

PotashCorp – New Brunswick Division Picadilly Potash Project

ETAP SIMULATION

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1. GENERAL

1.1 Purpose of this Study

The purpose of this study is to check the harmonic distortion at the Point of Common Coupling in compliance with IEEE 519 guidelines. This study is based on available data as indicated in the next section. The system simulation has been performed using ETAP Software Version 5.5.6

1.2 Data Available

Following files and documents were available:

Penobsquis VFD MCCs.pdf	Motor List
Picadilly VFD MCCs.pdf	Motor List
Load Distribution for Cap Banks Pic and Pen.xls	Excel Spreadsheet
PSMV1003-1.dwg	Drawing # 130-20-10000
PSMV1003-1.dwg	Drawing # 130-20-10001
PSMV1003-2.dwg	Drawing # 130-20-10002
320-20-41201%20R1_6142-1.pdf	System Layout

Filter Data

BANKS 1,2		
Step1		
Nominal	2000	KVAR
Effective	2011	KVAR @ 13.8 KV
C	26.74	μF / ph
C	6x500.06	KVAR @ 9.96 KV
XL	4.490	Ohms
N	4.70	h
Step2		
Nominal	2000	KVAR
Effective	1968	KVAR @ 13.8 KV
C	27.86	μF
C	6x500.73	KVAR @ 9.96 KV
XL	2.199	Ohms
N	6.58	h
BANKS 3, 4, 5		
Step1		
Nominal	2500	KVAR
Effective	2632	KVAR @ 13.8 KV
C	35.00	μF
C	6x600.45	KVAR @ 9.54 KV
XL	3.431	Ohms
N	4.70	h
Step2		
Nominal	2500	KVAR
Effective	2572	KVAR @ 13.8 KV
C	35.00	μF
C	6x600.39	KVAR @ 9.54 KV
XL	1.751	Ohms
N	6.58	h
Step3		
Nominal	2500	KVAR
Effective	2535	KVAR @ 13.8 KV
C	34.98	μF
C	6x600.07	KVAR @ 9.54 KV
XL	0.706	Ohms
N	10.34	h

1.3 Assumptions

Following the data specified above and having installed the one line diagram on ETAP, the following assumptions were made:

Utility: Isc = 4.18 kA sym. @ 138 kV
1,000 MVA

Tie-breakers Open at all voltage levels

Feeder 1007A Open

Harmonic Injections As per Amec Specifications #156930-E-SP-16331,
Section 2.2 Sources of Harmonic Currents, pages 14 -16

1.4 Summary

Harmonic Currents - IEEE519 Compliance

As per Section 2.2 of this report, a compliance with IEEE 519 guidelines was found for the simulated system at the PCC point. The only remark due is that the mine hoist drives do not show any low end harmonic injection for $n < 35$, but adding limited harmonics (less than 5%) below that frequency does not change the results.

2. RESULTS

2.1 ETAP Single Line Diagram

2.2 Current and Voltage Harmonics at PCC

The following table shows the harmonic currents at the primary side of the main 40 MVA 138/13.8 kV transformers T303 and T304:

		T303	T304	T303	T304
		[%]	[%]	Amp	Amp
1	IEEE	100	100	115.06	96.20
5	4	0.2750	0.3243	0.32	0.31
7	4	0.0347	0.0532	0.04	0.05
11	2	0.0105	0.0211	0.01	0.02
13	2	0.0122	0.0271	0.01	0.03
17	1.5	0.0088	0.0188	0.01	0.02
19	1.5	0.0083	0.0169	0.01	0.02
23	0.6	0.0055	0.0100	0.01	0.01
25	0.6	0.0039	0.0073	0.00	0.01
29	0.6	0.0040	0.0071	0.00	0.01
31	0.6	0.0035	0.0066	0.00	0.01
35	0.3	0.0731	0.1439	0.08	0.14
37	0.3	0.0469	0.0906	0.05	0.09
41	0.3	0.0017	0.0024	0.00	0.00
43	0.3	0.0018	0.0024	0.00	0.00
47	0.3	0.0588	0.1042	0.07	0.10
49	0.3	0.0467	0.0811	0.05	0.08
59	0.3	0.0172	0.0282	0.02	0.03
61	0.3	0.0105	0.0169	0.01	0.02
71	0.3	0.0037	0.0056	0.00	0.01
73	0.3	0.0075	0.0113	0.01	0.01
THD	5	0.3016	0.3970		

The above table show comfortable compliance with IEEE limits for $I_{sc}/I_L < 20$ (most demanding condition, worst case possible).

The following table shows the voltage harmonics at the main 13.8 kV busses SGR303 and SGR304 (40 MVA main transformers, secondary side):

	SGR303	SGR304	SGR303	SGR304
	[%]	[%]	Volts	Volts
1	100	100	13800	13800
5	0.1511	0.1501	20.85	20.71
7	0.0291	0.0336	4.02	4.64
11	0.0142	0.0196	1.96	2.71
13	0.0209	0.0300	2.89	4.14
17	0.0193	0.0274	2.67	3.78
19	0.0199	0.0277	2.74	3.82
23	0.0151	0.0201	2.08	2.77
25	0.0116	0.0158	1.61	2.17
29	0.0134	0.0179	1.84	2.47
31	0.0126	0.0177	1.74	2.44
35	0.3161	0.4416	43.63	60.94
37	0.2114	0.2945	29.17	40.64
41	0.0073	0.0088	1.01	1.22
43	0.0076	0.0091	1.05	1.26
47	0.3169	0.4364	43.73	60.22
49	0.2590	0.3553	35.74	49.03
59	0.1091	0.1503	15.05	20.74
61	0.0678	0.0934	9.36	12.89
71	0.0267	0.0367	3.68	5.06
73	0.0551	0.0757	7.60	10.44
THD	0.60	0.82		

Voltage THD values are well below IEEE limit of 3% for Special Applications (worst case).

2.3 Filter Currents

The following tables show the filter currents for the different filter steps:

	F1.STP1	F1.STP2	F1.STP1	F1.STP2	F3.STP1	F3.STP2	F3.STP3	F3.STP1	F3.STP2	F3.STP3
	[%]	[%]	Amps	Amps	[%]	[%]	[%]	Amps	Amps	Amps
1	100	100	83.13	81.37	100	100	100	109.81	107.32	105.75
5	5.4861	1.7564	4.56	1.43	4.9544	1.7440	0.9789	5.44	1.87	1.04
7	0.1866	1.7576	0.16	1.43	0.1590	1.2774	0.3724	0.17	1.37	0.39
11	0.0466	0.1189	0.04	0.10	0.0332	0.0841	0.8508	0.04	0.09	0.90
13	0.0567	0.1328	0.05	0.11	0.0388	0.0904	0.4394	0.04	0.10	0.46
17	0.0372	0.0811	0.03	0.07	0.0256	0.0556	0.1852	0.03	0.06	0.20
19	0.0331	0.0708	0.03	0.06	0.0231	0.0493	0.1527	0.03	0.05	0.16
23	0.0194	0.0407	0.02	0.03	0.0141	0.0294	0.0841	0.02	0.03	0.09
25	0.0139	0.0290	0.01	0.02	0.0099	0.0205	0.0572	0.01	0.02	0.06
29	0.0135	0.0278	0.01	0.02	0.0096	0.0197	0.0533	0.01	0.02	0.06
31	0.0124	0.0255	0.01	0.02	0.0084	0.0172	0.0460	0.01	0.02	0.05
35	0.2743	0.5597	0.23	0.46	0.1834	0.3735	0.9829	0.20	0.40	1.04
37	0.1727	0.3517	0.14	0.29	0.1150	0.2338	0.6117	0.13	0.25	0.65
41	0.0046	0.0094	0.00	0.01	0.0035	0.0072	0.0186	0.00	0.01	0.02
43	0.0046	0.0093	0.00	0.01	0.0035	0.0071	0.0182	0.00	0.01	0.02
47	0.2002	0.4053	0.17	0.33	0.1302	0.2632	0.6757	0.14	0.28	0.71
49	0.1562	0.3160	0.13	0.26	0.1012	0.2044	0.5235	0.11	0.22	0.55
59	0.0547	0.1104	0.05	0.09	0.0339	0.0682	0.1733	0.04	0.07	0.18
61	0.0329	0.0663	0.03	0.05	0.0202	0.0406	0.1031	0.02	0.04	0.11
71	0.0111	0.0223	0.01	0.02	0.0065	0.0131	0.0331	0.01	0.01	0.03
73	0.0222	0.0447	0.02	0.04	0.0129	0.0260	0.0657	0.01	0.03	0.07
THD %	5.51	2.63			4.97	2.24	2.05			
IRMS A			83.26	81.40				109.95	107.35	105.77

Where: F1.STP1 is Filter 1 Step1, etc.

Note: Only Filters 1 and 3 are listed above. The fundamental and harmonic currents of Filter 2 are almost identical as for Filter 1. The fundamental and harmonic currents of Filters 4 and 5 are almost identical as for Filter 3. This is because the currents depend mainly on the filter components (Filter 1 and 2 are identical and Filters 3 to 5 are identical). The bus impedances are also basically identical on each of both filter types, as no cabling has been considered in this simulation and the transformers for feeding each filter type are identical. Loads are all different though, but they do not affect the Z bus /Z filter ratio calculation by any considerable value. This fact was double-checked on the ETAP model.

The table above shows there will be no major harmonic over-loading of the filter reactors due to the extremely limited harmonic currents.

2.4 Capacitor Voltages

The following tables show the filter voltages for the different filter steps:

	F1.STP1	F1.STP2	F3.STP1	F3.STP2	F3.STP3
	Volts	Volts	Volts	Volts	Volts
1	13,800	13,800	13,800	13,800	13,800
5	94.42	32.44	101.23	34.83	19.28
7	2.33	18.32	2.36	18.54	5.33
11	0.27	0.67	0.32	0.79	7.90
13	0.31	0.71	0.32	0.72	3.45
17	0.16	0.35	0.16	0.35	1.15
19	0.13	0.28	0.13	0.28	0.84
23	0.07	0.13	0.07	0.13	0.38
25	0.04	0.09	0.04	0.09	0.24
29	0.04	0.07	0.04	0.07	0.19
31	0.03	0.06	0.03	0.06	0.17
35	0.75	1.49	0.75	1.49	3.87
37	0.44	0.88	0.44	0.88	2.28
41	0.01	0.02	0.01	0.02	0.04
43	0.01	0.02	0.01	0.02	0.04
47	0.39	0.78	0.40	0.79	1.99
49	0.29	0.58	0.30	0.58	1.47
59	0.08	0.16	0.08	0.16	0.41
61	0.05	0.09	0.05	0.09	0.24
71	0.01	0.03	0.01	0.03	0.07
73	0.03	0.05	0.03	0.05	0.13
SUM	13,900	13,857	13,907	13,860	13,849

Where: F1.STP1 is Filter 1 Step1, etc.

Note: Only Filters 1 and 3 are listed above. Same is valid as for the harmonic currents.

2.5 Conclusions

As per Section 2.2 of this report, a compliance with IEEE 519 guidelines was found for the simulated system at the PCC point and there will be no major harmonic over-loading of the filter reactors due to the extremely limited harmonic currents of the hoist drives. Voltage harmonics will also not represent any major problem for the capacitors. Some harmonics at the low frequency end could result higher than the predicted values from this model, as some 5th, 7th and 11th harmonics will most likely spill over from the large hoist drives anyhow. A hoist duty cycle would help to improve the accuracy of the predicted harmonic levels considering that peak torque requirements of mine hoist drives for about 10 to 20 seconds every 2 minutes are normally about 200% or even higher.

3. APPENDIX

3.1 IEEE Guidelines

IEEE 519 Guidelines for Current Distortion

IEEE Std 519-1992

IEEE RECOMMENDED PRACTICES AND REQUIREMENTS

Table 10-3—Current Distortion Limits for General Distribution Systems (120 V Through 69 000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	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

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

* All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L .

where

I_{sc} = maximum short-circuit current at PCC.

I_L = maximum demand load current (fundamental frequency component) at PCC.

IEEE 519 Guidelines for Voltage Distortion

Table 10-2—Low-Voltage System Classification and Distortion Limits

	Special Applications *	General System	Dedicated System †
Notch Depth	10%	20%	50%
THD (Voltage)	3%	5%	10%
Notch Area (A_N) ‡	16 400	22 800	36 500

NOTE — The value A_N for other than 480 V systems should be multiplied by $V/480$

*Special applications include hospitals and airports.

†A dedicated system is exclusively dedicated to the converter load.

‡In volt-microseconds at rated voltage and current.