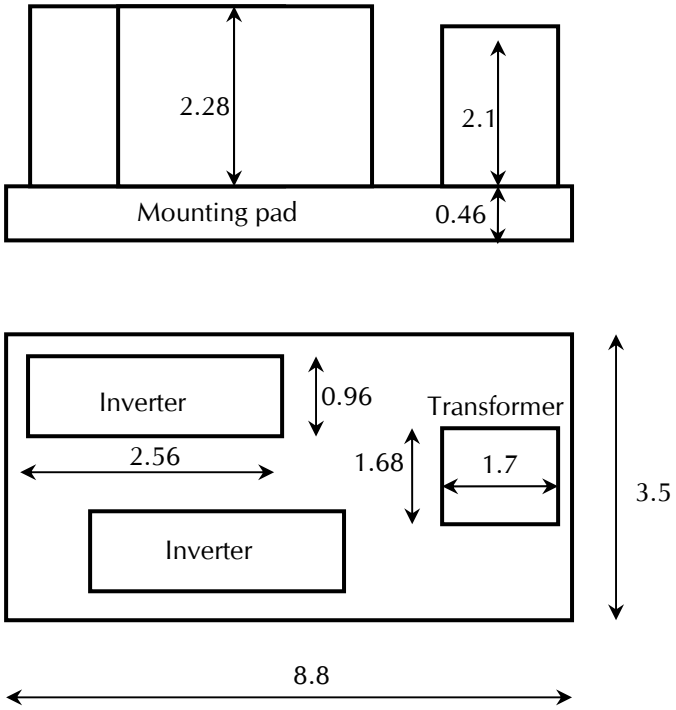

Figure 3.1 Schematic Inverter Cluster Layout
(all dimensions in metres)

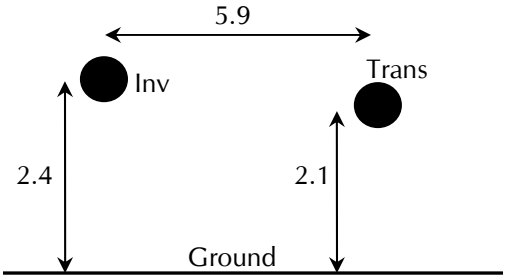

Figure 3.2 Inverter Cluster CADNA-A Acoustical Model

where: Inv = Noise Source Representing Two Sunny Central 800CP Inverters; and Trans = Noise Source Representing 27.6-kV/1.6-MVA Cluster Transformer (all dimensions in metres).

3.3 Noise Summary Table

A summary of the sound sources described above, including sound power level, characteristics and proposed noise control measures, is presented in Table 3.1.

Table 3.1 Noise Source Summary

Source ID	Description	Total Sound Power Level (dBA)	Source Location	Sound Characteristics	Noise Control Measures
Sub	44-kV/10-MVA substation transformer	90.8	O	S-T	U
Inv1	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Inv2	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Inv3	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Inv4	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Inv5	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Inv6	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Inv7	Two Sunny Central 800CP inverters	91.3	O	S-T	U
Trans1	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U
Trans2	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U
Trans3	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U
Trans4	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U
Trans5	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U
Trans6	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U
Trans7	27.6-kV/1.6-MVA cluster transformer	79.7	O	S-T	U

Notes:
1. A 5-dBA penalty is included in this table.
2. Location: Inside building (I), Outside building (O).
3. Sound Characteristics: Steady (S), Tonal (T), Impulsive (I), Quasi-Steady Impulsive (QSI).
4. Noise Control: Silencer (S), Acoustic lining (A), Barrier (B), Lagging (L), Enclosure (E), Other (O), Uncontrolled (U).

4. Points of Reception

The POR used in this study were identified from the OBM and Google Earth Pro imagery (September 2005) within 1.2-km distance from the Project Site boundary.

The total number of POR considered in this study within a 1.2-km distance from the Project Site boundary is 125 (see Figure A.1 and Figure A.2 in Appendix A). Three of these noise receptors, identified in Table 4.1, were chosen as representative receptors for evaluating the noise contribution from each individual source. These three receptors were chosen in order to represent sound pressure levels on three sides of the Project Location. Each receptor was deemed the best representation of a given side. The complete set of results for all 125 noise receptors is provided in Appendix C, including two noise maps from CADNA-A. For this study, the POR elevation above ground is 4.5-m.

Table 4.1 Point of Reception Noise Impact (Day Time)

Source ID	POR 3		POR 5		POR 10	
	Distance (m)	L_{eq} Sound Level (dBA)	Distance (m)	L_{eq} Sound Level (dBA)	Distance (m)	L_{eq} Sound Level (dBA)
Sub	924	13.4	296	28.9	457	21.9
Inv1	219	32.3	934	14.4	883	14.9
Inv2	418	25.8	884	15.5	624	21.9
Inv3	315	29.1	839	18.8	790	18.8
Inv4	474	20.8	702	21.5	630	20.1
Inv5	636	17.9	555	23.9	515	24.6
Inv6	873	14.7	312	29.2	498	21.2
Inv7	859	14.9	416	23.1	870	17.3
Trans1	222	20.7	932	2.5	885	2.9
Trans2	416	15.0	880	3.6	625	10.4
Trans3	317	17.5	837	7.3	792	6.9
Trans4	475	9.0	699	9.9	633	7.6
Trans5	637	6.1	552	12.3	519	12.9
Trans6	875	2.8	308	17.8	504	9.3
Trans7	863	2.9	418	11.0	875	4.0

5. Mitigation Measures

While the analysis indicates that no mitigation will be required, the noise levels will be verified at the closest POR after the Project goes into service. If measurements indicate a need to reduce sound levels to satisfy MOE criteria, mitigation measures will be installed at the sources.

6. Impact Assessment

The purpose of the acoustic Assessment report is to demonstrate that the facility is in compliance with the noise performance limits. The Project will be located in a Class 3 Area, based on the classification defined in Publication NPC-232 by the MOE. Class 3 area means a rural area with an acoustical environment that is dominated by natural sounds, having little or no traffic, such as an agricultural area.

Table 6.1 shows the performance limits set by the MOE for Class 3 Areas, according to Publication NPC-232.

Table 6.1 Performance Limits (One-Hour L_{eq}) by Time of Day for Class 3 Areas.

Time of Day	One Hour L_{eq} (dBA) Class 3 Area
07:00 to 19:00	45.0
19:00 to 23:00	40.0
23:00 to 07:00	40.0

The solar facility will be operating during the day light hours, that is, before 19:00 during most days of the year. However, in the summer months the sun may shine until past 21:00, although the inverters will be below 100% loading conditions. As such, during the summer the facility will be operating at the time the applicable performance limit changes from 45-dBA to 40-dBA. Also, the transformers remain energized at night. In order to account for this the noise model assumes that the cluster transformers and substation transformer will be operating 24 hours and compares the impact from the facility with the 40-dBA limit. In reality, the cooling fans will not be in operation at night.

For this study, the overall ground attenuation coefficient was estimated to be 0.7. Appendix D includes a list of all the parameters used in the CADNA-A model to predict the sound pressure levels at the POR.

The modelling does not consider the effect of the solar panels on the predicted sound pressure levels at the points of reception. The solar panels may act as barriers to further reduce noise at the POR.

6.1 Compliance With Performance Limits

Table 6.2 presents the predicted sound pressure levels for the representative POR. The complete set of results is included in Appendix C. Appendix D includes a detailed calculation log of the representative POR with the highest Sound Pressure Level.

Table 6.2 Acoustic Assessment Summary (Day and Night Time).

POR ID	POR Description	Total Sound Level at POR (L_{eq}) Day/Night (dBA)	Verified by Acoustic Audit (Yes/No)	Performance Limit (L_{eq}) Day/Night (dBA)	Compliance With Performance Limit (Yes/No)
3	Existing house - South	35.3/23.9	No	45.0/40.0	Yes
5	Existing house - North	33.9/29.5	No	45.0/40.0	Yes
10	Existing house - East	30.2/23.2	No	45.0/40.0	Yes

The results of this study show that all POR are compliant with MOE guidelines based on the performance limits.

7. Conclusions and Recommendations

For the North Burgess Solar Project, the sound pressure levels at the POR have been estimated using the CADNA-A model, based on ISO 9613-2. The performance limits used for comparison correspond to Class 3 areas, with 45-dBA during day time (7:00 a.m. to 7:00 p.m.) and 40-dBA during night time. It has been determined that no mitigation measures are needed for the Project operation.

Based on the results obtained in this study, it is concluded that the sound pressure levels at the POR will be below MOE requirements for Class 3 areas at night time (40-dBA) and day time (45-dBA).

8. References

Ontario Regulation 359/09. Environmental Protection Act. Renewable Energy Approvals Under Part V.0.1 of the Act.

Ontario Regulation 521/10 made under Environmental Protection Act amending O.Reg. 359/09.

Ministry of the Environment (MOE). 2004. Basic Comprehensive Certificates of Approval (Air) – User Guide (Appendix A). Environmental Assessment and Approvals Branch.

Handbook of Noise and Vibration Control; Malcolm J. Crocker, 2007;

IEEE. 2006. C57.12.90-2006: Standard Test Code for Liquid-Immersed, Power and Regulating Transformers. pp 64 to 76.

Ministry of the Environment (MOE). 1997. Noise Assessment Criteria in Land Use Planning. Publication LU-131. Ontario Ministry of the Environment. 12 pp + Annex.

MOE. 1995. Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban). Publication NPC-205. Ontario Ministry of the Environment. 6 pp + Annex.

MOE. 1995. Sound Level Limits for Stationary Sources in Class 3 Areas (Rural). Publication NPC-232. Ontario Ministry of the Environment. 8 pp + Annex.

NEMA. 2000. Standards Publication No. TR 1-1993 (R2000): Transformers, Regulators and Reactors. National Electrical Manufacturers Association. 31 pp. (This reference probably not needed now).

International Organization for Standardization (ISO). Standard 1996-1: Description, Measurement and Assessment of Environmental Noise – Part 1: Basic Quantities and Assessment Procedures.

International Organization for Standardization (ISO). Standard 1913-2: Acoustics – Attenuation of sound during propagation outdoors – Part 2: General Method of Calculation.

Appendix A

Land Use Zoning Designation Plan and Area Location Plan

Figure A.1 Land Use Zoning Designation Plan

Inert Figure A.1 in original size and orientation

Figure A.2 Area Location Plan

Inert Figure A.2 in original size and orientation.

Appendix B

Noise Sources

Table B.1 Point Sources Used in CADNA-A, Includes Tonality Penalty of 5.0-dBA. NAD83 Zone18.

Source ID	Description	Spectra ID	Total Sound Power Level (dBA)		Correction (dBA)		Height (m)	Coordinates (m)		
			Day	Night	Day	Night		X	Y	Z
Sub	44-kV/10-MVA substation transformer	T44kV_10MVA	90.8	90.8	5.0	5.0	3.0	396675	4963866	159.3
Inv1	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	396776	4963160	167.4
Inv2	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	397007	4963360	167.3
Inv3	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	396775	4963263	167.4
Inv4	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	396800	4963431	163.9
Inv5	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	396773	4963592	161.4
Inv6	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	396649	4963808	158.4
Inv7	Two Sunny Central 800CP inverters	SMA_SC800CPX2	91.3	0.0	5.0	0.0	2.4	396323	4963624	156.4
Trans1	27.6-kV/1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	396770	4963160	167.1
Trans2	27.6-kV/1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	397001	4963360	167.1
Trans3	27.6-kV/1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	396769	4963263	167.1
Trans4	27.6-kV /1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	396794	4963431	163.3
Trans5	27.6-kV/1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	396767	4963592	161.0
Trans6	27.6-kV/1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	396643	4963808	158.0
Trans7	27.6-kV/1.6-MVA cluster transformer	T27.6kV_1.6MVA	79.7	79.7	5.0	5.0	2.1	396317	4963624	155.8

Table B.2 Frequency Spectra Used for Modelling the Noise Sources, Not Including Tonality Penalty.

Spectra ID	Octave Spectrum (dBA)										
	31.5	63	125	250	500	1000	2000	4000	8000	A	lin
SMA_SC800CPX2		63.1	73.9	80.5	82.3	78.7	74.1	65.0	72.7	86.3	95.0
T27.6kV_1.6MVA	31.9	51.1	63.2	65.7	71.1	68.3	64.5	59.3	50.2	74.7	83.3
T44kV_10MVA	43.0	62.2	74.3	76.8	82.2	79.4	75.6	70.4	61.3	85.8	94.4

Insert 4 pages: Appendix B - Inverter Specs - SMA SUNNY CENTRAL 720CP-760CP-800CP.pdf

Terz-midle-frequency [kHz]	Soundpower-level L_{xpA} [dB_A]500kW	Soundpower-level L_{xpA} [dB_A]640kW	Soundpower-level L_{xpA} [dB_A]720kW	Soundpower-level L_{xpA} [dB_A]760kW	Soundpower level L_{xpA} [dB_A]800kW
0,05	63,30	55,30	57,70	67,00	56,50
0,063	60,80	53,10	56,80	63,20	54,00
0,08	63,90	56,30	56,50	59,50	55,20
0,1	64,10	66,20	65,00	66,50	68,10
0,125	65,70	64,50	60,60	65,20	62,00
0,16	72,30	65,80	65,50	63,20	66,40
0,2	67,30	64,60	66,80	64,90	67,80
0,25	66,10	76,20	77,50	70,80	72,40
0,315	78,40	79,80	77,70	82,20	75,10
0,4	73,70	73,90	73,90	72,80	66,70
0,5	77,80	78,70	77,70	77,40	74,70
0,63	78,90	78,90	74,60	77,40	77,00
0,8	70,60	72,50	74,10	70,60	72,00
1	72,20	71,00	70,00	68,90	67,90
1,25	72,40	72,00	71,50	70,80	71,80
1,6	67,30	68,30	76,70	68,60	68,50
2	69,30	66,30	66,50	67,20	65,30
2,5	65,10	66,80	64,60	64,80	63,90
3,15	62,60	64,30	65,00	63,20	61,00
4,0	53,50	54,20	54,70	52,30	53,80
5,0	51,30	49,50	50,50	51,20	49,80
6,3	68,90	72,60	73,50	73,50	69,70

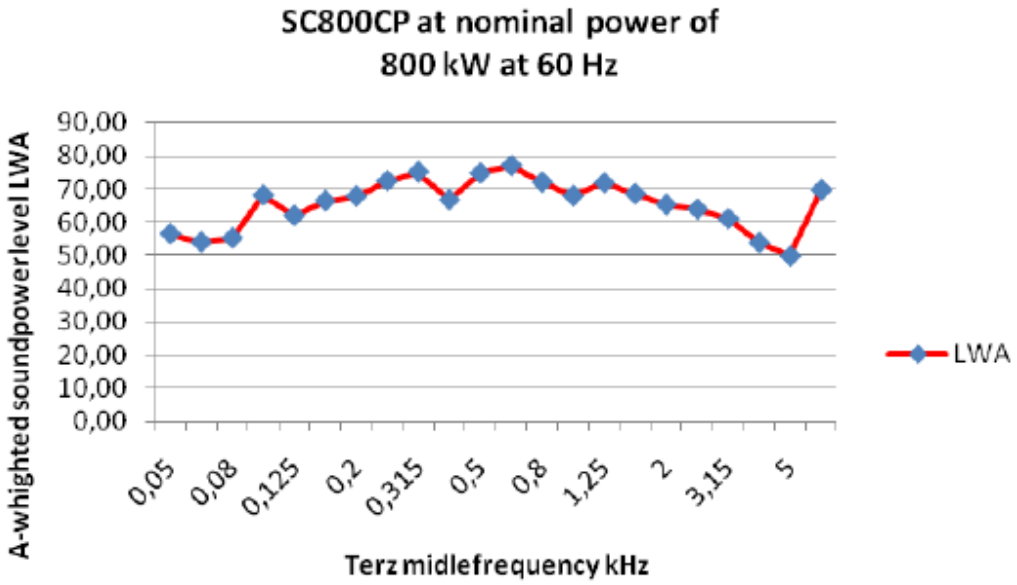

Figure B.1 SC800CP Inverter Sound Power Level as Provided by SMA. Note that the Header in the Table above Represents Various Inverter Models of CS###CP Series.

Estimated Frequency Spectra for Transformers

Transformer - 44kV/10MVA

From Handbook of Noise and Vibration Control (Crocker, 2007, page 1335-1336, Eq. 18 and Table 20)

Average LpA	68 dBA	Based on NEMA TR1-1993 (R2000), Table 0-2
Estimated surface area	35 m^2	Can be assumed, 25% of change will produce a difference of 1 dB on Lw, try to estimate on the high side

Correction factors are in dB

Freq. (Hz)	31	63	125	250	500	1000	2000	4000	8000	Notes
C1	-11.0	-5.0	-3.0	-8.0	-8.0	-14.0	-19.0	-24.0	-31.0	Outdoors, indoors in mechanical room over 140 m^3
C2	-11	-2	3	-2	-2	-11	-19	-24	-31	Indoors
C3	-11	-2	3	2	2	-4	-9	-14	-21	Serious Noise Problems

Sound Power Level calculated as Lw=Average LpA + 10*log(Estimated surface area) + C + 10

Freq. (Hz)	31	63	125	250	500	1000	2000	4000	8000	Combined [dB]
C1 based [dB]	82.4	88.4	90.4	85.4	85.4	79.4	74.4	69.4	62.4	**94.5**
C2 based [dB]	82.4	91.4	96.4	91.4	91.4	82.4	74.4	69.4	62.4	**99.5**
C3 based [dB]	82.4	91.4	96.4	95.4	95.4	89.4	84.4	79.4	72.4	**101.5**

Resulting A-weighted sound power level

Freq. (Hz)	A-Weight	C1 based [dBA]	C2 based [dBA]	C2 based [dBA]
31	-39.4	43.0	52.0	57.0
63	-26.2	62.2	65.2	65.2
125	-16.1	74.3	80.3	80.3
250	-8.6	76.8	82.8	86.8
500	-3.2	82.2	88.2	92.2
1000	0	79.4	82.4	89.4
2000	1.2	75.6	75.6	85.6
4000	1	70.4	70.4	80.4
8000	-1.1	61.3	61.3	71.3
LwA [dBA]		**85.8**	**90.8**	**95.6**

Used in the study

Figure B.2 Sound Power Level Calculation for 44-kV/10-MVA Substation Transformer.

Sound Power Level Calculation for SMA Sunny Central 800CP, 100% LOAD

Third octave, as provided		
Freq #	Freq (Hz)	LwA (dBA)
1	25	
2	31.5	
3	40	
4	50	56.5
5	63	54.0
6	80	55.2
7	100	68.1
8	125	62.0
9	160	66.4
10	200	67.8
11	250	72.4
12	315	75.1
13	400	66.7
14	500	74.7
15	630	77.0
16	800	72.0
17	1000	67.9
18	1250	71.8
19	1600	68.5
20	2000	65.3
21	2500	63.9
22	3150	61.0
23	4000	53.8
24	5000	49.8
25	6300	69.7
26	8000	
27	10000	
	Total LwA	**83.3**

Full octave, as used in CADNA-A model			
Freq #	Freq (Hz)	LwA 1 inverter (dBA)	LwA 2 inverters (dBA)
	31.5		
5	63	60.1	63.1
8	125	70.9	73.9
11	250	77.5	80.5
14	500	79.3	82.3
17	1000	75.7	78.7
20	2000	71.1	74.1
23	4000	62.0	65.0
26	8000	69.7	72.7
	Total LwA	**83.3**	**86.3**

$$10\log\left(10^{\frac{56.5}{10}}+10^{\frac{54.0}{10}}+10^{\frac{55.2}{10}}\right)=60.1dBA$$

$$10\log\left(10^{\frac{60.1}{10}}+10^{\frac{60.1}{10}}\right)=63.1dBA$$

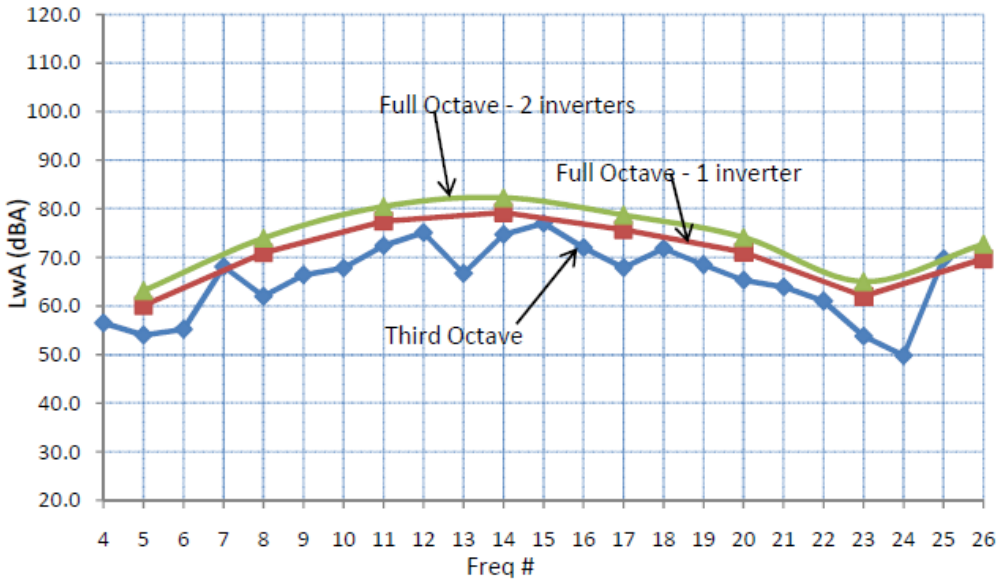

Figure B.3 Sound Power Level Calculation for SMA Sunny Central 800CP, 100% LOAD.

Estimated Frequency Spectra for Transformers

Transformer - 27.6kV/1.6MVA

From Handbook of Noise and Vibration Control (Crocker, 2007, page 1335-1336, Eq. 18 and Table 20)

Average LpA	61 dBA	Based on NEMA TR1-1993 (R2000), Table 0-2
Estimated surface area	13.52 m^2	Can be assumed, 25% of change will produce a difference of 1 dB on Lw, try to estimate on the high side

Correction factors are in dB

Freq. (Hz)	31	63	125	250	500	1000	2000	4000	8000	Notes
C1	-11.0	-5.0	-3.0	-8.0	-8.0	-14.0	-19.0	-24.0	-31.0	Outdoors, indoors in mechanical room over 140 m^3
C2	-11	-2	3	-2	-2	-11	-19	-24	-31	Indoors
C3	-11	-2	3	2	2	-4	-9	-14	-21	Serious Noise Problems

Sound Power Level calculated as Lw=Average LpA + 10*log(Estimated surface area) + C + 10

Freq. (Hz)	31	63	125	250	500	1000	2000	4000	8000	Combined [dB]
C1 based [dB]	71.3	77.3	79.3	74.3	74.3	68.3	63.3	58.3	51.3	**83.4**
C2 based [dB]	71.3	80.3	85.3	80.3	80.3	71.3	63.3	58.3	51.3	**88.4**
C3 based [dB]	71.3	80.3	85.3	84.3	84.3	78.3	73.3	68.3	61.3	**90.4**

Resulting A-weighted sound power level

Freq. (Hz)	A-Weight	C1 based [dBA]	C2 based [dBA]	C2 based [dBA]
31	-39.4	31.9	40.9	45.9
63	-26.2	51.1	54.1	54.1
125	-16.1	63.2	69.2	69.2
250	-8.6	65.7	71.7	75.7
500	-3.2	71.1	77.1	81.1
1000	0	68.3	71.3	78.3
2000	1.2	64.5	64.5	74.5
4000	1	59.3	59.3	69.3
8000	-1.1	50.2	50.2	60.2
LwA [dBA]		**74.7**	**79.6**	**84.5**

Used in the study

Figure B.4 Sound Power Level Calculation for 27.6-kV/1.6-MVA Cluster Transformer.

Appendix C

Sound Pressure Levels for Points of Reception and Noise Maps from CADNA-A

Table C.1 Calculated Sound Pressure Levels at POR (shaded rows correspond to representative POR). Existing = Existing dwelling. NAD83 Zone18.

ID	Description	Total Sound Pressure Level		Performance Limit		Height (m)	Coordinates			Min dist to source (m)
		Day (dBA)	Night (dBA)	Day (dBA)	Night (dBA)		X (m)	Y (m)	Z (m)	
1	existing	34.4	23.1	45.0	40.0	4.5	397091	4963140	167.0	235
2	existing	34.4	22.9	45.0	40.0	4.5	397133	4963187	165.7	214
3	existing	35.3	23.9	45.0	40.0	4.5	396873	4962964	169.5	219
4	existing	35.2	23.8	45.0	40.0	4.5	396808	4962944	169.5	219
5	existing	33.9	29.5	45.0	40.0	4.5	396427	4964027	157.5	296
6	existing	32.2	21.0	45.0	40.0	4.5	397085	4963040	166.9	329
7	existing	29.9	24.5	45.0	40.0	4.5	396374	4964017	154.8	337
8	existing	31.1	26.7	45.0	40.0	4.5	396403	4964056	156.3	332
9	existing	33.0	28.5	45.0	40.0	4.5	396425	4964075	157.4	326
10	existing	30.2	23.2	45.0	40.0	4.5	397119	4963974	164.5	457
11	existing	29.9	22.7	45.0	40.0	4.5	397139	4963975	164.5	476
12	existing	29.9	19.0	45.0	40.0	4.5	397218	4963044	164.5	379
13	existing	28.4	17.5	45.0	40.0	4.5	397277	4963002	162.6	448
14	existing	30.8	22.4	45.0	40.0	4.5	395989	4963439	158.3	377
15	existing	28.9	17.8	45.0	40.0	4.5	397382	4963152	163.6	429
16	existing	28.8	17.7	45.0	40.0	4.5	397377	4963132	163.1	434
17	existing	30.7	22.4	45.0	40.0	4.5	395973	4963467	157.2	378
18	existing	28.3	17.4	45.0	40.0	4.5	397423	4963166	164.2	459
19	existing	30.6	26.4	45.0	40.0	4.5	396457	4964264	159.5	454
20	existing	29.9	21.7	45.0	40.0	4.5	395951	4963398	159.5	430
21	existing	30.4	26.1	45.0	40.0	4.5	396438	4964271	159.5	469
22	existing	27.5	17.1	45.0	40.0	4.5	397512	4963405	164.5	507
23	existing	27.0	16.3	45.0	40.0	4.5	397304	4962942	161.1	512
24	existing	28.8	17.9	45.0	40.0	4.5	396577	4962694	169.5	505
25	existing	28.8	20.7	45.0	40.0	4.5	395871	4963400	158.6	499
26	existing	25.3	14.8	45.0	40.0	4.5	397056	4962694	164.8	544
27	existing	25.2	14.7	45.0	40.0	4.5	397101	4962704	164.5	560
28	existing	28.1	19.9	45.0	40.0	4.5	395898	4963219	159.5	583
29	existing	28.4	20.3	45.0	40.0	4.5	395860	4963346	159.0	535
30	existing	28.5	20.5	45.0	40.0	4.5	395844	4963410	158.0	519
31	existing	27.9	19.7	45.0	40.0	4.5	395899	4963193	159.5	600
32	existing	28.0	18.5	45.0	40.0	4.5	395831	4963663	154.5	488
33	existing	26.1	18.2	45.0	40.0	4.5	396080	4962873	160.7	748
34	existing	26.6	18.2	45.0	40.0	4.5	396160	4962786	164.5	715
35	existing	26.9	16.2	45.0	40.0	4.5	396447	4962611	169.5	638
36	existing	26.9	16.0	45.0	40.0	4.5	396620	4962545	167.5	634
37	existing	25.9	17.5	45.0	40.0	4.5	396175	4962709	164.9	747
38	existing	24.4	16.2	45.0	40.0	4.5	395761	4963357	156.2	617
39	existing	26.3	15.6	45.0	40.0	4.5	396419	4962572	169.5	685
40	existing	24.5	14.7	45.0	40.0	4.5	397715	4963578	164.5	741

ID	Description	Total Sound Pressure Level		Performance Limit		Height (m)	Coordinates			Min dist to source (m)
		Day (dBA)	Night (dBA)	Day (dBA)	Night (dBA)		X (m)	Y (m)	Z (m)	
41	existing	24.1	14.5	45.0	40.0	4.5	397738	4963599	164.5	769
42	existing	24.1	14.4	45.0	40.0	4.5	397739	4963617	164.4	776
43	existing	22.7	14.1	45.0	40.0	4.5	395711	4963335	154.8	671
44	existing	25.9	17.8	45.0	40.0	4.5	395855	4962970	159.5	800
45	existing	24.0	14.4	45.0	40.0	4.5	397745	4963607	164.5	778
46	existing	24.0	14.0	45.0	40.0	4.5	396214	4962603	166.4	787
47	existing	25.6	14.8	45.0	40.0	4.5	396420	4962508	168.2	741
48	existing	25.3	14.9	45.0	40.0	4.5	396345	4962512	169.1	775
49	existing	25.2	14.5	45.0	40.0	4.5	396396	4962482	167.5	775
50	existing	25.9	17.0	45.0	40.0	4.5	396226	4962553	167.6	815
51	existing	22.2	13.6	45.0	40.0	4.5	395659	4963320	154.5	725
52	existing	22.1	13.5	45.0	40.0	4.5	395649	4963317	154.5	735
53	existing	25.3	14.8	45.0	40.0	4.5	396309	4962492	169.3	811
54	existing	22.0	13.7	45.0	40.0	4.5	395627	4963335	154.5	748
55	existing	25.2	17.9	45.0	40.0	4.5	396595	4964631	159.5	769
56	existing	25.7	16.7	45.0	40.0	4.5	396232	4962510	168.9	844
57	existing	25.7	16.7	45.0	40.0	4.5	396242	4962494	169.5	850
58	existing	24.1	17.3	45.0	40.0	4.5	396630	4964646	159.5	781
59	existing	24.1	17.6	45.0	40.0	4.5	396610	4964655	159.5	792
60	existing	24.8	14.1	45.0	40.0	4.5	396283	4962460	168.7	853
61	existing	21.9	12.0	45.0	40.0	4.5	396327	4962433	167.1	852
62	existing	24.8	17.5	45.0	40.0	4.5	396584	4964666	159.5	805
63	existing	22.7	13.1	45.0	40.0	4.5	397870	4963612	164.0	899
64	existing	25.2	16.3	45.0	40.0	4.5	396225	4962461	169.5	887
65	existing	21.7	11.8	45.0	40.0	4.5	396311	4962419	167.0	872
66	existing	23.0	12.5	45.0	40.0	4.5	397661	4962791	164.5	866
67	existing	24.4	14.8	45.0	40.0	4.5	395547	4963430	154.5	794
68	existing	22.5	12.5	45.0	40.0	4.5	396148	4962473	167.0	927
69	existing	24.2	15.6	45.0	40.0	4.5	395784	4964266	151.5	835
70	existing	24.2	14.6	45.0	40.0	4.5	395531	4963421	154.5	812
71	existing	21.2	11.3	45.0	40.0	4.5	396277	4962388	167.0	917
72	existing	22.4	14.3	45.0	40.0	4.5	395517	4963369	154.5	840
73	existing	24.0	15.6	45.0	40.0	4.5	395795	4964316	152.2	867
74	existing	24.2	13.5	45.0	40.0	4.5	396214	4962398	169.1	944
75	existing	21.3	12.9	45.0	40.0	4.5	396257	4962378	167.3	936
76	existing	23.1	12.8	45.0	40.0	4.5	396246	4962366	167.4	952
77	existing	23.3	14.5	45.0	40.0	4.5	395645	4964153	149.5	855
78	existing	23.2	14.5	45.0	40.0	4.5	395660	4964184	149.5	863
79	existing	24.2	15.5	45.0	40.0	4.5	396176	4962382	169.3	979
80	existing	20.9	12.6	45.0	40.0	4.5	396239	4962347	167.3	971
81	existing	24.8	19.1	45.0	40.0	4.5	395978	4964547	156.6	975
82	existing	24.1	15.4	45.0	40.0	4.5	396171	4962374	169.2	989
83	existing	20.9	12.0	45.0	40.0	4.5	395486	4963221	154.5	924
84	existing	24.0	15.3	45.0	40.0	4.5	396180	4962361	169.5	994

ID	Description	Total Sound Pressure Level		Performance Limit		Height (m)	Coordinates			Min dist to source (m)
		Day (dBA)	Night (dBA)	Day (dBA)	Night (dBA)		X (m)	Y (m)	Z (m)	
85	existing	23.0	12.6	45.0	40.0	4.5	396210	4962345	168.2	989
86	existing	24.7	18.9	45.0	40.0	4.5	395981	4964571	158.8	989
87	existing	20.2	11.8	45.0	40.0	4.5	395452	4963363	151.2	903
88	existing	23.8	15.1	45.0	40.0	4.5	396134	4962360	168.4	1023
89	existing	23.1	12.5	45.0	40.0	4.5	396179	4962315	168.7	1032
90	existing	19.7	11.2	45.0	40.0	4.5	395413	4963335	149.7	949
91	existing	24.1	18.4	45.0	40.0	4.5	396010	4964668	159.5	1042
92	existing	21.2	14.0	45.0	40.0	4.5	396836	4964863	159.5	1010
93	existing	22.1	11.7	45.0	40.0	4.5	396166	4962249	169.0	1094
94	existing	20.8	13.6	45.0	40.0	4.5	396869	4964897	159.5	1049
95	existing	22.3	11.8	45.0	40.0	4.5	396157	4962224	169.5	1119
96	existing	20.1	11.0	45.0	40.0	4.5	395420	4962940	156.7	1128
97	existing	18.9	9.3	45.0	40.0	4.5	396219	4962164	166.0	1139
98	existing	19.1	11.0	45.0	40.0	4.5	396173	4962164	167.4	1162
99	existing	23.0	16.8	45.0	40.0	4.5	395670	4964535	154.5	1117
100	existing	19.3	10.7	45.0	40.0	4.5	395278	4963288	152.2	1092
101	existing	19.2	10.3	45.0	40.0	4.5	395295	4963160	153.1	1122
102	existing	19.4	10.6	45.0	40.0	4.5	395295	4963126	154.1	1137
103	existing	19.9	10.9	45.0	40.0	4.5	395261	4963261	153.3	1117
104	existing	22.4	13.7	45.0	40.0	4.5	395999	4962212	169.5	1222
105	existing	22.1	13.5	45.0	40.0	4.5	396050	4962177	169.5	1219
106	existing	22.1	13.5	45.0	40.0	4.5	396037	4962182	169.5	1223
107	existing	19.7	10.5	45.0	40.0	4.5	395268	4963141	154.0	1155
108	existing	18.2	8.6	45.0	40.0	4.5	396168	4962089	164.6	1229
109	existing	18.0	8.4	45.0	40.0	4.5	396157	4962068	164.2	1253
110	existing	19.3	9.6	45.0	40.0	4.5	398279	4963379	164.5	1272
111	existing	17.9	8.4	45.0	40.0	4.5	396119	4962067	165.3	1273
112	existing	17.9	8.4	45.0	40.0	4.5	396103	4962072	166.0	1277
113	existing	17.7	8.2	45.0	40.0	4.5	396108	4962043	165.3	1299
114	existing	18.8	9.2	45.0	40.0	4.5	398314	4963339	164.5	1307
115	existing	17.2	7.7	45.0	40.0	4.5	396151	4961960	161.4	1351
116	existing	20.4	14.1	45.0	40.0	4.5	395270	4964494	154.8	1361
117	existing	15.7	3.3	45.0	40.0	4.5	396293	4961768	155.2	1472
118	existing	15.6	3.3	45.0	40.0	4.5	396358	4961742	154.5	1477
119	existing	13.2	7.7	45.0	40.0	4.5	395842	4965290	154.5	1650
120	existing	13.1	7.5	45.0	40.0	4.5	395844	4965313	153.4	1669
121	existing	11.1	6.4	45.0	40.0	4.5	395950	4965523	152.5	1809
122	existing	8.7	5.4	45.0	40.0	4.5	395961	4965646	145.9	1918
123	existing	-88.0	-88.0	45.0	40.0	4.5	396143	4965805	150.6	2011
124	existing	-88.0	-88.0	45.0	40.0	4.5	396128	4965804	150.3	2014
125	existing	-88.0	-88.0	45.0	40.0	4.5	396213	4965907	145.9	2093

Figure C.1 Noise Map – Day Time.
Insert Figure C.1 in original size and orientation.

Figure C.2 Noise Map – Night Time.
Insert Figure C.2 in original size and orientation.

Appendix D

CADNA-A Sample Calculations

Insert: Appendix D - CADNA-A sample calculations.pdf