765 kV Substation Acoustic Noise Impact Study by Predictive Software and Computational Approach

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Background

- Most utilities use electronic and barrier methods to reduce substation equipment (transformer, reactors, etc.) noise levels.
- It is important to have reliable predictions of future noise levels for the increasing number of power substations being installed.
- Planning new substations or expanding existing ones in built-up areas must take into account the impact on local environmental noise, and comply with community noise regulations.
- Audible noise in substations emanates principally from the vibrations from transformer cores and from the cooling system (fans, pumps, radiators, etc.). The problem becomes acute because transformer noise is continuous while noise limits are significantly reduced during night-time.

Background

- As a basis for evaluating different approaches, one needs to predict the noise levels around a substation as accurately as possible before committing additional equipment.

- Since an accurate assessment of the noise levels must consider all propagation paths the sound waves take to travel from source to receivers (reflections on barriers and ground, diffraction around barriers, transmission through barriers, etc.), a PC computer program best performs all the calculation chores.

- This paper addresses such a computer program, available on a PC to help the substation designer estimate the contours of noise levels resulting from a selected substation layout.

Minimize the Impact of Power Substations on Environmental Noise

- Select a proper site for a new substation.
- Reduce noise at the source by improving the performance of magnetic material or by using noise absorbing screens.
- Locate noise sources (transformers) near the control buildings to screen and restrict the propagation of sound waves.
- Erect noise absorbing barriers at selected locations along the borderline of the substation.

Noise Level Criteria

- A large degree of international consensus has emerged over the years as what constitutes unacceptable levels of noise exposure and what should be the maximum levels of exposure for certain specific situations.
- At the international level, the World Health Organisation (WHO) together with the Organisation for Economic Co-operation and Development (OECD) are two of the main bodies that have collected data and developed their own assessments on the effects of the exposure to environmental noise.
- On the basis of these assessments, guideline values for different time periods and situations have been suggested.
- The WHO has recommended that a standard guideline value for average outdoor noise levels of 55 dBA be applied during normal day-time in order to prevent significant interference with the normal activities of local communities.
- The ambient sound level is defined as the equivalent continuous A-weighted sound pressure level (L_{Aeq}) at a specific place and over a specific time inclusive of intruding noises. Intruding noise in this context is defined as noise in spaces that is generated by sources other than those resulting from the intended activities in those spaces.

Ambient Noise Levels

- The degree of annoyance with continuous audible noise is dependent in a large part upon the relative level of the ambient noise.
- The human ear will normally notice the more dominant of several noises only.
- Sources of ambient noise in the community include vehicular or railway traffic, factories, aircraft, animals, and appliances such as attic fans, air conditioners, and lawn mowers.
- If ambient noise is very low, even a small amount of wind can override the other noise sources and become the dominant ambient noise.
- The human ear distinguishes a particular sound source and establishes whether it is objectionable or not by comparing it to the general background or ambient noise to which it has become accustomed.
- Ambient noise is generally a broadband noise that covers a large range of frequencies, with no pronounced or outstanding tones.
- The addition of another broadband noise source, such as a fan, would not likely be distinguishable by the human ear. Car horns, gun shots, and transformer noise, being more or less of a pure tone, can readily be distinguished by the human ear if loud enough. Some jurisdictions may have additional requirements related to pure tones.
- Highway traffic can provide a base ambient noise that can help shield substation noise. While it is easy to measure traffic noises near the highway, it becomes increasingly difficult to measure them at distances of 1.5 km to 3 km. A substation could benefit from the shielding effect of highway noise if it is located less than 3 km from a highway.

South African Noise Criteria

- Main controlling criteria in South Africa:

- SANS 10103:2003 (SABS 0103)
- National Noise Control Regulations

- SANS 10103:2003, the Code of Practice for ***The Measurement and Rating of Environmental Noise with Respect to Land Use, Health, Annoyance and Speech Communication*** recommends maximum noise levels for residential and non-residential areas.

Typical Noise Levels for Different Districts from SANS 10103 (Table 2)

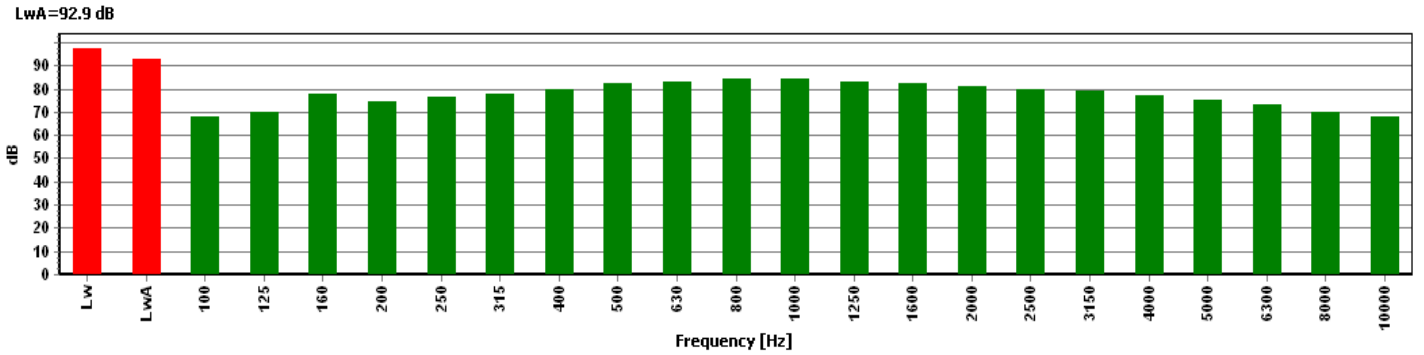
1	2	3	4	5	6	7
Type of district	**Equivalent continuous rating level ($L_{Req,T}$) for noise dBA**					
	Outdoors			**Indoors, with open windows**		
	Day/night $L_{R,dn}$[a]	**Daytime $L_{Req,d}$[b]**	**Night-time $L_{Req,n}$[b]**	**Day/night $L_{R,dn}$[a]**	**Daytime $L_{Req,d}$[b]**	**Night-time $L_{Req,n}$[b]**
a) Rural districts	45	45	35	35	35	25
b) Suburban districts with little road traffic	50	50	40	40	40	30
c) Urban districts	55	55	45	45	45	35
d) Urban districts with one or more of the following: workshops; business premises; and main roads	60	60	50	50	50	40
e) Central business districts	65	65	55	55	55	45
f) Industrial districts	70	70	60	60	60	50

765 kV Substation Layouts

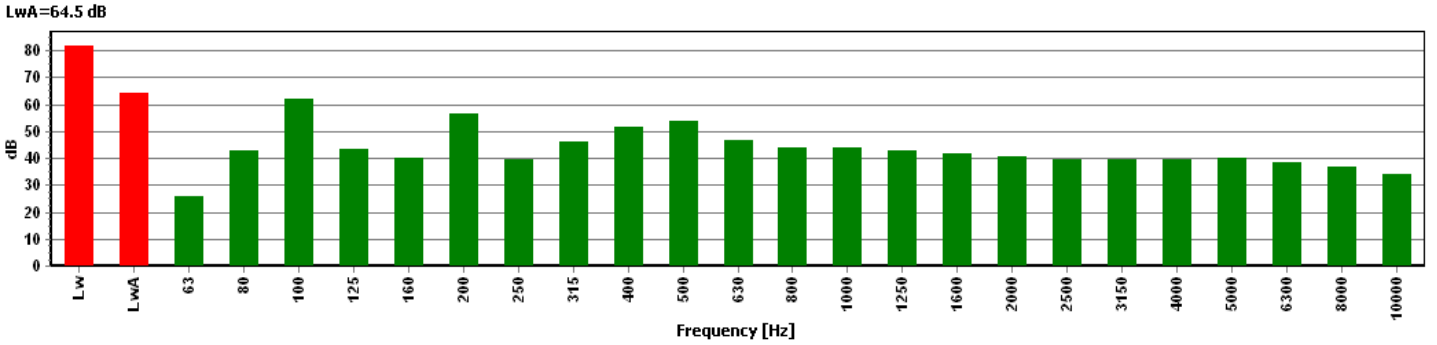
Substation A

Substation B

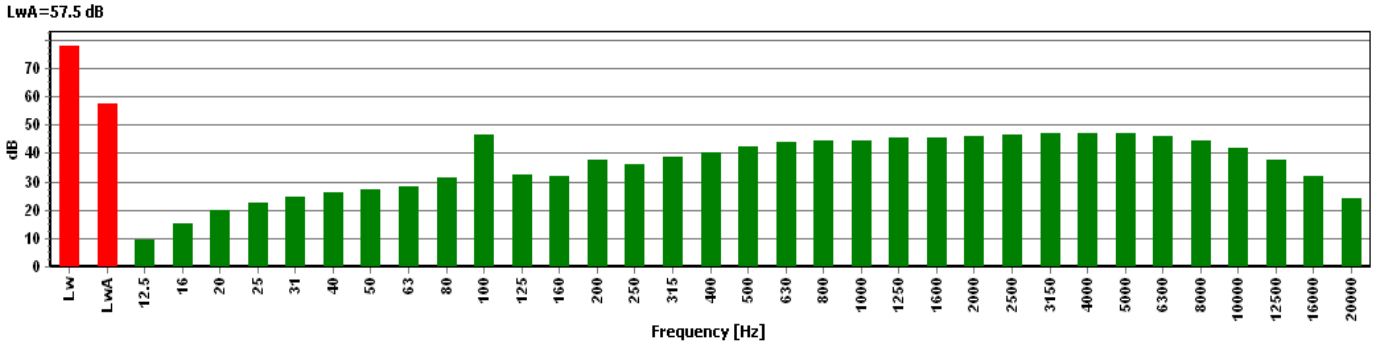
Noise Sources - Predictions



Transformer

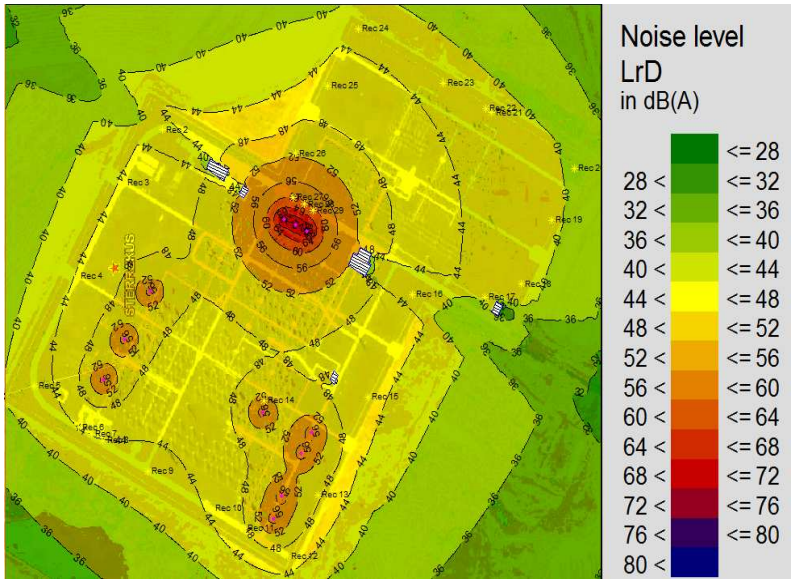


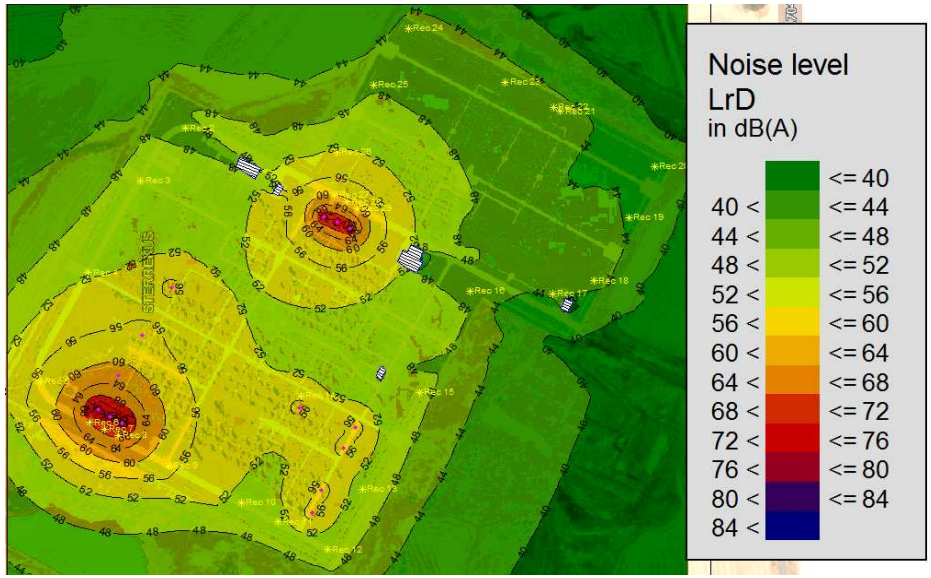
Reactor



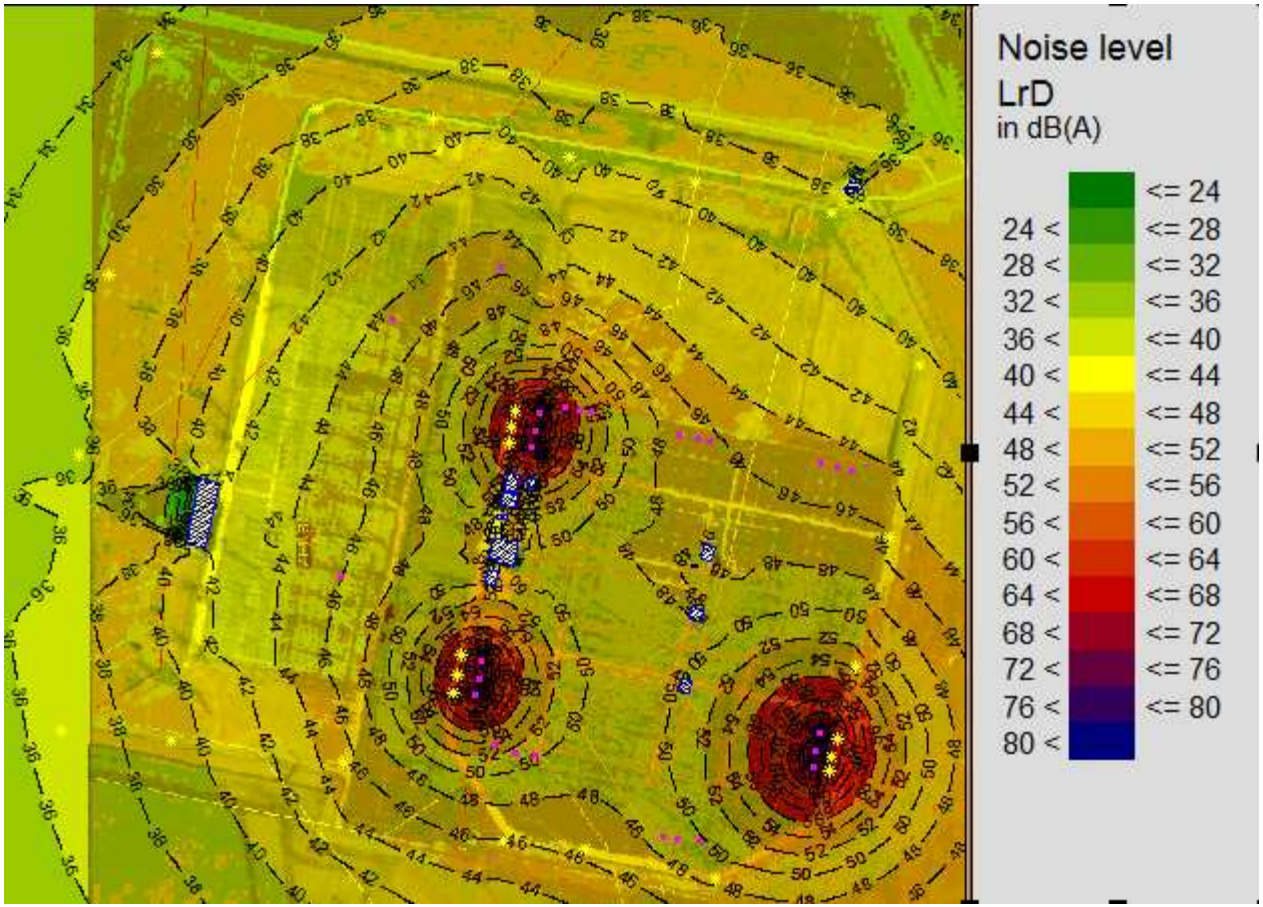
Corona

Substation A Predictions





Substation B Predictions



Measurement Procedure

- Based on the SANS 10103 and SANS 10083 standards.
- Predefined measurements positions were selected around the perimeter of the 765 kV substations.
- A RION NA-28 sound level meter and third octave band real-time analyser was used to measure the audible noise.
- Prior to commencing with the measurements, the sensitivity of the sound level meter together with its associated microphone and preamplifier were checked with the RION NA-74 acoustic calibrator in accordance with the manufacturer's instructions.
- On completion of the day's measurements, the calibration check was repeated.
- The weather parameters were also recorded throughout the time of measurement at spot times.

Weather Conditions

DATE:	16 February 2017		17 February 2017	
TIME:	21:57	22:34	08:29	11:52
TEMPERATURE (°C):	19.6	18.5	21.5	28.5
HUMIDITY (%RH)	70.6	78.0	60.0	36.2
PRESSURE (hPA)	1005.2	1003.6	1002.4	1001.9
WIND SPEED (m/s)	< 3.8	< 3	< 2	< 2
COMMENTS	Clear moonlight sky, with slight breeze		Weather was fine, sunny and no clouds present	

Weather Parameters Conducted During the Measurement Program on the 16 and 17 February 2017 for Substation A

TIME	TEMPERATURE (°C)	HUMIDITY (%RH)	PRESSURE (hPA)	WIND SPEED (m/s)
15:04	29.8	30.5	836.9	< 3
15:32	28.2	31.2	836.4	< 3.2
22:00	18.6	63.5	838.5	No wind
22:44	17.0	69.1	839.2	No wind
00:00	21.5	56.2	839.4	< 0.1

Weather Parameters Conducted During the Measurement Program on the 15 March 2017 for Substation B

Measured and Predicted Noise Level Comparison – Substation A

POSITION	DAY-TIME		NIGHT-TIME		COMMENTS
	LA_{eq}	LA_{eq} (Predicted)	LA_{eq}	LA_{eq} (Predicted)	
CAL	93.9		93.9		Calibration of instrument
REC 2	49.6	40.3	47.2	47.2	
REC 3	48.2	44.6	48.8	49.6	
REC 4	50.2	44.3	52.0	52.2	
REC 5	48.4	42.4	59.0	56.8	
REC 6	49.4	44.1	64.4	68.2	Reactor 1
REC 7	49.6	44.2	69.8	69.8	Reactor 2
REC 8	50.7	43.9	69.4	69.2	Reactor 3
REC 9	51.4	43.1	57.7	56.9	
REC 10	49.7	44.6	52.5	51.9	
REC 11	50.2	47.5	54.0	51.6	Line trap/ surge arrestors
REC 12	50.1	46.3	53.6	50	
REC 13	51.8	48.5	53.6	51	
REC 14	55.5	53.3	57.5	54.8	Beneath the PI with no corona rings
REC 15	51.3	46.0	53.7	49.1	
REC 16	49.0	41.2	52.9	46.1	
REC 17	45.0	40.9	47.0	44.9	
REC 18	43.2	41.7	46.1	44.8	
REC 19	41.3	40.8	44.8	44.1	
REC 20	39.7	39.9	44.0	43.1	
REC 21	45.5	42.1	52.5	44.8	
REC 22	45.5	42.2	50.2	44.9	
REC 23	44.1	43.1	49.9	45.5	
REC 24	44.5	43.5	45.6	45.6	
REC 25	49.9	46.4	47.8	48.1	
REC 26	51.5	51.6	50.4	52.5	
REC 27	60.0	59.9	54.7	60.1	Transformer 1
REC 28	59.6	60.9	55.0	61.1	Transformer 2
REC 29	57.1	60.9	55.6	61	Transformer 3
REC 30	93.9		93.9		

Measured and Predicted Noise Level Comparison – Substation B

POSITION	DAY-TIME		NIGHT-TIME		COMMENTS
	LA_{eq}	LA_{eq} (Predicted)	LA_{eq}	LA_{eq} (Predicted)	
CAL	93.9	-	93.9	-	Calibration of instrument
REC 2	47.1	39.6	49.0	39.6	
REC 3	47.3	39.8	50.2	39.8	
REC 4	46.6	39.3	49.6	39.3	
REC 5	49.9	40.7	53.5	40.7	
REC 6	54.0	45	59.0	45	
REC 7	57.7	53.4	59.8	53.4	
REC 8	69.9	65.5	70.3	65.5	Reactor 1
REC 9	66.9	67.5	71.5	67.5	Reactor 2
REC 10	70.3	66	72.1	66	Reactor 3
REC 11	55.2	48.3	58.2	48.3	
REC 12	52.6	46.2	55.7	46.2	
REC 13	54.0	45.3	56.6	45.3	
REC 14	49.4	44.4	50.0	44.4	
REC 15	45.1	38.1	44.8	38.1	
REC 16	40.5	35.5	41.0	35.5	
REC 17	39.4	34.5	45.0	34.5	
REC 18	38.5	35	42.7	35	
REC 19	38.9	33	42.5	33	
REC 20	42.0	36	45.4	36	
REC 21	41.9	37.7	46.4	37.7	
REC 22	63.1	60.2	58.9	60.2	Transformer 1
REC 23	61.6	60.9	58.2	60.9	Transformer 1
REC 24	60.5	60.4	58.0	60.4	Transformer 1
REC 25	61.5	60.6	57.9	60.6	Transformer 2
REC 26	64.0	61.6	59.2	61.6	Transformer 2
REC 27	59.7	60.5	60.9	60.5	Transformer 2
REC 28	93.9	-	93.9	-	Calibration of instrument

Conclusions

- Measurements of the existing audible noise levels from both the 765 kV substations at the boundary fence for both the day-time and night-time were conducted,
- Predictions based on the noise sources of the existing station with and without the reactors energised were conducted,
- Measured and predictions of the audible noise from the two 765 kV substations were analysed,

Conclusions

- The main noise sources come from the transformers; reactors and corona in both the 765 kV substations. They are mainly in middle and low-frequency band. However, the noise level of the reactors is relatively higher than that of main transformers. The cooling fans can influence the noise of main transformers.
- Interference phenomenon exists in the noise propagation process of the transformers and reactors, and the interference of 100 and 200Hz is most obvious. Layout optimization of the HV reactors could reduce the noise emission level at the substation boundary.
- It can be seen that at each location the noise levels are consistent and that there is little variation between the day-time and night-time periods, except near the reactors. This was due to the reactors being out of service during the day-time measurements. This observation indicates that the noise climate in the area is dominated by plant and industrial noise.

Conclusions

- Within the South African context, SANS 10103:2003 gives an indication of the criteria for an assessment of annoyance.
- This scientific approach is complex and it is not appropriate to provide all the details in this report.
- In overview this Standard indicates that there are likely to be specific responses by communities/groups to given changes in noise level from the residual noise level of an area.
- From the predictions and measurements conducted, for the transformers and reactors both for the day-time and night-time and comparing it to the acceptable noise levels, it is concluded, that the noise levels exceed the rural and suburban districts with little road traffic.

Questions

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