Welcome

Power Survey Application & Product Training

Power Survey International – Company profile

- Established since 1948

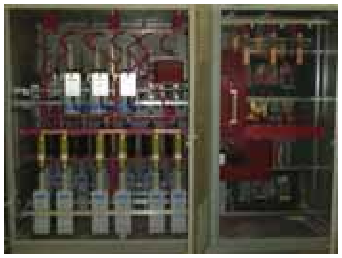
- Manufacturer of low and medium voltage products:
    - Power Factor correction system
    - Harmonic Filter system
    - Steel Cabinet – customized to your needs
    - Other products to come….

- Sales throughout United States, Canada, South America, Middle East and the rest of the world.

Available products at Power Survey

- **<u>Industrial & Commercial Market</u>**
  - ✓ Static capacitor unit – PowerCap
  - ✓ Automatic capacitor bank - PowerVar
  - ✓ Fixed harmonic filter – PowerCap Filter
  - ✓ Automatic Harmonic filter – PowerVar Filter
  - ✓ On site harmonic study
  - ✓ Simulation / Electrical network analysis

- **<u>Utility Market</u>**
  - ✓ Metal Enclosed Capacitor Bank – Medium Voltage
  - ✓ Harmonic Filter - Medium Voltage
  - ✓ Pad Mount type



- **<u>Steel Enclosure</u>**
  - ✓ Manufactured according to customer specifications

Installing capacitors…. Why?

- Increase the PF/effiency of the electrical network
- Utilities penalize their customers if PF:
  - ✓ < 100 %

OR

  - ✓ < 90 %

- Average payback of our equipment is between 1 to 2 years
- Average lifetime of our equipment is approximatively 20 years

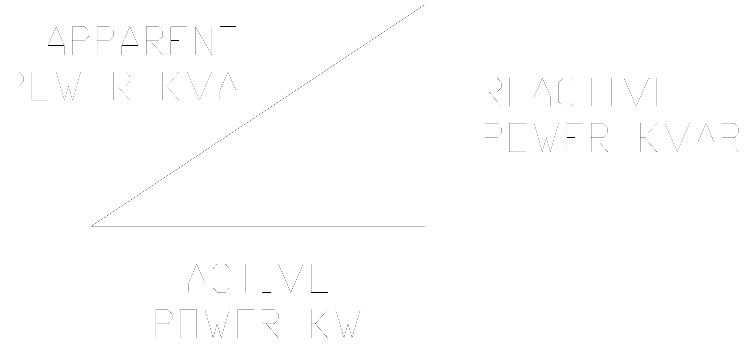
Installing capacitor - technically?

- ✓ Savings of $$ through power factor penalties,
  - Usually less than 2 year payback
  - Most Utilities requires a 90% or higher PF
- ✓ Voltage improvement,
- ✓ Reduced system losses through cables and transformers,
- ✓ Increases power transmission capacity in cables,
- ✓ Increases transformer capacity

Introduction

What is power factor and related formulas:

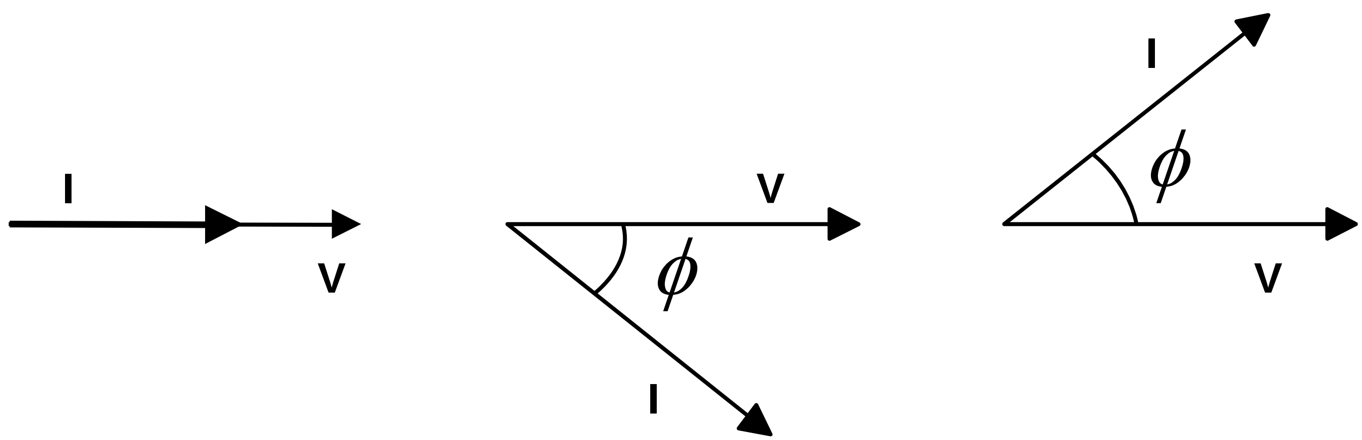
$$P.F. = \frac{\text{Active Power}}{\text{Apparent Power}} = \frac{KW}{KVA}$$



$$KVA = \sqrt{(kW)^2 + (kvar)^2}$$

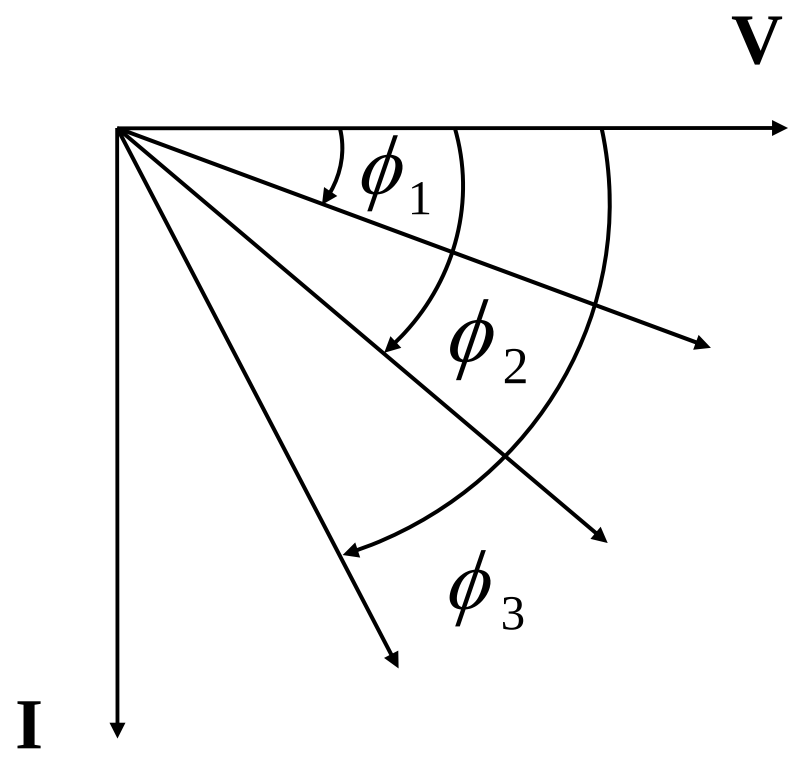
Phase diagram of voltage and current

Resistive current **Inductive current** **Capacitive current**



Power Factor – phase angle

ϕ	PF=Cos ϕ
0	1
30	0,866
60	0,5
90	0

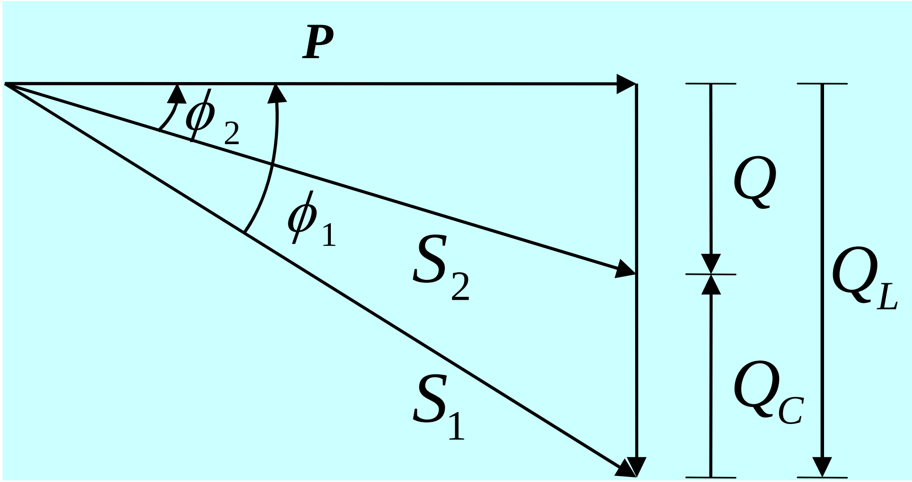


Power Factor – Phase Angle

- Q (kvar) varies depending on phase angle

- From this figure:

$$Q_c = Q_L - Q$$



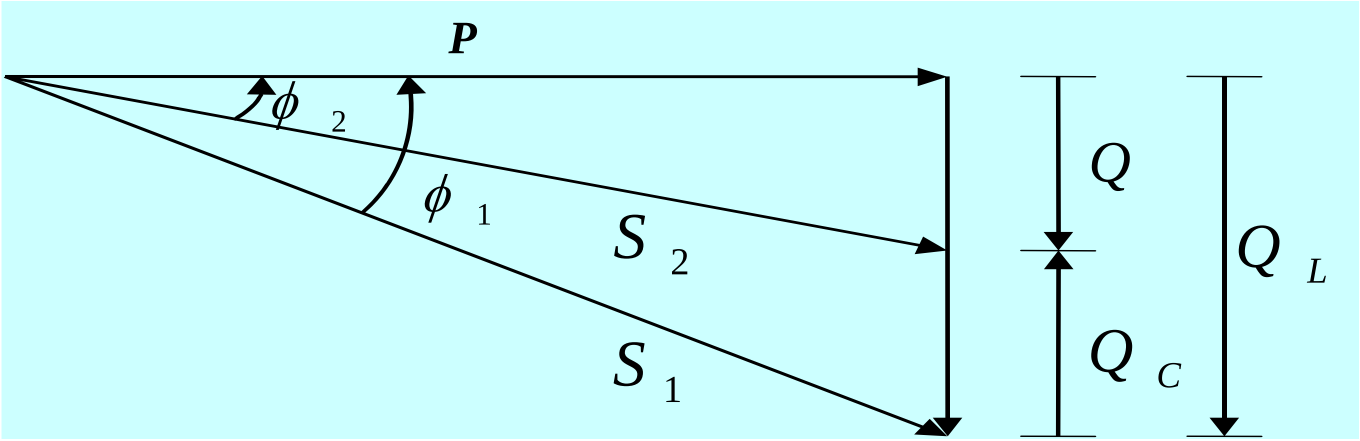
- Mathematically:

$$\Rightarrow Q_c = P(Tan\phi_1 - Tan\phi_2)$$

- Simple calculation:

$$Q_c = P * K$$

Reactive power formulas (kVAR)



$$\mathrm{tg}\,\phi = \frac{kVAR}{kW} \longrightarrow \phi = \mathrm{tg}^{-1}\left[\frac{kVAR}{kW}\right]$$

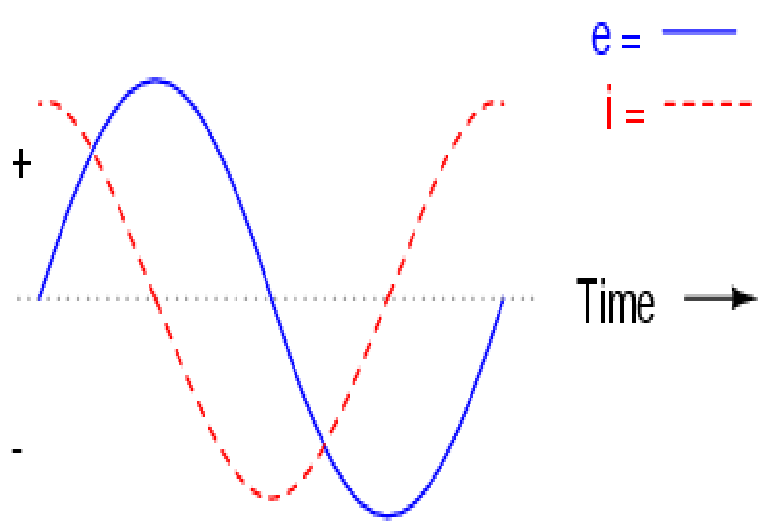
$$FP = Cos\phi \longrightarrow \phi = Cos^{-1}\ FP$$

$$kVAR = kW * \mathrm{tg}\ \phi \longrightarrow kVAR = kW * \mathrm{tg}\left(Cos^{-1}\ FP\right)$$

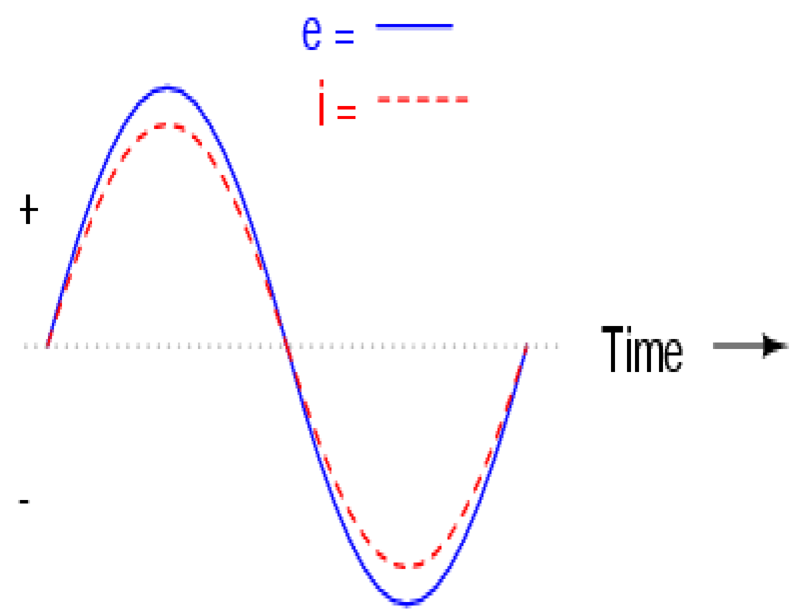
$$kVAR = kW\left[\ \mathrm{tg}\left(\cos^{-1}\ FP_1\right) - \mathrm{tg}\left(\cos^{-1}\ FP_2\right)\right]$$

Voltage and current sine wave

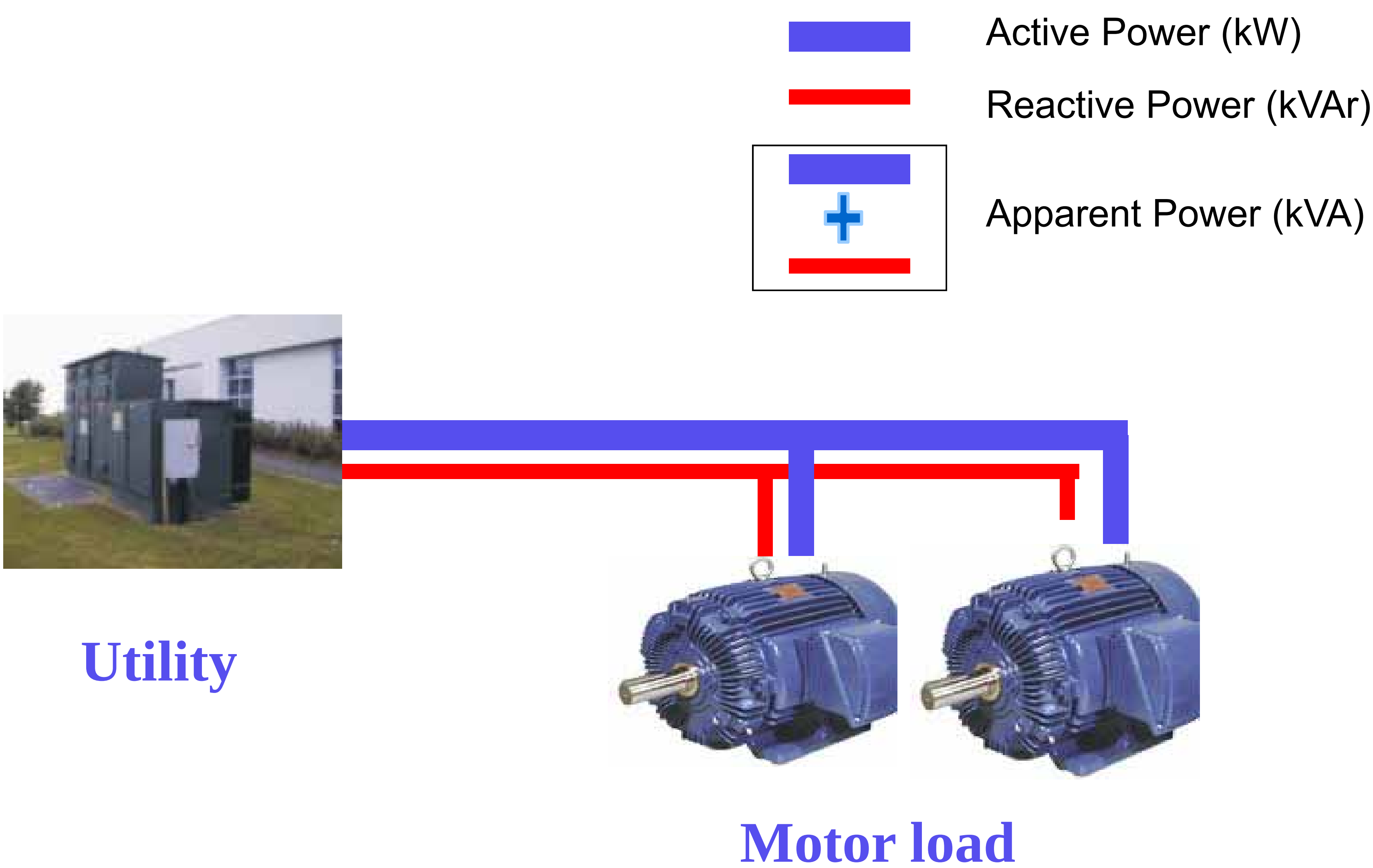
- Capacitor current leads the voltage sinewave



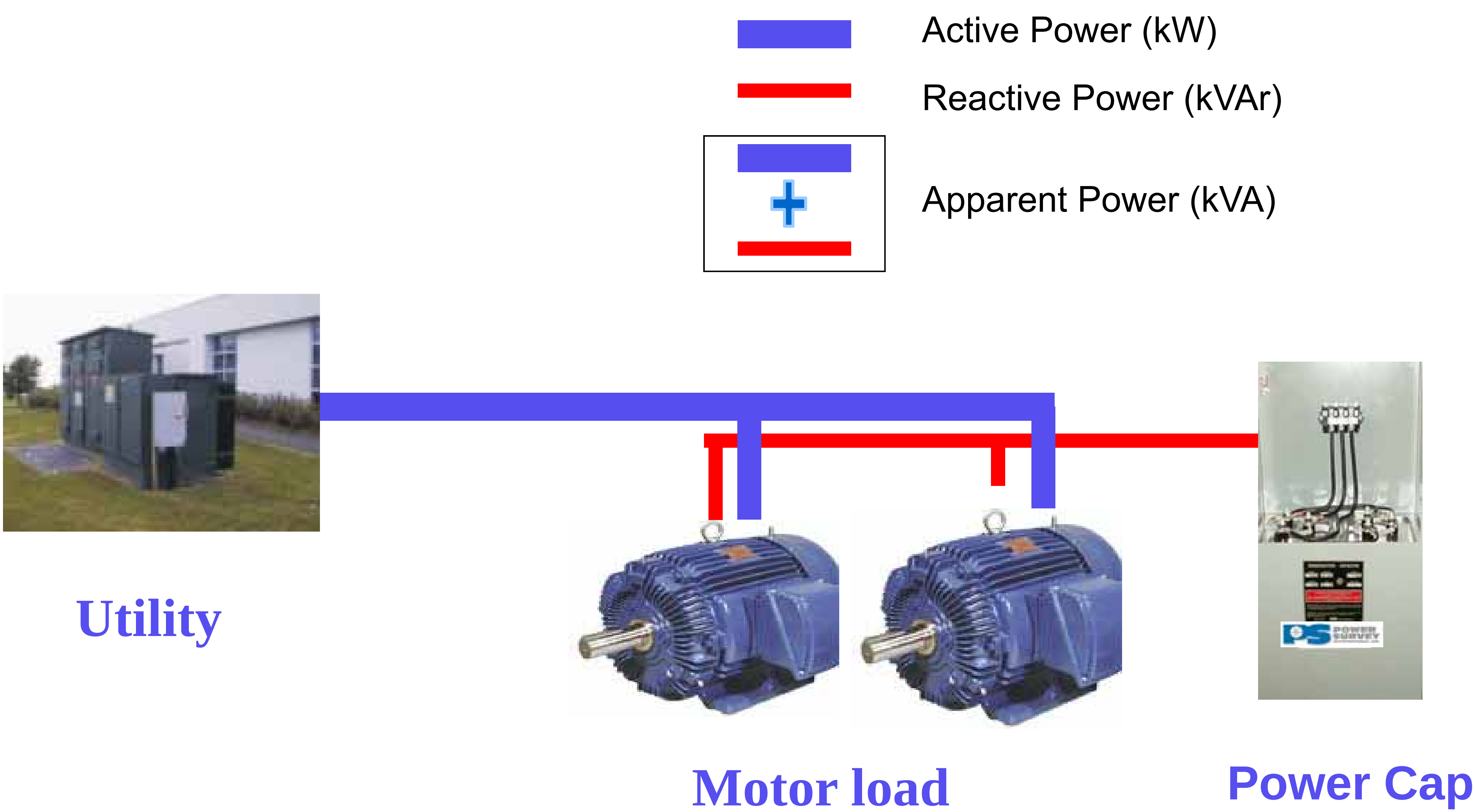
- Resistive current is in phase with voltage sinewave



Electrical network without capacitor



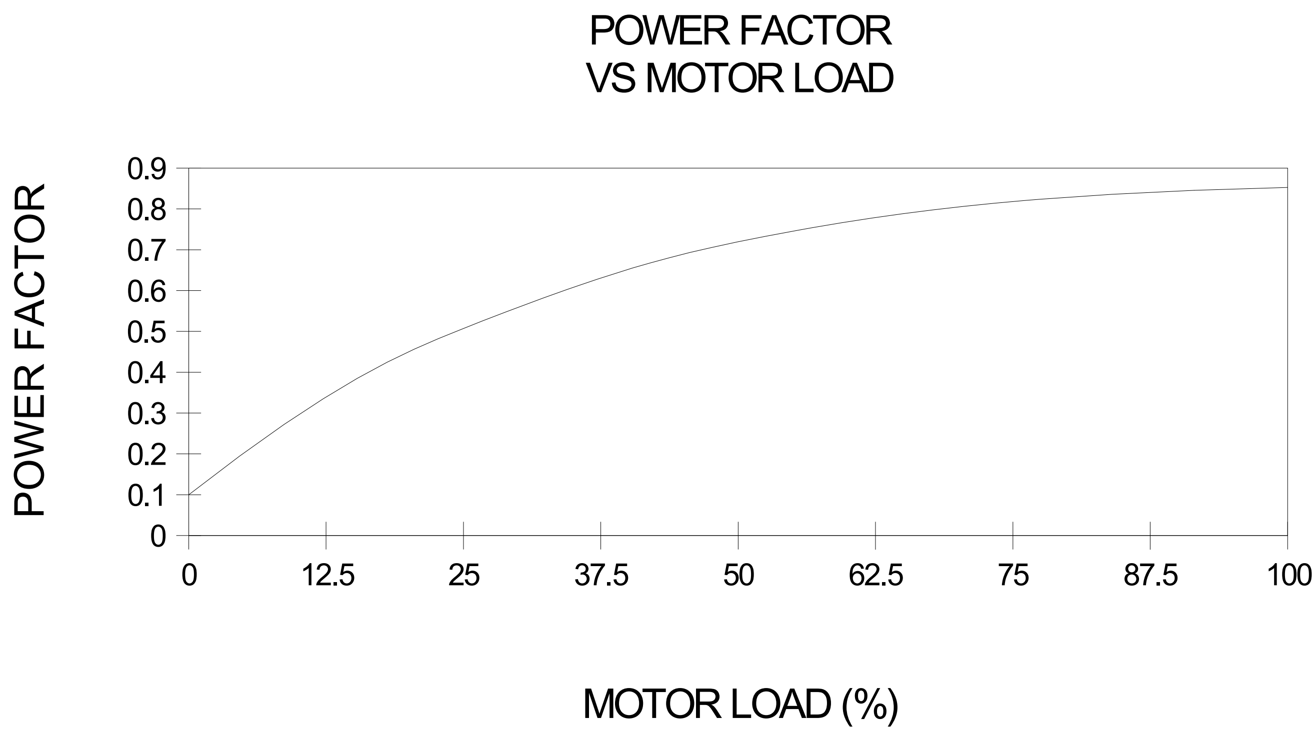
Electrical network with capacitor



Power Factor & Buck of beer!!

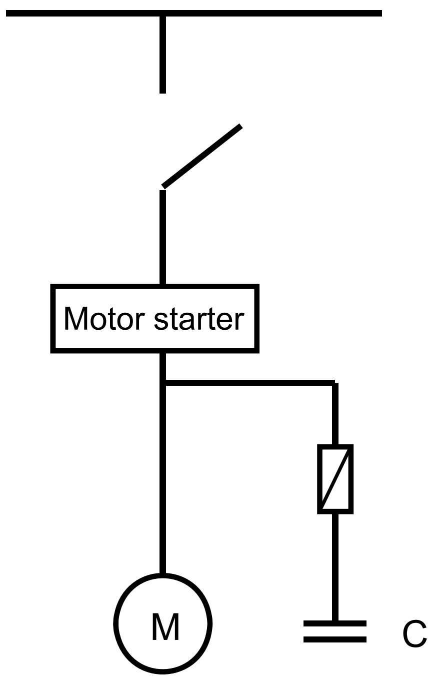
Power factor versus motor load

➢ <u>Motor</u>
- Higher efficiency when used at full load
- Kvar is almost the same when running at low & full load



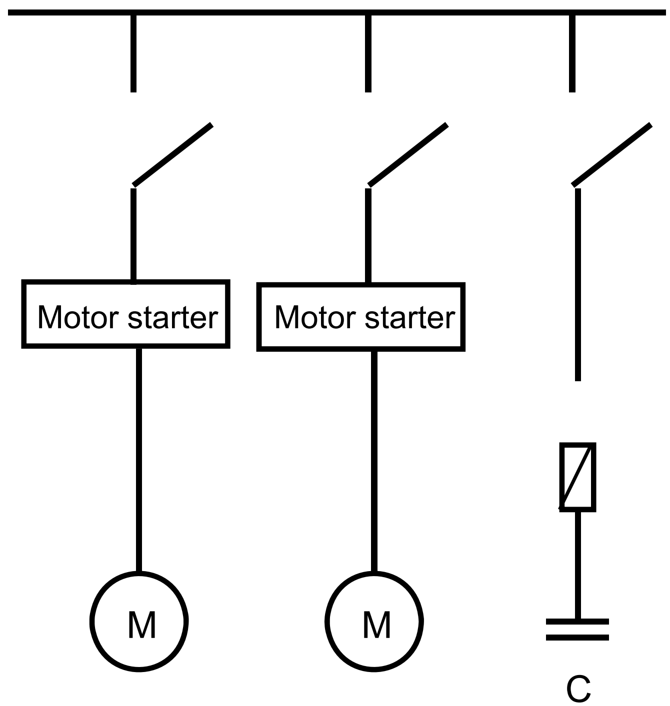
Compensation Method

- **Capacitor connected to motor**



Compensation Method

- **Fixed capacitor connected to a PDC or MCC**



Motor compensation

- Power Survey Rule of thumb:
  - Kvar = 1/3 of size of HP
  - Kvar = 40% of motor kW

- Selection of a capacitor for a specific motor requires HP and RPM of motor:
  - Use following table

Capacitor selection as per motor size

USED FOR HIGH EFFICIENCY MOTORS AND OLDER DESIGN (PRE "T-FRAME") MOTORS*

Induction Motor Horsepower Rating	No. of Poles and Nominal Motor Speed in RPM: 2 — 3600 RPM Capacitor KVAR	2 — 3600 RPM Current Reduction %	4 — 1800 RPM Capacitor KVAR	4 — 1800 RPM Current Reduction %	6 — 1200 RPM Capacitor KVAR	6 — 1200 RPM Current Reduction %	8 — 900 RPM Capacitor KVAR	8 — 900 RPM Current Reduction %	10 — 720 RPM Capacitor KVAR	10 — 720 RPM Current Reduction %	12 — 600 RPM Capacitor KVAR	12 — 600 RPM Current Reduction %
3	1.5	14	1.5	15	1.5	20	2	27	2.5	35	3	41
5	2	12	2	13	2	17	3	25	4	32	4	37
7.5	2.5	11	2.5	12	3	15	4	22	5	30	6	34
10	3	10	3	11	3	14	5	21	6	27	7.5	31
15	4	9	4	10	5	13	6	18	8	23	9	27
20	5	9	5	10	6	12	7.5	16	9	21	12.5	25
25	6	9	6	10	7.5	11	9	15	10	20	15	23
30	7	8	7	9	9	11	10	14	12.5	18	17.5	22
40	9	8	9	9	10	10	12.5	13	15	16	20	20
50	12.5	8	10	9	12.5	10	15	12	20	15	25	19
60	15	8	15	8	15	10	17.5	11	22.5	15	27.5	19
75	17.5	8	17.5	8	17.5	10	20	10	25	14	35	18
100	22.5	8	20	8	25	9	27.5	10	35	13	40	17
125	27.5	8	25	8	30	9	30	10	40	13	50	16
150	30	8	30	8	35	9	37.5	10	50	12	50	15
200	40	8	37.5	8	40	9	50	10	60	12	60	14
250	50	8	45	7	50	8	60	9	70	11	75	13
300	60	8	50	7	60	8	60	9	80	11	90	12
350	60	8	60	7	75	8	75	9	90	10	95	11
400	75	8	60	6	75	8	85	9	95	10	100	11
450	75	8	75	6	80	8	90	9	100	9	110	11
500	75	8	75	6	85	8	100	9	100	9	120	10

*For use with 3-phase, 60 hertz NEMA Classification B Motors to raise full load power factor to approximately 95%.

TABLE 2: SUGGESTED MAXIMUM CAPACITOR RATINGS — "T-FRAME" NEMA "DESIGN B" MOTORS*

Induction Motor Horsepower Rating	No. of Poles and Nominal Motor Speed in RPM: 2 — 3600 RPM Capacitor KVAR	2 — 3600 RPM Current Reduction %	4 — 1800 RPM Capacitor KVAR	4 — 1800 RPM Current Reduction %	6 — 1200 RPM Capacitor KVAR	6 — 1200 RPM Current Reduction %	8 — 900 RPM Capacitor KVAR	8 — 900 RPM Current Reduction %	10 — 720 RPM Capacitor KVAR	10 — 720 RPM Current Reduction %	12 — 600 RPM Capacitor KVAR	12 — 600 RPM Current Reduction %
2	1	14	1	24	1.5	30	2	42	2	40	3	50
3	1.5	14	1.5	23	2	28	3	38	3	40	4	49
5	2	14	2.5	22	3	26	4	31	4	40	5	49
7.5	2.5	14	3	20	4	21	5	28	5	38	6	45
10	4	14	4	18	5	21	6	27	7.5	36	8	38
15	5	12	5	18	6	20	7.5	24	8	32	10	34
20	6	12	6	17	7.5	19	9	23	10	29	12.5	30
25	7.5	12	7.5	17	8	19	10	23	12.5	25	17.5	30
30	8	11	8	16	10	19	15	22	15	24	20	30
40	12.5	12	15	16	15	19	17.5	21	20	24	25	30
50	15	12	17.5	15	20	19	22.5	21	22.5	24	30	30
60	17.5	12	20	15	22.5	17	25	20	30	22	35	28
75	20	12	25	14	25	15	30	17	35	21	40	19
100	22.5	11	30	14	30	12	35	16	40	15	45	17
125	25	10	35	12	35	12	40	14	45	15	50	17
150	30	10	40	12	40	12	50	14	50	13	60	17
200	35	10	50	11	50	11	70	14	70	13	90	17
250	40	11	60	10	60	10	80	13	90	13	100	17
300	45	11	70	10	75	12	100	14	100	13	120	17
350	50	12	75	8	90	12	120	13	120	13	135	15
400	75	10	80	8	100	12	130	13	140	13	150	15
450	80	8	90	8	120	10	140	12	160	14	160	15
500	100	8	120	9	150	12	160	12	180	13	180	15

use with 3-phase, 60 hertz NEMA Classification B Motors to raise full load power factor to approximately 95%.

Selection of a PowerCap

Dimensions listed are for standardized units / only without options — Consult factory for dimensions with options.

KVAR	240V Cat #	Current (amps)	Weight (lbs)	KVAR	480V Cat #	Current (amps)	Weight (lbs)	KVAR	600V Cat #	Current (amps)	Weight (lbs)
1	PS2P1A	2.4	12	1	PS4P1A	1.2	12	1	PS6P1A	1.0	12
1.5	PS2P1.5A	3.6	13	1.5	PS4P1.5A	1.8	12	1.5	PS6P1.5A	1.4	12
2	PS2P2A	4.8	13	2	PS4P2A	2.4	12	2	PS6P2A	1.9	12
2.5	PS2P2.5A	6.0	13	2.5	PS4P2.5A	3.0	13	2.5	PS6P2.5A	2.4	13
3	PS2P3A	7.2	14	3	PS4P3A	3.6	13	3	PS6P3A	2.9	13
4	PS2P4A	9.6	14	4	PS4P4A	4.8	13	4	PS6P4A	3.8	13
5	PS2P5A	12.0	15	5	PS4P5A	6.0	14	5	PS6P5A	4.8	14
6	PS2P6A	14.4	15	6	PS4P6A	7.2	14	6	PS6P6A	5.8	14
7.5	PS2P7.5A	18.0	20	7.5	PS4P7.5A	9.0	14	7.5	PS6P7.5A	7.2	14
8	PS2P8A	19.2	29	8	PS4P8A	9.6	28	8	PS6P8A	7.7	28
9	PS2P9A	21.7	29	9	PS4P9A	10.8	29	9	PS6P9A	8.7	29
10	PS2P10A	24.1	22	10	PS4P10A	12.0	15	10	PS6P10A	9.6	15
11	PS2P11B	26.5	30	11	PS4P11A	13.2	18	11			
12.5	PS2P12.5B	30.1	30	12.5	PS4P12.5A	15.0	19	12.5	PS6P12.5A	12.0	19
15	PS2P15B	36.1	31	15	PS4P15A	18.0	20	15	PS6P15A	14.4	20
17.5	PS2P17.5B	42.1	32	17.5	PS4P17.5A	21.0	20	17.5	PS6P17.5A	16.8	20
20	PS2P20B	48.1	34	20	PS4P20A	24.1	21	20	PS6P20A	19.2	21
22.5	PS2P22.5C	54.1	40	22.5	PS4P22.5A	27.1	22	22.5	PS6P22.5A	21.7	22
25	PS2P25C	60.1	41	25	PS4P25A	30.1	23	25	PS6P25A	24.1	23
27.5	PS2P27.5C	66.2	43	27.5	PS4P27.5B	33.1	25	27.5	PS6P27.5B	26.5	25
30	PS2P30C	72.2	45	30	PS4P30B	36.1	26	30	PS6P30B	28.9	26
32.5	PS2P32.5D	78.2	46	32.5	PS4P32.5B	39.1	26	32.5	PS6P32.5B	31.3	26
35	PS2P35D	84.2	47	35	PS4P35B	42.1	27	35	PS6P35B	33.7	27
37.5	PS2P37.5D	90.2	48	37.5	PS4P37.5B	45.1	27	37.5	PS6P37.5B	36.1	27
40	PS2P40D	96.2	50	40	PS4P40B	48.1	28	40	PS6P40B	38.5	28
42.5	PS2P42.5E	102.2	60	42.5	PS4P42.5B	51.1	28	42.5	PS6P42.5B	40.9	28
45	PS2P45E	108.3	62	45	PS4P45B	54.1	29	45	PS6P45B	43.3	29
50	PS2P50E	120.3	64	50	PS4P50B	60.1	29	50	PS6P50B	48.1	29
55				55	PS4P55C	66.2	33	55	PS6P55C	52.9	33
60	PS2P60E	144.3	68	60	PS4P60C	72.2	34	60	PS6P60C	57.7	34
65				65	PS4P65C	78.2	36	65	PS6P65C	62.5	36
70	PS2P70G	168.4	75	70	PS4P70C	84.2	37	70	PS6P70C	67.4	37
75	PS2P75G	180.4	78	75	PS4P75C	90.2	38	75	PS6P75C	72.2	38
80	PS2P80G	192.5	80	80	PS4P80D	96.2	40	80	PS6P80D	77.0	40
85				85	PS4P85D	102.2	42	85	PS6P85D	81.8	42
90	PS2P90G	216.5	84	90	PS4P90D	108.3	43	90	PS6P90D	86.6	43
100	PS2P100G	240.6	86	100	PS4P100D	120.3	44	100	PS6P100D	96.2	44
120	PS2P120M	288.7	165	120	PS4P120E	144.3	46	120	PS6P120E	115.5	46
125	PS2P125M	300.7	170	125	PS4P125E	150.4	48	125	PS6P125E	120.3	48
140	PS2P140M	336.8	180	140	PS4P140G	168.4	49	140	PS6P140G	134.7	49
150	PS2P150M	360.8	185	150	PS4P150G	180.4	50	150	PS6P150G	144.3	50
160	PS2P160M	384.9	190	160	PS4P160G	192.5	72	160	PS6P160G	154.0	72
175	PS2P175M	421.0	210	175	PS4P175M	210.5	74	175	PS6P175M	168.4	74
180	PS2P180M	433.0	215	180	PS4P180M	216.5	75	180	PS6P180M	173.2	75
200	PS2P200M	481.1	220	200	PS4P200M	240.6	76	200	PS6P200M	192.5	76
225				225	PS4P225G	270.6	79	225	PS6P225G	216.5	79
250				250	PS4P250G	300.7	83	250	PS6P250G	240.6	83
300				300	PS4P300M	360.8	170	300	PS6P300M	288.7	170
350				350	PS4P350M	421.0	180	350	PS6P350M	336.8	180
400				400	PS4P400M	481.1	195	400	PS6P400M	384.9	195

OPTIONS		
	3 PILOT LIGHTS	ADD SUFFIX L (STANDARD IS LIGHTS OFF, IF LIGHTS ON ALL THE TIME REQUIRED, ADD "ON" SUFFIX
	3 FUSES	ADD SUFFIX F
	NEMA 3 ENCLOSURE	ADD SUFFIX 3
	DRY FILLED CELLS	CHANGE P (4TH DIGIT OF CAT #) TO D
	OTHER RATINGS	CONSULT FACTORY (208V, 380V, 440V, 700V OR OTHER)
	OTHER SIZES	CONSULT FACTORY

Back to back switching and reactor selection for inrush current

- Requirements
  - Transient current kept below 10 kA due to equipment rating(fuses, vacuum switches, etc)
- Transient capacitor current
  - •Inrush current from capacitor upon energization
- Back to back switching
  - Charged capacitor discharging into newly energized capacitor

Transient Current calculation.lnk

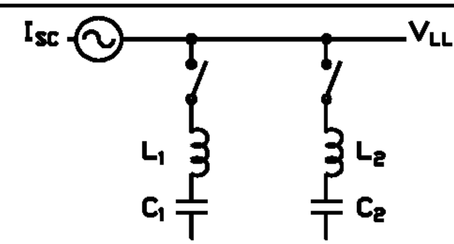
LES EQUIPEMENTS POWER SURVEY

A votre service depuis 1948

CAPACITOR SWITCHING - TRANSIENT CURRENT CALCULATION

PROJECT POWER FACTOR STUDY

DESCRIPTION SWITCHING TRANSIENT CALCULATIONS
REACTOR NEED TO LIMIT INRUSH TO 10KA



STAND ALONE SWITCHING				
C1	600	(KVAR)		
VII	12,47	(KV)	INRUSH CURRENT (PEAK)	1,1454 KA
Isc	25	(KA)		
L1	40	(uH)	INRUSH FREQUENCY	1754,6 Hz
STAND ALONE SWITCHING				
C2	600	(KVAR)		
VII	12,47	(KV)	INRUSH CURRENT (PEAK)	1,1454 KA
Isc	25	(KA)		
L2	40	(uH)	INRUSH FREQUENCY	1754,6 Hz
BACK TO BACK SWITCHING				
C1	600	(KVAR)		
L1	40	(uH)	INRUSH CURRENT (PEAK)	2,7566 KA
C2	600	(KVAR)		
L2	40	(uH)	INRUSH FREQUENCY	7269,3 Hz

PowerCap

☞ Range

- 2 kvar – 10 Mvar

☞ Network voltage

- 208v – 35,000v
- Other voltage available

☞ Option

- Contactor - LV (semi-automatic)
- External Fuse
- Blown Fuse Indicator
- NEMA 3R Enclosure

Calculation of kvar required using power bills

- <u>On the bill we have:</u>
  - PF (Power Factor) = 85.33%
  - Active Power (kW Demand) = 2852 kW
- <u>From the chart:</u>
  - The multiplier from 85% to 92% is 0.194
- <u>The solution:</u>
  - kVAr = multiplier X kW
  - kVAr = 0.194 X 2852
  - kVAr = 527

Before & After PF chart

TABLE 3: MULTIPLIERS TO DETERMINE CAPACITOR KILOVARS REQUIRED FOR POWER FACTOR CORRECTION

Orig-inal Power Factor	Corrected Power Factor																				
	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.0
0.50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.440	1.481	1.529	1.589	1.732
0.51	0.937	0.962	0.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
0.52	0.893	0.919	0.945	0.971	0.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
0.53	0.850	0.876	0.902	0.928	0.954	0.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
0.54	0.809	0.835	0.861	0.887	0.913	0.939	0.966	0.992	1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.559
0.55	0.769	0.795	0.821	0.847	0.873	0.899	0.926	0.952	0.979	1.007	1.035	1.063	1.093	1.124	1.156	1.190	1.227	1.268	1.316	1.376	1.519
0.56	0.730	0.756	0.782	0.808	0.834	0.860	0.887	0.913	0.940	0.968	0.996	1.024	1.054	1.085	1.117	1.151	1.188	1.229	1.277	1.337	1.480
0.57	0.692	0.718	0.744	0.770	0.796	0.822	0.849	0.875	0.902	0.930	0.958	0.986	1.016	1.047	1.079	1.113	1.150	1.191	1.239	1.299	1.442
0.58	0.655	0.681	0.707	0.733	0.759	0.785	0.812	0.838	0.865	0.893	0.921	0.949	0.979	1.010	1.042	1.076	1.113	1.154	1.202	1.262	1.405
0.59	0.619	0.645	0.671	0.697	0.723	0.749	0.776	0.802	0.829	0.857	0.885	0.913	0.943	0.974	1.006	1.040	1.077	1.118	1.166	1.226	1.369
060	0.583	0.609	0.635	0.661	0.687	0.713	0.740	0.766	0.793	0.821	0.849	0.877	0.907	0.938	0.970	1.004	1.041	1.082	1.130	1.190	1.333
0.61	0.549	0.575	0.601	0.627	0.653	0.679	0.706	0.732	0.759	0.787	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.156	1.299
0.62	0.516	0.542	0.568	0.594	0.620	0.646	0.673	0.699	0.726	0.754	0.782	0.810	0.840	0.871	0.903	0.937	0.974	1.015	1.063	1.123	1.266
0.63	0.483	0.509	0.535	0.561	0.587	0.613	0.640	0.666	0.693	0.721	0.749	0.777	0.807	0.838	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.474	0.503	0.529	0.555	0.581	0.608	0.634	0.661	0.689	0.717	0.745	0.775	0.806	0.838	0.872	0.909	0.950	0.998	1.068	1.201
0.65	0.419	0.445	0.471	0.497	0.523	0.549	0.576	0.602	0.629	0.657	0.685	0.713	0.743	0.774	0.806	0.840	0.877	0.918	0.966	1.026	1.169
0.66	0.388	0.414	0.440	0.466	0.492	0.518	0.545	0.571	0.598	0.626	0.654	0.682	0.712	0.743	0.775	0.809	0.846	0.887	0.935	0.995	1.138
0.67	0.358	0.384	0.410	0.436	0.462	0.488	0.515	0.541	0.568	0.596	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.965	1.108
0.68	0.328	0.354	0.380	0.406	0.432	0.458	0.485	0.511	0.538	0.566	0.594	0.622	0.652	0.683	0.715	0.749	0.786	0.827	0.875	0.935	1.078
0.69	0.299	0.325	0.351	0.377	0.403	0.429	0.456	0.482	0.509	0.537	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.906	1.049
0.70	0.270	0.296	0.322	0.348	0.374	0.400	0.427	0.453	0.480	0.508	0.536	0.564	0.594	0.625	0.657	0.691	0.728	0.769	0.817	0.877	1.020
0.71	0.242	0.268	0.294	0.320	0.346	0.372	0.399	0.425	0.452	0.480	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.214	0.240	0.266	0.292	0.318	0.344	0.371	0.397	0.424	0.452	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.186	0.212	0.238	0.264	0.290	0.316	0.343	0.369	0.396	0.424	0.452	0.480	0.510	0.541	0.573	0.607	0.644	0.685	0.733	0.793	0.936
0.74	0.159	0.185	0.211	0.237	0.263	0.289	0.316	0.342	0.369	0.397	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.132	0.158	0.184	0.210	0.236	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.288	0.315	0.343	0.371	0.399	0.429	0.460	0.492	0.526	0.563	0.604	0.652	0.712	0.855
0.77	0.079	0.105	0.131	0.157	0.183	0.209	0.236	0.262	0.289	0.317	0.345	0.373	0.403	0.434	0.466	0.500	0.537	0.578	0.626	0.685	0.829
0.78	0.052	0.078	0.104	0.130	0.156	0.182	0.209	0.235	0.262	0.290	0.318	0.346	0.376	0.407	0.439	0.473	0.510	0.551	0.599	0.659	0.802
0.79	0.026	0.052	0.078	0.104	0.130	0.156	0.183	0.209	0.236	0.264	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.633	0.776
0.80	0.000	0.026	0.052	0.078	0.104	0.130	0.157	0.183	0.210	0.238	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.609	0.750
0.81		0.000	0.026	0.052	0.078	0.104	0.131	0.157	0.184	0.212	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82			0.000	0.026	0.052	0.078	0.105	0.131	0.158	0.186	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.555	0.698
0.83				0.000	0.026	0.052	0.079	0.105	0.132	0.160	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.529	0.672
0.84					0.000	0.026	0.053	0.079	0.106	0.134	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85						0.000	0.027	0.053	0.080	0.108	0.136	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86							0.000	0.026	0.053	0.081	0.109	0.137	0.167	0.198	0.230	0.264	0.301	0.342	0.390	0.450	0.593
0.87								0.000	0.027	0.055	0.083	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88									0.000	0.028	0.056	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89										0.000	0.028	0.056	0.086	0.117	0.149	0.183	0.220	0.261	0.309	0.369	0.512
0.90											0.000	0.028	0.058	0.089	0.121	0.155	0.192	0.233	0.281	0.341	0.484
0.91												0.000	0.030	0.061	0.093	0.127	0.164	0.205	0.253	0.313	0.456
0.92													0.000	0.031	0.063	0.097	0.134	0.175	0.223	0.283	0.426
0.93														0.000	0.032	0.066	0.103	0.144	0.192	0.252	0.395
0.94															0.000	0.034	0.071	0.117	0.160	0.220	0.363
0.95																0.000	0.037	0.079	0.126	0.186	0.329
0.96																	0.000	0.041	0.089	0.149	0.292
0.97																		0.000	0.048	0.108	0.251
0.98																			0.000	0.060	0.203
0.99																				0.000	0.143
																					0.000

Instructions: 1. Find the present power factor in column 1 2. Read across to optimum power factor column 3. Multiply that number by KW demand

Example: If your plant consumed 410 KW, was currently operating at 73% power factor and you wanted to correct power factor to 95%, you would:
1. Find 0.73 in column 1 2. Read across to 0.95 column 3. Multiply 0.607 by 410 = 249 (round to 250)
4. You need 250 KVAR to bring your plant to 95% power factor If you don't know the existing power factor level of your plant, you will have to calculate it before using Table 3. To calculate existing power factor: KW divided by KVA = Power Factor

Example using formulas

- <u>On the bill we have:</u>

  - PF (Power Factor) = 85.33%
  - Active Power (kW Demand) = 2852 kW

- <u>Mathematical calculation:</u>

$$kVAR = kW \left[\text{tg} \left(\cos^{-1} FP_1 \right) - \text{tg} \left(\cos^{-1} FP_2 \right) \right]$$

- <u>The solution:</u>

  - kVAr = 2852kW {tg ($\cos^{-1}$ .8533) - tg($\cos^{-1}$ .92)}
  - kVAr = 2852kW {tg (31.427) - tg(23.07)}
  - kVAr = 527 kvar

Monthly Savings from utility bill

POWER SURVEY INTERNATIONAL INC.

Serving you since 1948

Potential savings graphic from your utility bills with Power Survey capacitor

Customer: Name

Data entry:
Distribution charge: 8,45 $
PF required: 92%

Data entry
If capacity installed: 600 kVAr

Savings applicable if PF: 92%						
Month	kW Measured	KVA Measured	PF Calculated	New Billing Demand	Savings at (PF) 92%	kVAr required for 92%
January	3430	3842	89,3%	3728	$961	270
February	3250	3747	86,7%	3533	$1 812	480
March	3175	3632	87,4%	3451	$1 529	411
April	3087	3543	87,1%	3355	$1 585	424
May	2785	3245	85,8%	3027	$1 841	479
June	2788	3269	85,3%	3030	$2 016	519
July	2640	3132	84,3%	2870	$2 218	561
August	2760	3276	84,2%	3000	$2 332	589
September	2792	3281	85,1%	3035	$2 081	534
October	2852	3342	85,3%	3100	$2 045	527
November	3080	3530	87,3%	3348	$1 539	413
December	3127	3590	87,1%	3399	$1 615	431

Saving applicable if 600 kVAr is always running on the electrical network				
kVAr required for (PF) 100%	kVAr by utility	New kVA with (kVAr) 600	PF with (kVAr) 600	Savings with (kVAr) 600
1731	1131	3612	95,0%	1 947 $
1865	1265	3487	93,2%	2 193 $
1764	1164	3382	93,9%	2 116 $
1739	1139	3290	93,8%	2 135 $
1665	1065	2982	93,4%	2 224 $
1707	1107	3000	92,9%	2 276 $
1685	1085	2854	92,5%	2 346 $
1765	1165	2996	92,1%	2 368 $
1723	1123	3009	92,8%	2 294 $
1742	1142	3072	92,8%	2 280 $
1725	1125	3279	93,9%	2 122 $
1764	1164	3336	93,7%	2 143 $

Projected monthly savings if plant PF: 92% =======> $1 798

Projected annual savings if plant PF: 92% =======> $21 572

Minimum kVAr required to reach PF: 92% =======> 589 kVAr

Monthly savings if: 600 kVAr is running in the plant ====> $2 204

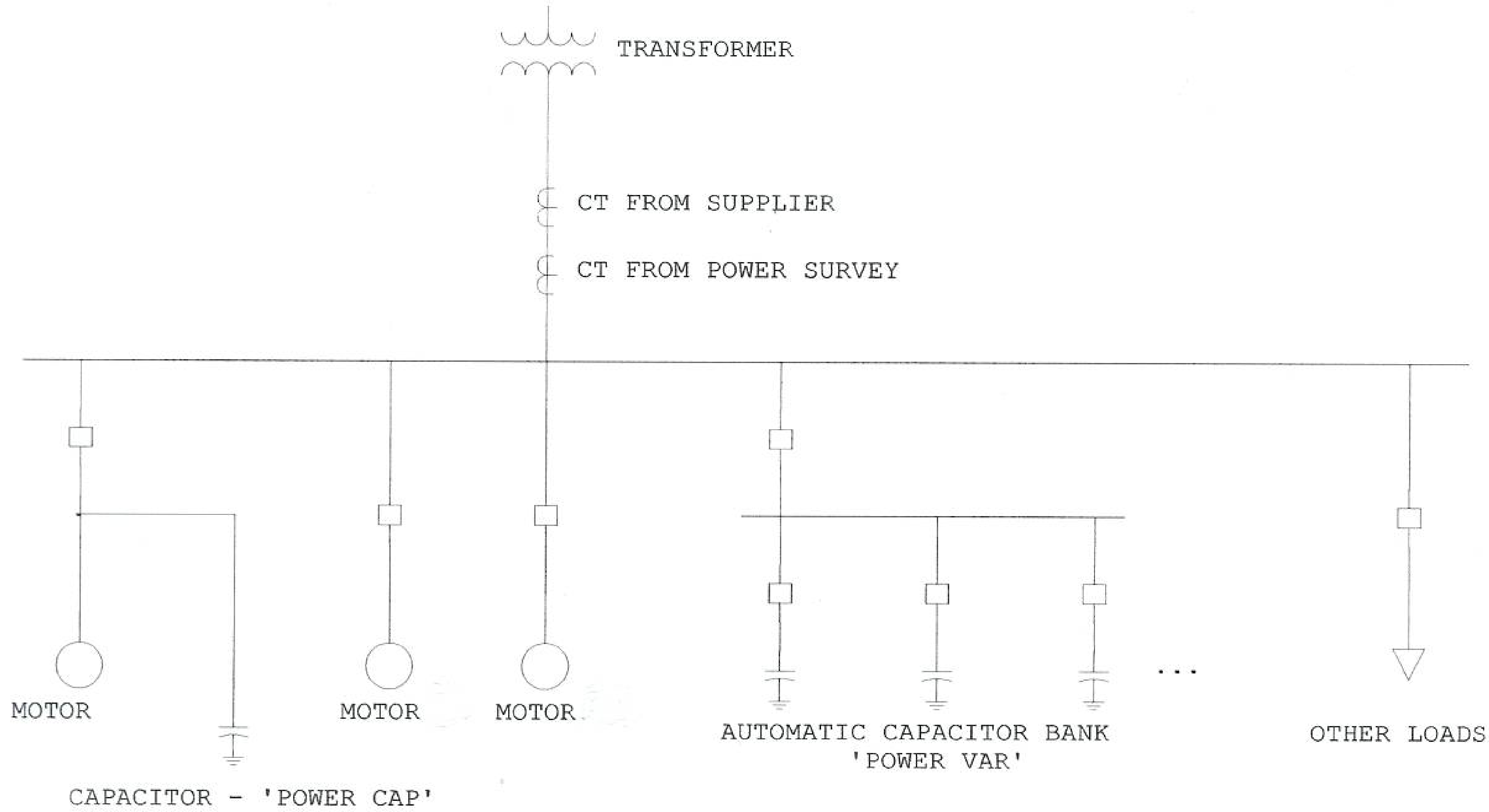
Annual savings if: 600 kVAr is running in the plant ====> $26 443

Solution to increase PF to 92%

- Propose an automatic capacitor bank:

➢ Type:	PowerVar
➢ Required power:	589 kVAr
➢ Suggested power:	600 kVAr
➢ Number of steps:	6
➢ Power per step:	100

Installation of a PowerCap and/or PowerVar



Required data for PFCC

- The last 12 months electrical billing history and Rate structure
- Motors lists (HP Ratings, speed and type of starters)
- Single line diagrams including:
  - Details on Non linear loads
  - Transformer data (KVA , Z%)
  - Harmonic distortion data from measurement, if available

PowerVar

- **Capacity**
  - 50 kvar – 20 Mvar
- **Network voltage**
  - 208v – 35,000v
  - Other voltages available
- **Option**
  - NEMA 12 & 3R enclosure
  - Main breaker
  - Main disconnect
  - Main fuse disconnect
  - Ground switch
  - Blown fuse indicator
  - Capacitor Life Indicator

Power Factor Controller

- <u>Power Survey</u>
  - PF indication and number of step
  - Energization sequence - FIFO
  - Manual and automatic selection
  - Up to 12 steps
  - Alarm if harmonic are overloaded
  - Power and Harmonic Measurement

Harmonics !!

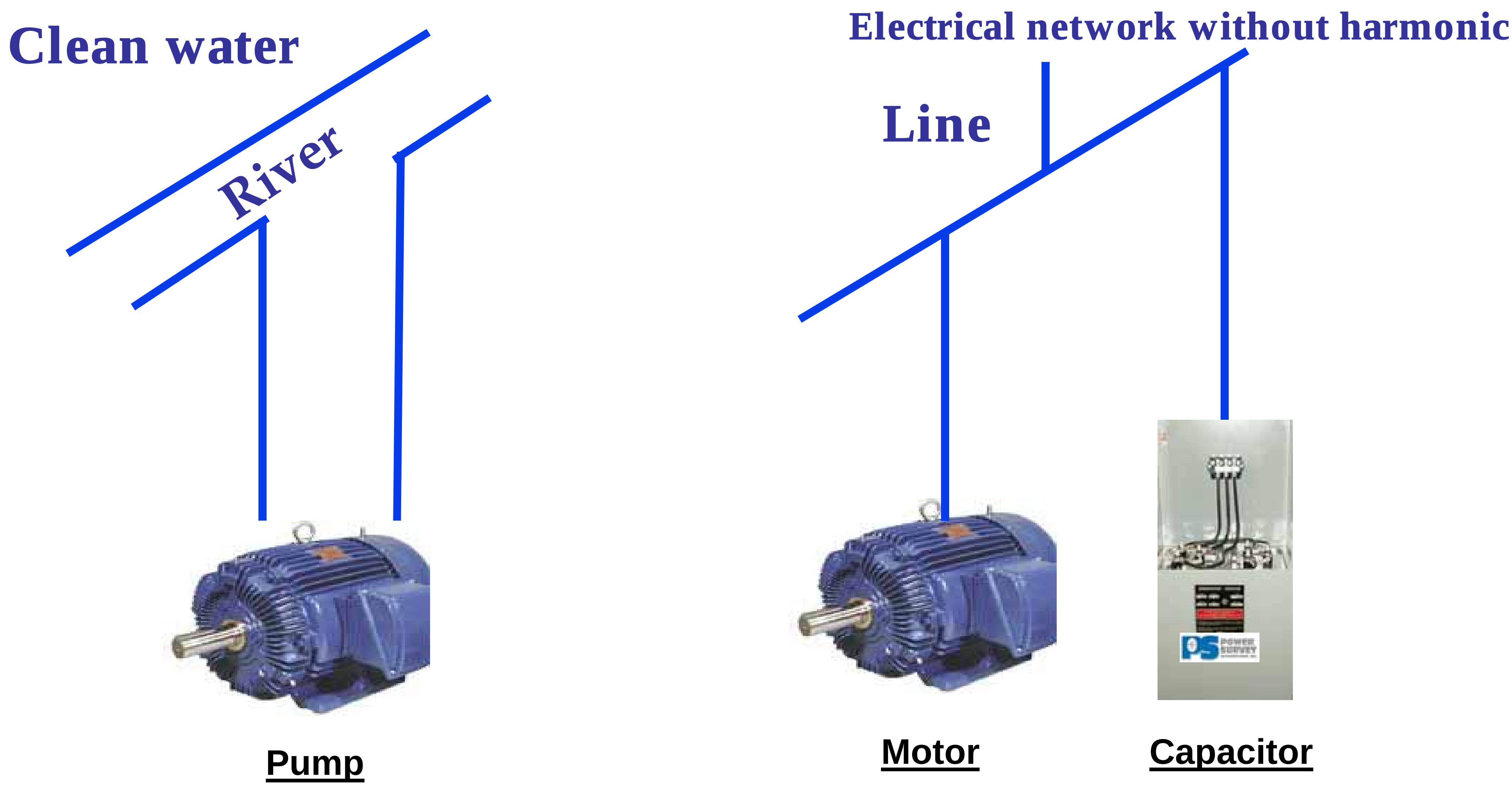
- Harmonic producing equipment:
  - AC & DC Drive
  - Welder
  - Induction furnaces
  - Arc furnaces
  - Any equipment with thyristor
  - AC & DC rectifier
  - Etc

Harmonics

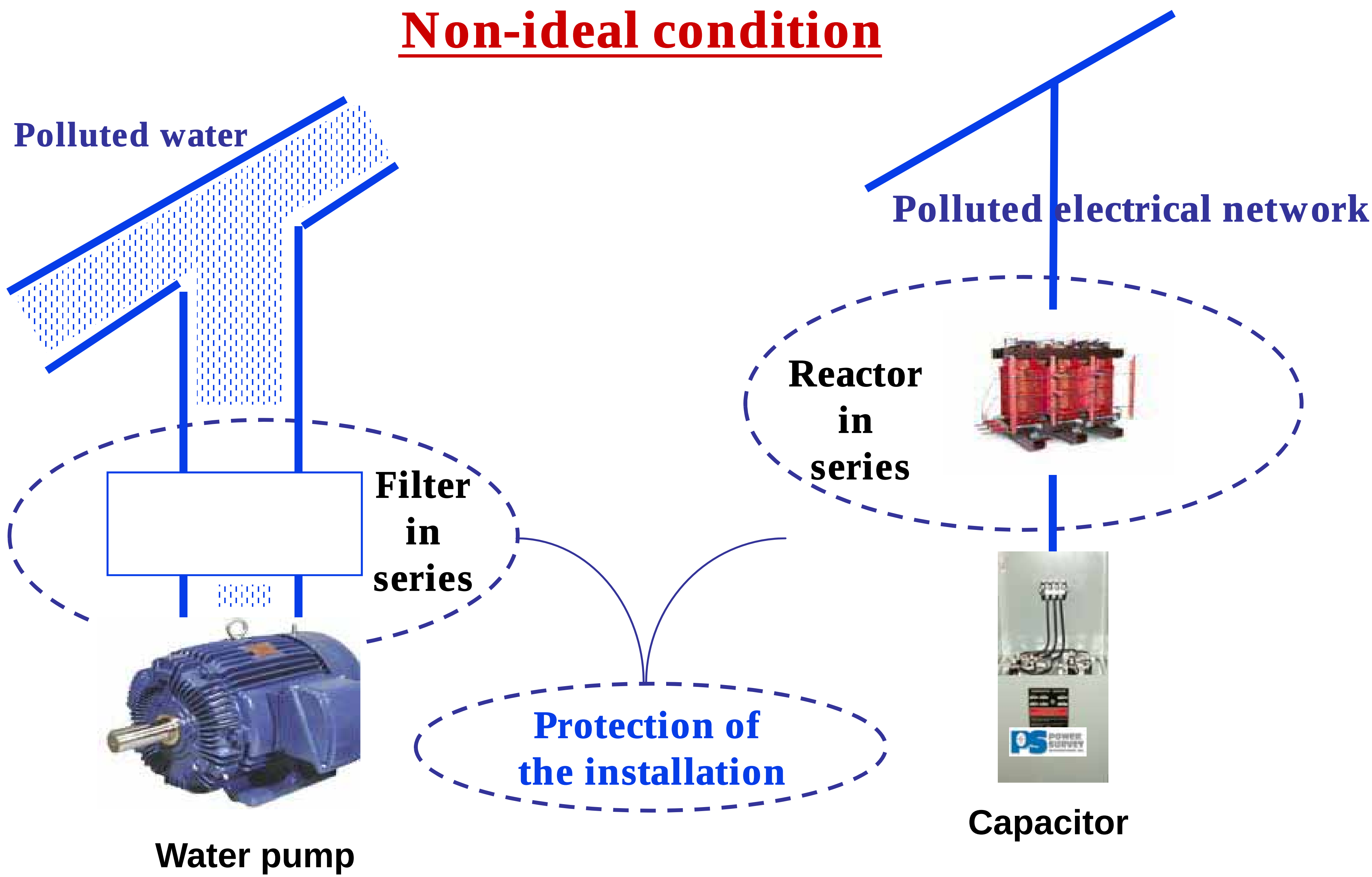
- By definition
  - It is a current or voltage of a frequency that is a multiple of the fundamental (60HZ)
    - 5^{th} harmonic = 5 * 60 Hz = 300 Hz
  - It is NOT a TRANSIENT phenomenon

Harmonics and a river!

Ideal condition



Harmonic and a river!



Capacitor and harmonic

- Power Survey rule of thumb!
  - Be careful! Is the total non linear load exceeding 20% of the total load?
    - If not, ex. (100 HP of drive versus 1000 HP total [10%]):
      - We will propose a PowerCap or PowerVar
    - If yes, ex. (500 HP of drive versus 1000 HP total [50%]):
      - We will propose a PowerCap filter or PowerVar filter because of the high harmonic content

Typical Harmonic Spectrum

Typical % values of a 6 pulse drive

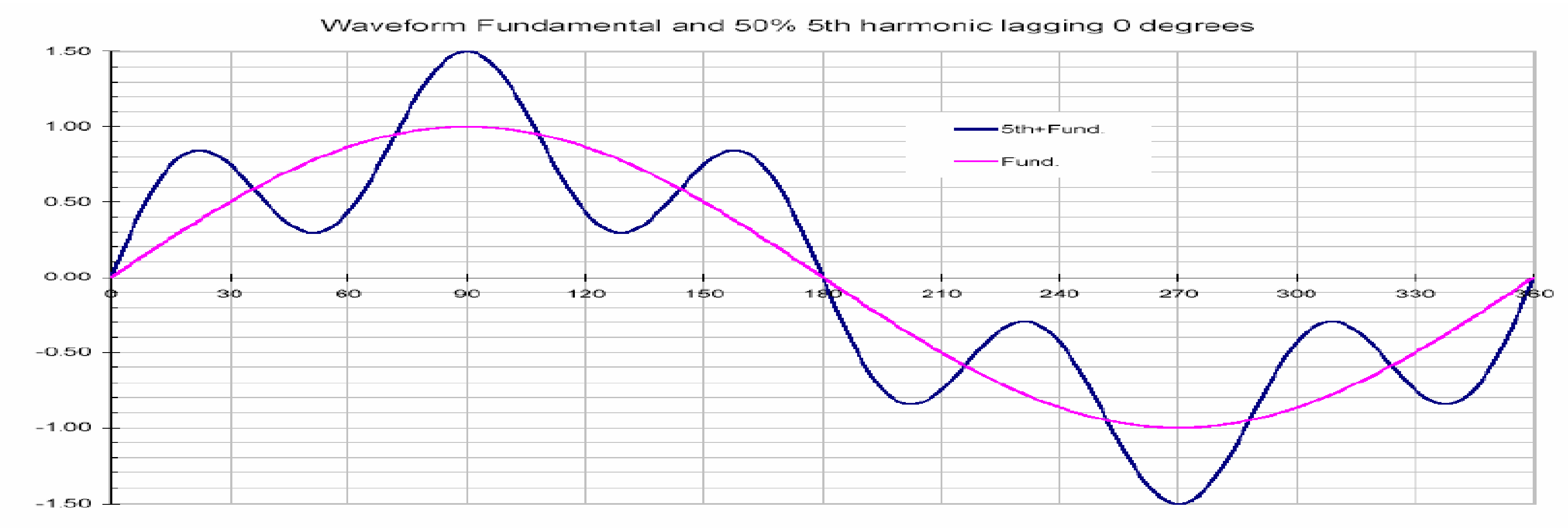
HARMONIC ORDER	CURRENT (% OF FUNDAMENTAL)
1	100%
3	0%
5	17.5%
7	11.1%
9	0%
11	4.5%
13	2.9%
15	1.0%

Effect of harmonic distortions

- Current distortion
  - Equipment overheating and additional losses
    - Transformers (eddy losses)
    - Cables (skin effect)
    - Capacitors (low impedance)
    - Resulting voltage distortion

Effects of harmonic distortion

- Voltage distortion
  - Distorted current on linear loads
  - Peak voltage increase (Insulation stress)
  - Bad operation on electronic devices
    - Drives
    - PLC
    - Breakers (Electronic trip unit)



IEEE guideline

- Worst case harmonic voltage distortion limit (THDv)

Table 11-1—Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

NOTE — High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

IEEE guideline

- Current distortion limit based on load size with respect to power system (I_{sc}/I_L)

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	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h$	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.

Effects of harmonics distortion

- Parallel resonance
  - Occurs when system inductance reactance and capacitor reactance are equal at some frequency (5th, 7th, etc)
    - Thus creating amplification of harmonic currents between shunt capacitor and the power system reactance

Consequences

  - Increase current harmonic distortion on capacitor and transformer
  - Increase voltage distortion throughout the network

- Results
  - Burns fuses
  - Capacitor failure or premature degradation
  - Transformer overheating

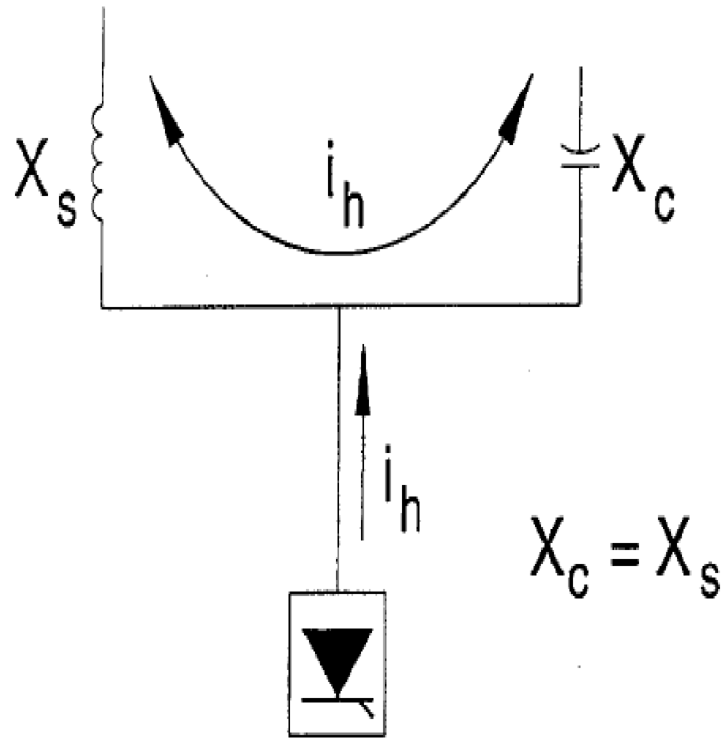
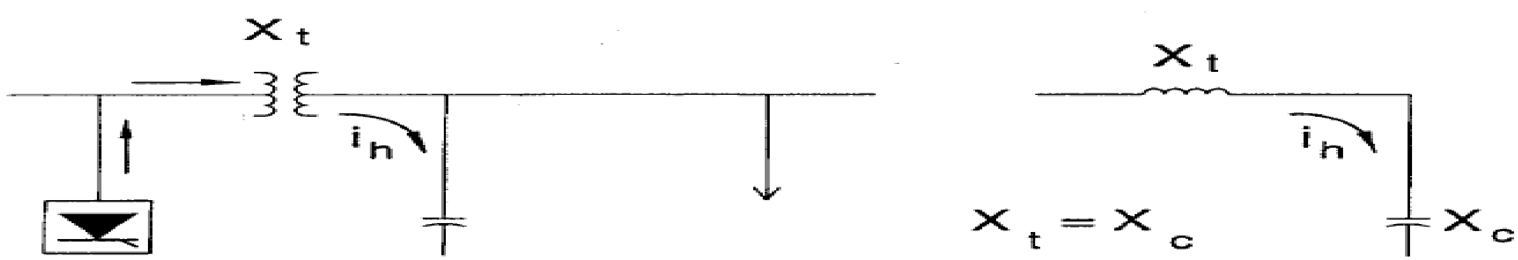


Figure 5-2—Parallel Resonance Condition

Effects of harmonic distortion

- Series resonance
  - Is a result of the series combination of capacitor and line inductances
    - Thus creates amplification of harmonic voltage at the capacitor and transformer
- Consequences
  - Increased voltage and insulation stress
  - Increased current
- Results
  - Burns fuses
  - Capacitor failure or premature degradation
  - Transformer overheating



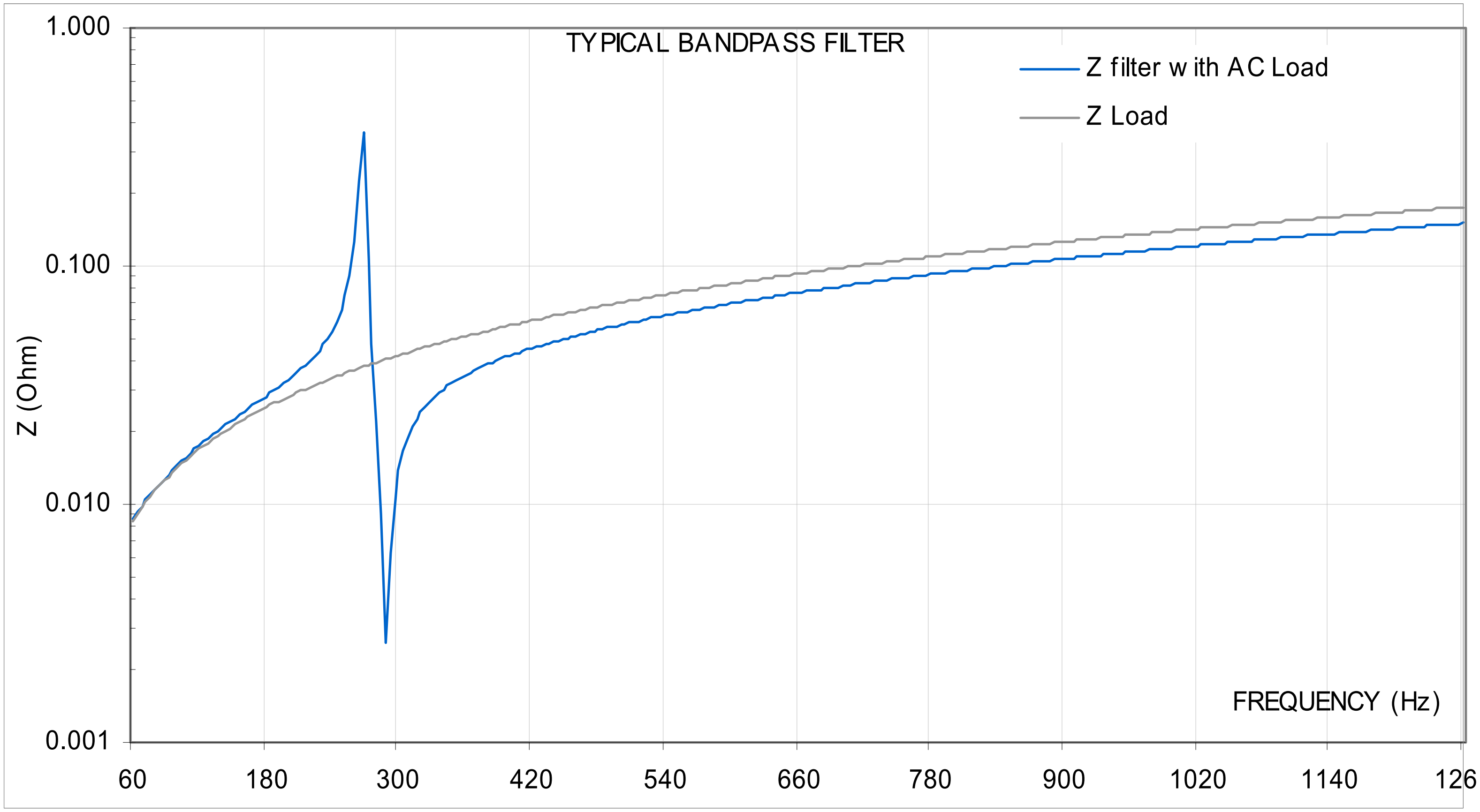
One Line Diagram

Impedance Diagram

Figure 5-3—Capacitor Bank Resulting in Series Resonance

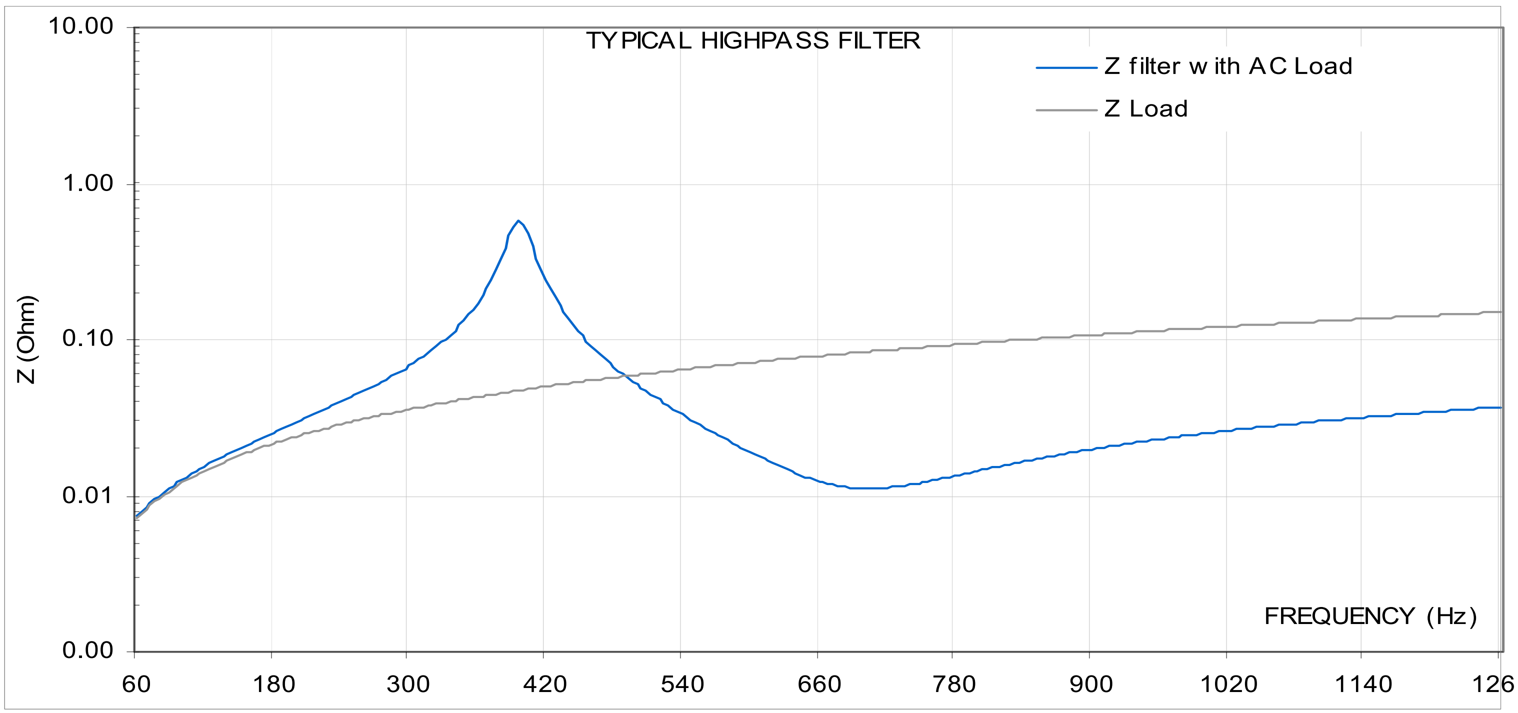
Harmonic filter type

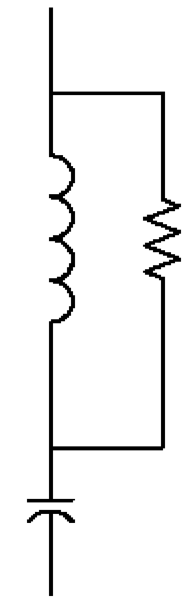
- Bandpass filter tuned to the 4.8th harmonic:
  - •Creates a low impedance only at a specific frequency
  - •Most frequently used harmonic filter



Harmonic filter type

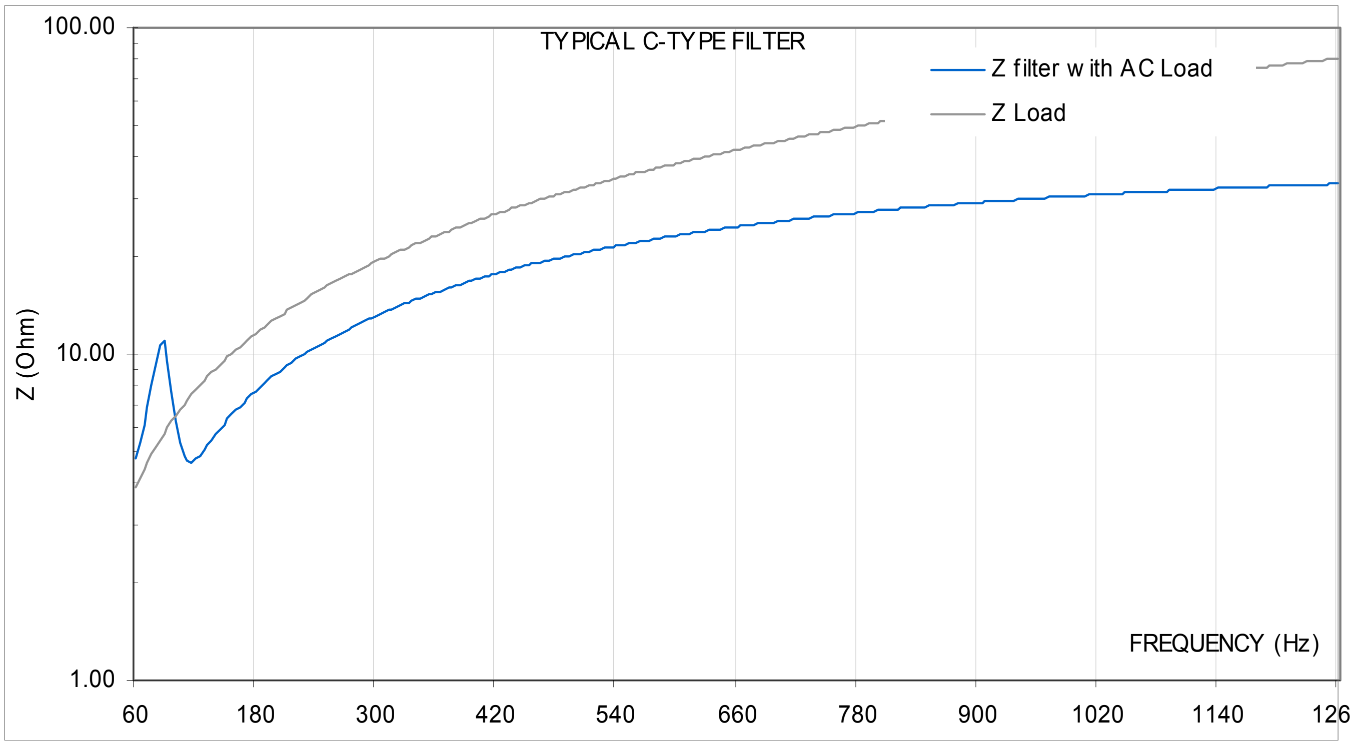
- Highpass filter tuned to the 12th harmonic
  - •Creates a continuous low impedance after the tuned frequency
  - •Also dampens high frequency notch-type oscillations
  - •Not recommended to tune at low frequency (5th) because R consumes substantial fundamental losses (see C-type filter)
  - •Usually installed after a bandpass filter

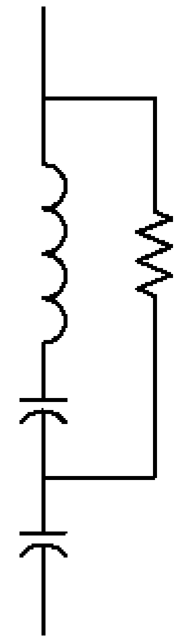




Harmonic filter type

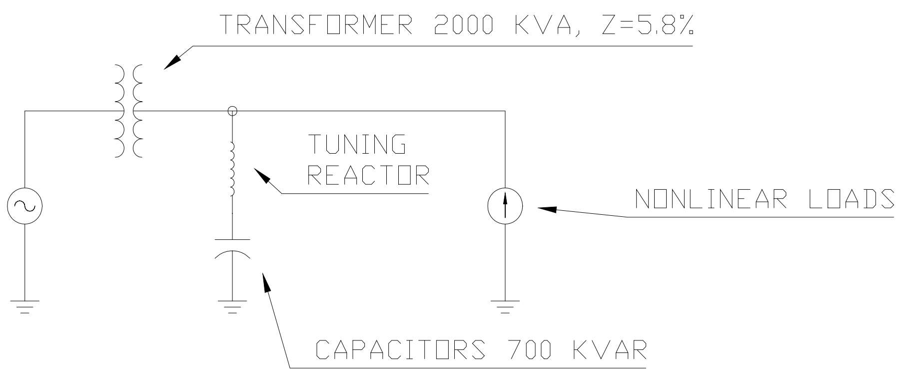
- C-Type filter tuned to the 2nd harmonic:
  - •Similar performances characteristics to the highpass filter
  - •Used for low tuning frequency
  - •R consumes no fundamental losses at nominal parameters
  - •Usually for arc furnace and cycloconverter application avoiding amplification of low order harmonic





PFCC in presence of harmonics

- Parallel resonance between system reactance (transformer + utility impedance) and the capacitor



- Important: the natural frequency of the oscillating circuit must not correspond to the harmonic currents generated by the non linear loads

Calculation of parallel harmonic resonance

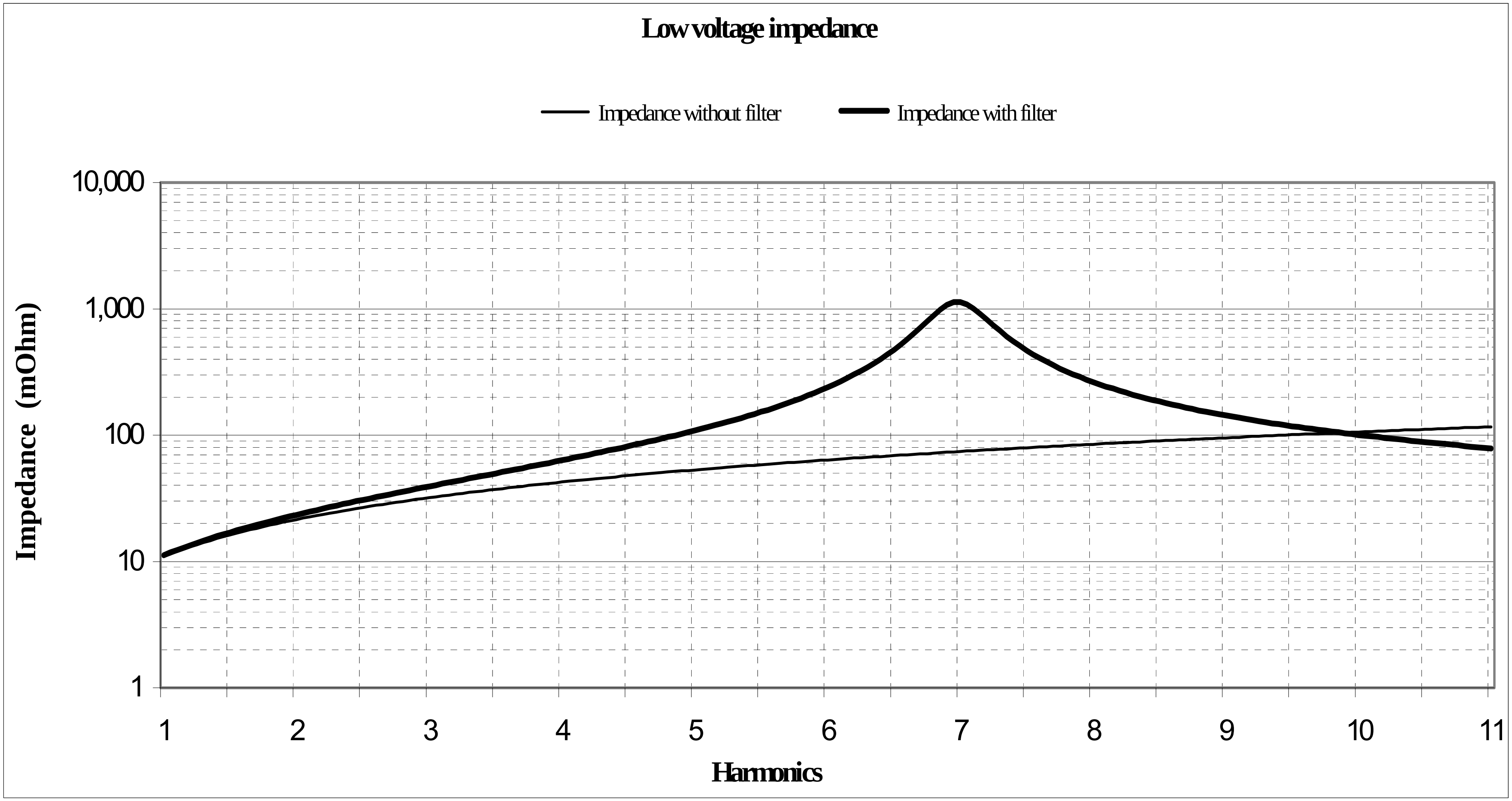
- Electrical network equipment characteristics:
  - Transformer: 2000 KVA, 5.8%
  - Capacitor: 700 kvar to be installed
  - Drives: non linear loads consists of 50% of total load

- Calculation using simple method
  - Fr = √{KVAsc / kvar}
  - Fr = √{(2000 KVA / .058)/700 kvar}
  - Fr = 7.02th harmonic

- Harmonic resonance is precisely on the 7th harmonic:
  - Strong potential of harmonic problems

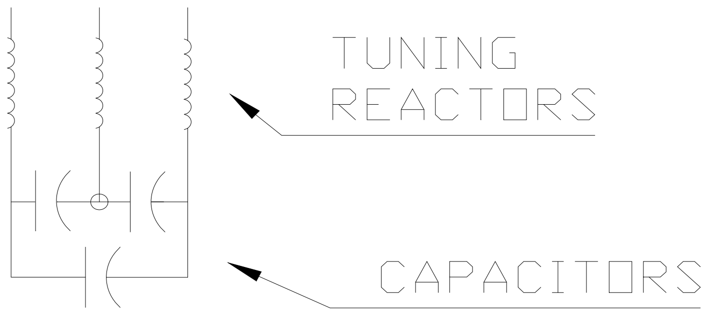
Calculation of parallel harmonic resonance

➢ Computer model of frequency response



Eliminating harmonic current resonance

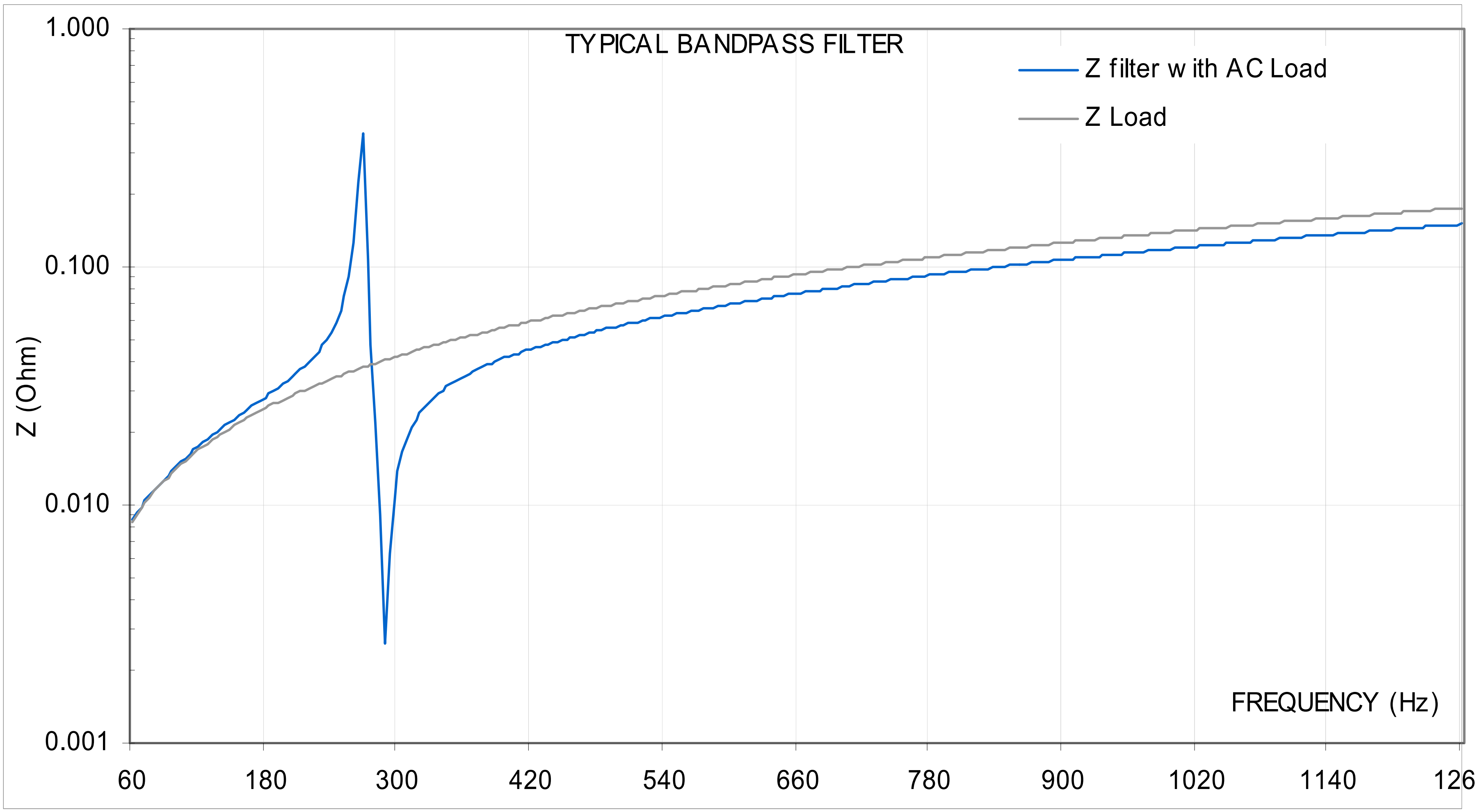
- Band pass filter:
  - Capacitor in series with a reactor



- Absorbs harmonic currents
- Controls parallel resonance
- Increase voltage at the capacitor bushing due to reactor:
  - $(\text{Nominal frequency/tuned frequency})^2$

Eliminating harmonic current resonance

- Computer model using a band pass filter tuned to 4.8th harmonic



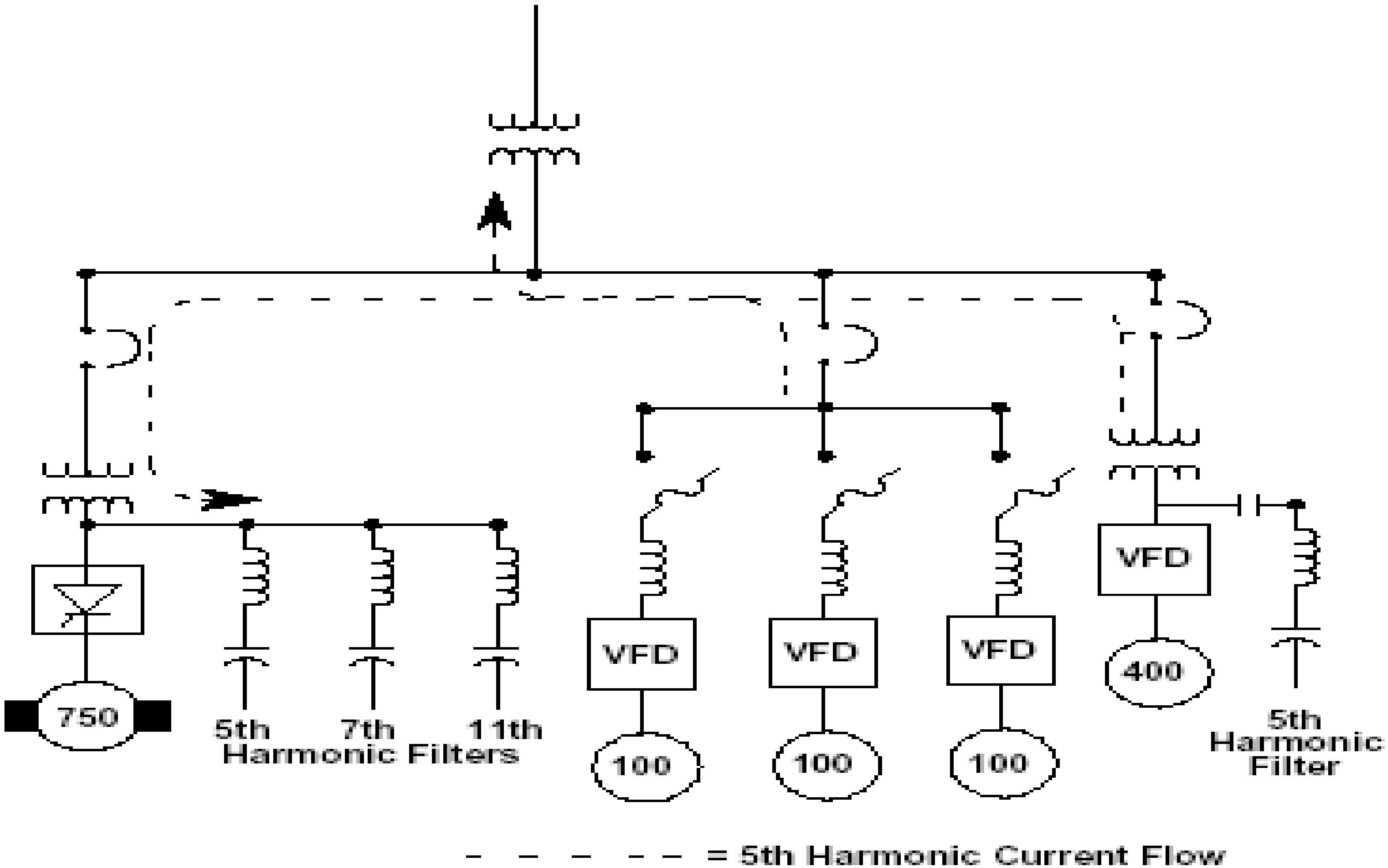
Potential harmonic problems: Yes/No?

✓ Power Survey rule of thumb:

- Resonance frequency calculation:
  - Fr = Should not be close to the 5th, 7th, 11th & 13th harmonic
  - Fr > 15th should be OK
  - Fr = Between 8th & 15th low potential problems
  - Fr < 8th high potential problems

- Comparing non linear load vs total connected load
  - Non linear load vs total load > 20 % Be careful
  - Non linear load vs total load < 20 % Should be OK

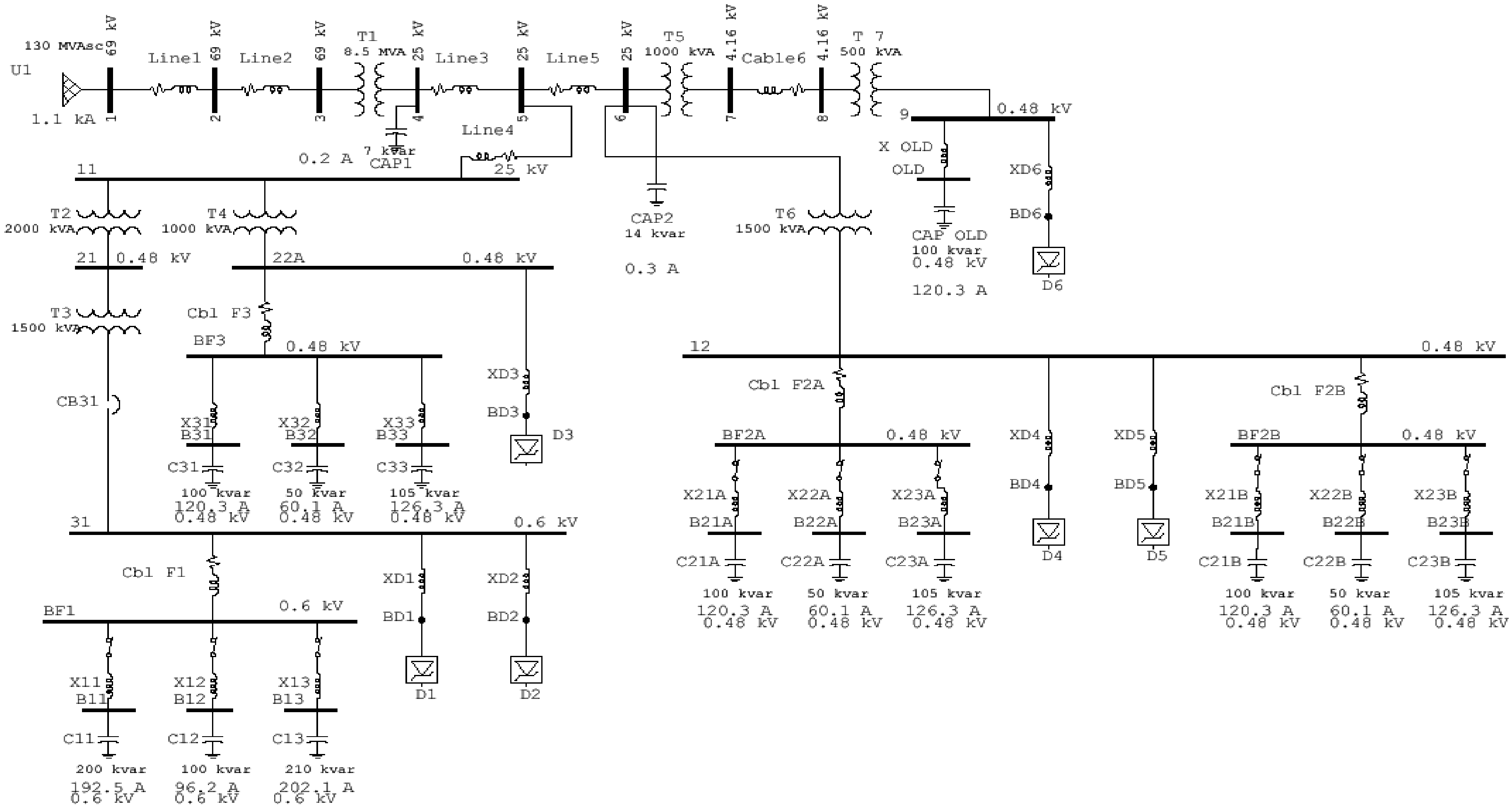
Flow of harmonic current



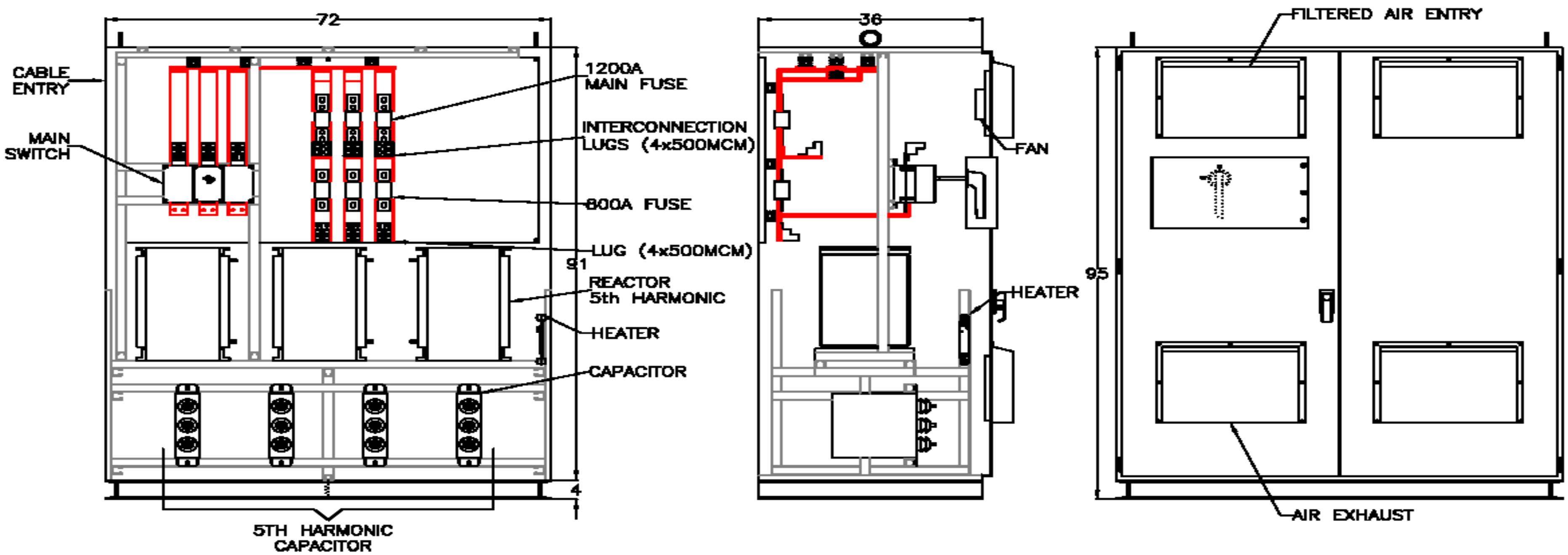
Lake Louise ski center project

Lake Louise ski center project

ETAP simulation



Lake Louise Ski Center



5TH HARMONIC FILTER

ENCLOSURE: 91+4H x 72W x 36D

HARMONIC FILTER
510 KVAR @ 600 V
5th FILTER: 1x200 KVAR
7th FILTER: 1x100 KVAR
11th FILTER: 1x210 KVAR

LAYOUT

POWER SURVEY LTD
8025, Transcanada Hwy
VILLE ST-LAURENT, Quebec, H4S 1S4
Tel : (514) 333-8392
Fax : (514) 333-8395

PROJECT : FRIENDLY GIANT + TOP OF WORLD
LAKE LOUISE SKI CENTRE

PROJECT ID :
DRAWING ID : fh 1x200+1x100+1x210kva MS 600V assem1 Friendly Giant+Top of world

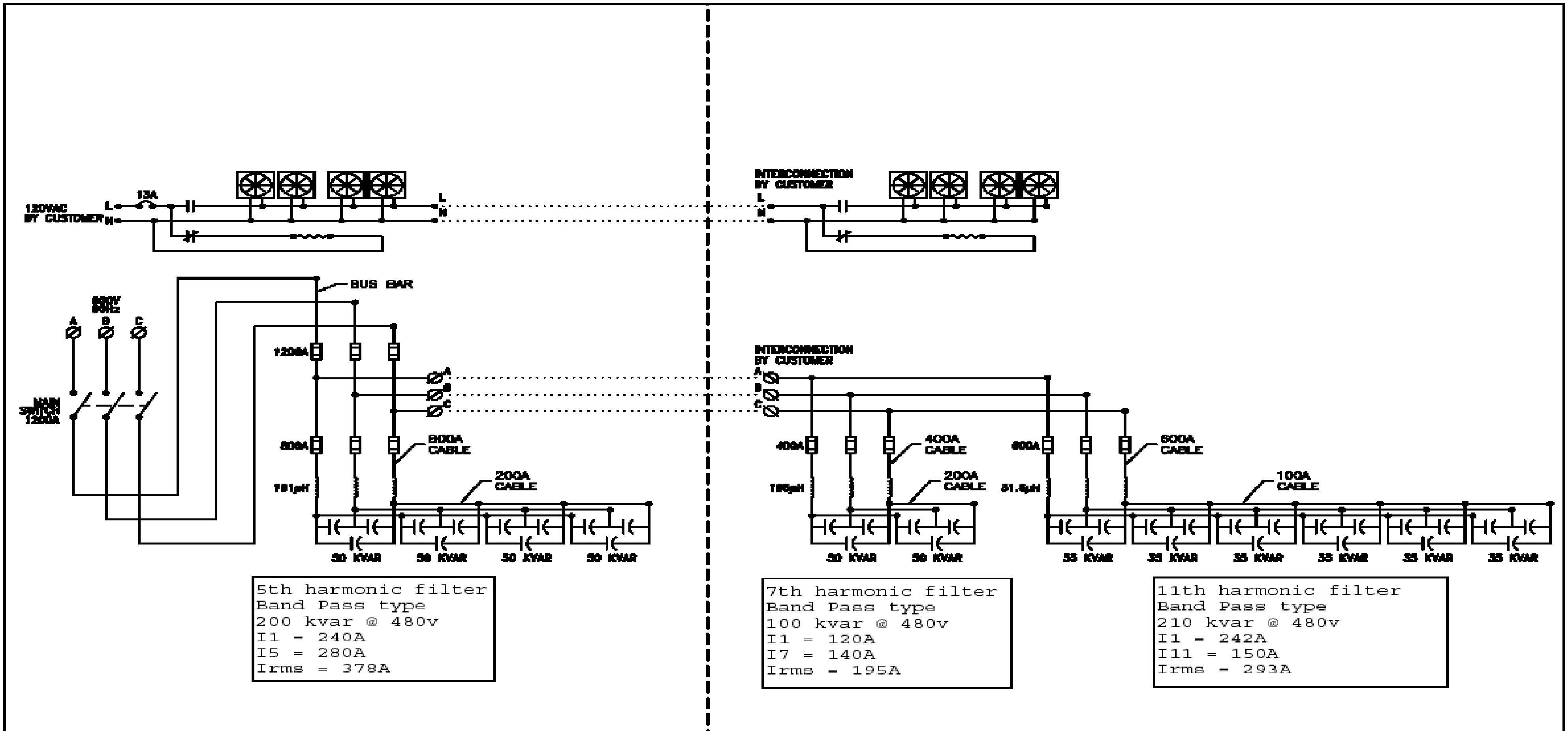
PAGE 1/4

SCALE : N/A

REV	DATE	BY	APP.
0	24-MAR-04	GL	

APPROVED BY:

Lake Louise Ski Center



HARMONIC FILTER
510 KVAR @ 600 V
5th FILTER: 1x200 KVAR
7th FILTER: 1x100 KVAR
11th FILTER: 1x210 KVAR

ELECTRICAL DIAGRAM

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PAGE 3/4

SCALE : N/A

REV	DATE	BY	APP.
0	24-MAR-04	GL	

APPROVED BY:

Canada - U.S.A
Latin America

Power Survey International

Lake Louise Ski Center

QUANTITY	DESCRIPTION	MANUFACTURER	CAT. #
1	ENCLOSURE 91H x 72W x 36D NEMA3R	POWER SURVEY	PS917236
1	ENCLOSURE 90H x 72W x 36D NEMA3R	POWER SURVEY	PS907236
6	CAPACITOR 50 KVAR @ 600V, FOR HIGH HARMONIC CONTENT (105)	POWER SURVEY	MMPB0050I33SF
6	CAPACITOR 35 KVAR @ 600V, FOR HIGH HARMONIC CONTENT (54)	POWER SURVEY	MMPB0035I33SF
3	REACTOR 191μH OR 217μH, OR 258μH, 378A RMS, 1 PHASE	REX MANUFACTURING	500C191E6/X
3	REACTOR 195μH OR 220μH OR 250μH, 195A RMS, 1 PHASE	REX MANUFACTURING	254C195E6/X
3	REACTOR 31.6μH OR 42μH, 293A RMS, 1 PHASE	REX MANUFACTURING	380C31E6/X
1	TIN PLATED COPPER BUS BAR 2 x 1/4 x 3" (1500A)	POWER SURVEY	750A
3	1200A FUSE	LIMITRON	KTU-1200
3	800A FUSE	LIMITRON	KTU-800
3	400A FUSE	FERRAZ	A4J400
3	600A FUSE	FERRAZ	A4J600
1	13A CONTROL BREAKER	E.T.A.	91H1213
2	THERMOSTAT N.O.	HOFFMAN	A-TEMNO
2	THERMOSTAT N.C.	HOFFMAN	A-TEMNC
8	FAN 120V, 32W	NMB	5915PC-12T-B30
2	HEATER 120V, 250W	CALORITECH	SS2061
15	LUGS 4x #2-600mcm	T&B	ASL60-42
1	MAIN SWITCH 1200A	SCHNEIDER	LK3WU3
1	HANDLE	SCHNEIDER	LK3AH170
1	SHAFT	SCHNEIDER	GS1AE6

HARMONIC FILTER
510 KVAR @ 600 V
5th FILTER: 1x200 KVAR
7th FILTER: 1x100 KVAR
11th FILTER: 1x210 KVAR

BILL OF MATERIAL

POWER SURVEY LTD
8025, Transcanada Hwy
VILLE ST-LAURENT, Quebec, H4S 1S4
Tel : (514) 333-8392
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PROJECT : FRIENDLY GIANT + TOP OF WORLD
LAKE LOUISE SKI CENTRE

PROJECT ID :
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PAGE 4/4

SCALE : N/A

REV	DATE	BY	APP.
0	24-MAR-04	GL	

APPROVED BY:

Harmonic filter components ratings - Capacitor

✓ Capacitor Assemblies

- Rated in uF for harmonic filter application (not in kVAR)
- Standard capacitor rating:
  - Voltage
    - Minimum 110% of Vn
  - Current*
    - Minimum 130% of In for LV
    - Minimum 170% of In for MV
- * Filter application – capacitor must withstand ($I_{rms} = \sqrt{I_1^2 + I_2^2 + I_3^2 + I_4^2 + I_5^2 \ldots}$)
  - Current of an individual harmonic could be greater than I_1
- Tolerances should be kept to minimum (0 – 3%) because it will be added to L tolerance
- Internally fused MV capacitor
  - Internal fuse operation causes less detuning
- Externally fused MV Capacitor
  - Internal fault takes out the complete capacitor unit which can result in severe detuning and/or unbalance conditions when few units in //
  - External fuse can be made of 50 kA current limiting and be equipped with an indicator transient and short time over voltage rating per IEEE 1036
- Operating temperature; especially for Metal enclosed construction
  - Capacitor lifetime are affected by over temperature

Harmonic filter components ratings - Capacitor

✓ <u>Capacitor Assemblies</u>

- Floating Y
  - Mostly for MV application
  - Limits the fault current across a shorted capacitor
  - Easy unbalance protection

- Grounded Y (solidly grounded system)
  - Most common on utility distribution system (small banks)
  - Possible high fault current

- Delta

  Require that both capacitor bushings be fused if using single phase units
  - Difficult unbalance protection

Internally fused and externally fused capacitor

Harmonic filter components ratings - Reactor

✓ Reactor Assemblies

- Rated in uHy (not in kVAR or %) and tolerance (0 - 3%)
- Calculation:
  - $F_{tuned} = 1/\{(2\pi\sqrt{(LC)}\}$
  - $L = \{1/ 2\pi f\}^2 * \{1/C\}$
- Rating:
  - I_{rms} according to current to be absorbed by filter ($I_{rms} = \sqrt{\{I_1^2 + I_2^2 + I_3^2 + I_4^2 + I_5^2 \ldots..\}}$
  - Current of an individual harmonic could be greater than I_1
- Iron core (single phase or three phase)
  - More compact design and does not require magnetic clearance
  - More practical and cost effective with small banks where uHy value is high and space limited.
  - Three phase reactor construction might show a slightly different B phase inductance, if fine tuning is required single phase reactors should be considered.
- Air core
  - Magnetic clearance makes it non practical for metal enclosed design
  - Usually more practical for large banks where current is high and uHy value is less
- BIL rating for coil to ground and across the coil
- Q Factor should be specified at tuning frequency and at the fundamental (most reactor are only tested at 60 Hz). Tolerance on Q Factor is typically of ±20%
- Taps are often practical for either fine tuning or provision for expansion

Iron core reactor with selective taps

Harmonic filter components ratings - Resistor

✓ Resistor Assemblies

- Rated in Ohms with tolerance (±5%)
- Continuous current spectrum for loss determination
- Overload RMS current and duration
- Cold resistance value
- BIL

Resistor mounted on top of capacitor enclosure

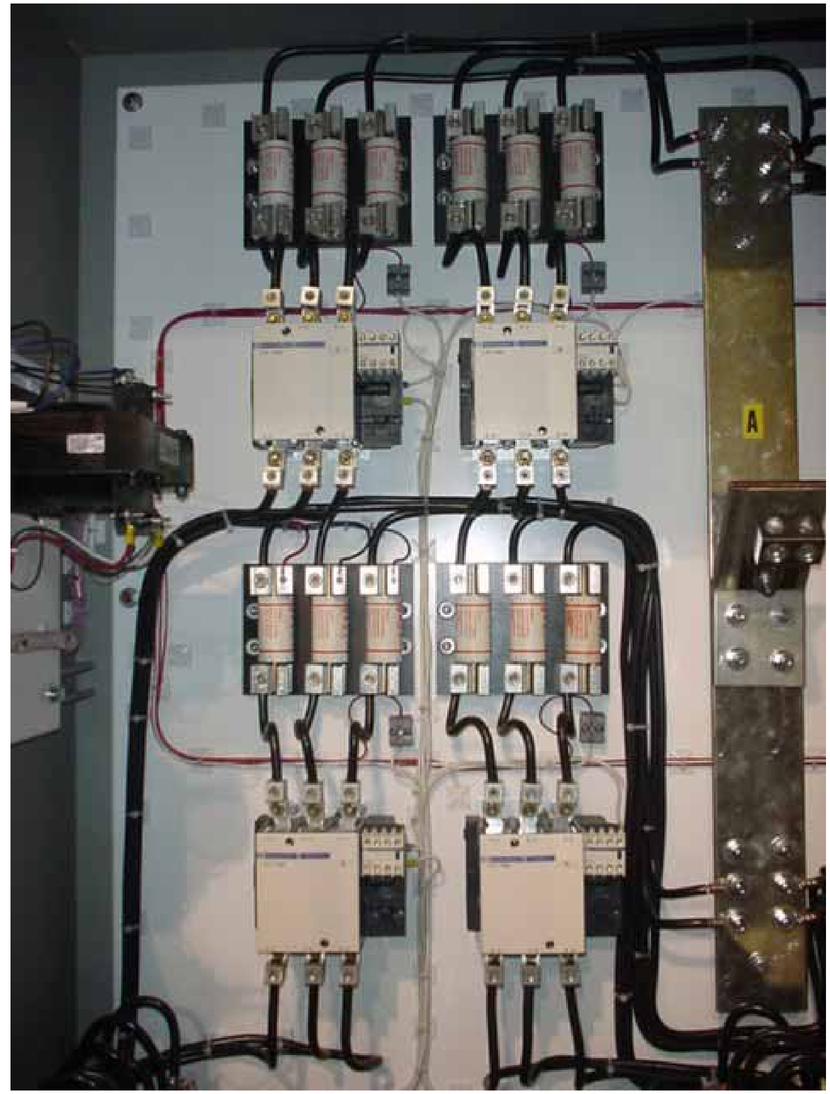
✓ Vacuum switches – MV application

- Voltage rating:
  - 5kV, 15kV, 25 kV and 34.5kV
- Current ratings:
  - 200A, 400A, 600A
- Configuration in single pole available for 15 and 25 kV design
- Position indicator standard, no visible contact
- Optional manual operator
- Oil filled switch (old design) generation not recommended unless used as a cut-out

✓ Contactors – LV application

- Voltage rating:
  - 600V and below
- Current ratings:
  - Multiple current rating up to 800A
- Configuration in 3 phase
- Closing time:
  - 12 – 16 msec
- Opening time:
  - 8 – 12 msec

Vacuum switch & LV contactor



Harmonic filter/Capacitor bank components ratings – Main & Ground switch

✓ Main switch (LV & MV application)

- Rating:
  - Minimum of 135% of I_{rms} (could be up to 165% of In)
- MV switches usually has very low capacitive breaking current capability
  - Vacuum switch is then used to open the capacitor circuit
- Used as an isolation switch and/or visible opening
- It can be fused for short circuit protection
- Kirk key interlock for safety reasons is normally provided between:
  - vacuum switch
  - main switch
  - ground switch
  - cubicle doors

✓ Ground Switch (MV application)

- Ground switch is provided as a safety features and insure full discharge of capacitors

✓ Breaker (LV application)

- Rating:
  - Minimum of 135% of I_{rms} (LV application)
- Requires to know the short circuit capacity of network
- If it operate (trips) only needs to switch it back to ON

LV main breaker & MV switch

Harmonic filter/Capacitor bank components ratings – Fuse

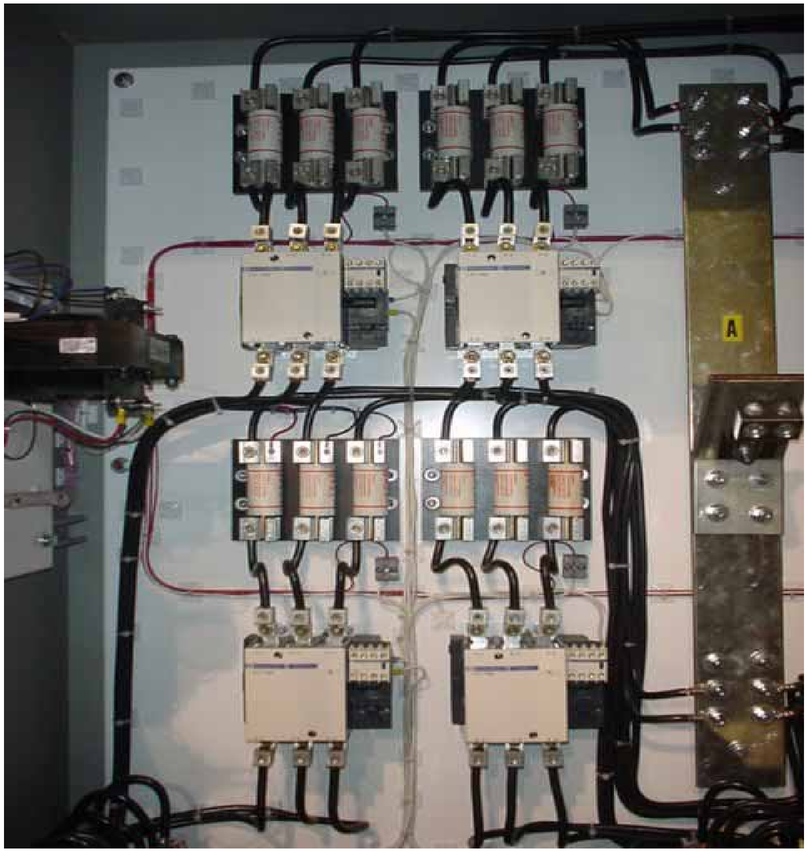
✓ Main fuse protection

- Rating:
  - Usually 165% of In for capacitor application
  - Up to 250% of I_{rms} for harmonic filter application
- Provides short circuit protection only
- Does not protect against overload

✓ Stage fuse protection

- Rating:
  - Usually 165% of In for capacitor application
  - Up to 250% of I_{rms} for harmonic filter application
- Stages or branches should be protected individually against short circuit
- MV fuses always have a visual trip indication and can be equipped with a remote trip contact.

LV & MV fuse and MV blown fuse indication



Safety – Capacitor / Filter protection

- ✓ Overcurrent protection
  - ➢ Relays used for overcurrent protection have to be true RMS style
    - Electromechanical relays cannot be used.
  - ➢ Tripping signal must be sent to either:
    - main breaker
    - vacuum switches
    - never to a load break with shunt trip.
  - ➢ Thermal sensors imbedded in the reactors can also be used to detect filter overloading.
- ✓ Over voltage current relaying
  - ➢ Over voltage protection is rarely provided as it is usually part of the bus protection
- ✓ Unbalance and detuning protection
  - ➢ On loss of capacitance unbalance occurs through:
    - neutral voltage sensing on floating Y capacitor where loss of capacitance will happens in large portion (i.e. externally fused capacitors)
    - Neutral current sensing used in a double floating Y configuration

Neutral CT in a floating Y-Y

Safety – Capacitor / Filter protection

Power Survey Capacitor Life Indicator

- Continuously monitor the current drawn from the capacitor
- When current is above 70% of its rated value a LED will stay ON.
- When current falls below 70% of its rated value the LED will switch OFF.
- It also monitors the capacitor fuse
- The percentage value can be adjusted to a different level.
- An output relay can also be added for remote application to a PLC, contactor, etc.
- This equipment is often used on harmonic filtering system.

Power Survey International – Project in service

- ✓ Application
  - ➢ Wind Tunnel - NASA Langley Virginia
- ✓ Harmonic generator
  - ➢ 18,000 HP @ 6.9kV - 12 Pulse drive
- ✓ Harmonic filter supplied
  - ➢ 11.4 Mvar @ 6.9 kV
    - 2 Mvar - 2^{nd} Band Pass harmonic filter
    - 2 Mvar - 3^{rd} Band Pass harmonic filter
    - 7.4 Mvar - 11^{th} High Pass harmonic filter

Power Survey International – Project in service

- NASA Langley Virginia Wind Tunnel

Power Survey International – Project in service

- ✓ Customer
  - ➢ Tennessee Valley Authority - TVA
- ✓ Harmonic filter supplied
  - ➢ 13.5 Mvar @ 13.8 kV
    - 5.2 Mvar – 5th Band Pass harmonic filter
    - 4 Mvar – 7th Band Pass harmonic filter
    - 2.3 Mvar - 11th Band Pass harmonic filter
    - 2 Mvar - 13th Band Pass harmonic filter

Power Survey International – Project in service

- Tennessee Valley Authority - TVA

Power Survey International – Project in service

- ✓ Application
  - ➢ Hypersonic Wind Tunnel – US Air Force (Arnold Base)
- ✓ Harmonic generator
  - ➢ 2 X 80,000 HP @ 13.8kV - 12 Pulse drive
- ✓ Harmonic filter supplied
  - ➢ 2 X 30 Mvar @ 13.8 kV
    - 2 Mvar - 3^{rd} C-Type harmonic filter
    - 14 Mvar - 5.5^{th} High Pass harmonic filter
    - 14 Mvar - 11.5^{th} High Pass harmonic filter

Power Survey International – Project in service

- US Air Force – Arnold Base

Power Survey International – Project in service

✓ Customer

- Falconbridge zinc Mine – Thunder Bay, Ontario

✓ Harmonic filter supplied – Rack mount type

- 3.8 Mvar @ 13.8 kV
  - 1.9 Mvar – 4.9th Band Pass harmonic filter (fixed)
  - 1.9 Mvar – 4.9th Band Pass harmonic filter (switched)

Power Survey International – Project in service

- FALCONBRIDGE – Thunder Bay Ontario

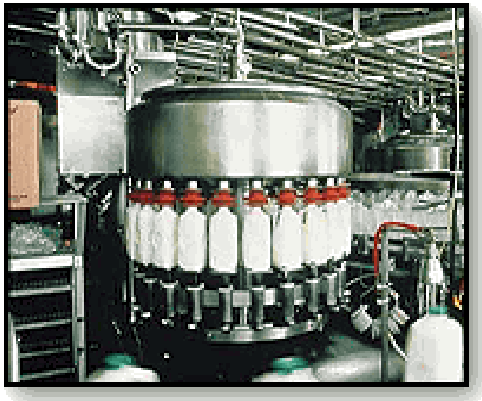
Power Survey Harmonic filter

- Capacity
  - 50 kvar to 20 Mvar
- Network voltage
  - 208v – 35,000v
  - Other voltages available
- Option
  - NEMA 12 & 3R enclosure
  - Main breaker
  - Main disconnect
  - Main fuse disconnect
  - Ground switch (MV application)
  - Capacitor Life indicator
  - Blown fuse indicator

Capacitor and harmonic filter references/standard

- IEEE 1531
  - Guide for Application and Specification of Harmonic Filters
- IEEE 18
  - Standard for Shunt Power Capacitors
- IEEE C37.99
  - Guide for Protection of Shunt Capacitor Banks
- IEEE 519
  - Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- IEEE 1036
  - Guide for Application of Shunt Power Capacitors
- IEEE C37.012
  - Application Guide for Capacitance Current Switching

Potential Market - Industrial




- <u>Industrial customers</u>

<u>Type</u>	<u>Typical PF</u>
• Printer	70%
• Plastic	70%
• Automobile	65%
• Saw mill	75%
• Pulp & Paper	70%
• Cement plant	70%
• Food & Process	80%
• Fisheries	80%
• Etc	

Potential Market - Commercial




- <u>Commercial customers</u>

Type	Typical PF
• Office tower	85%
• Shopping center	80%
• Grocery store	80%
• Arena	75%
• Pump station	75%
• Hospital	80%
• Etc	

References

- Falconbridge
- Québécor printing
- Nortel
- Kruger
- Canadian Forest Products
- Johnson & Johnson
- NASA
- Olympic stadium
- US Air Force, Arnold Base
- JFK Airport
- Chrysler
- Hyundai
- Vancouver WWTP
- Lafarge
- US Navy
- Shell
- Good Year
- Bowater
- Etc

Handy formulas

Useful Equations for Power Factor Correction and Harmonic Distortion (Balanced Phase Loads)

$$PF = \cos(\varphi) = \frac{kW}{kVA}$$

$$\% \text{ Voltage Rise} = \frac{KVAR \times \%Z}{\text{Transformer KVA}}$$

$$kVA = \frac{kW}{PF} = \sqrt{kW^2 + kVAr^2}$$

$$KW = KVA \times PF$$

$$kVA = \frac{V_L \times I_L}{1000} \quad \text{Single-Phase}$$

$$\% \text{ Power Loss Reduction} = 100 - 100\left(\frac{PF_O}{PF_T}\right)^2$$

$$kVA = \frac{\sqrt{3} \times V_L \times I_L}{1000} \quad \text{Three-Phase}$$

$$C_{ph} = \frac{KVAR \times 10^3}{(2\pi f)(KV)^2}$$

$$kVAr = \frac{2\pi \times f \times C_{ph} \times V_\phi^2}{1 \times 10^3}$$

$$X_C = \frac{10^6}{(2\pi f C)}$$

$$kVAr_E = kVAr_R \times \left(\frac{V_A}{V_R}\right)^2 \times \left(\frac{f_A}{f_R}\right) \quad \text{KVAR De-rating for Voltage \& Frequency}$$

$$kVAr = \frac{HP \times 0.746}{\eta}\left(\sqrt{\frac{1-PF_o^2}{PF_o^2}} - \sqrt{\frac{1-PF_T^2}{PF_T^2}}\right)$$

$$I_\Phi = \frac{KVAR \times 10^3}{\sqrt{3} \times V_L} \quad \text{Three Phase}$$

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \times 100\%$$

$$I_\Phi = \frac{KVAR \times 10^3}{V_L} \quad \text{Single Phase}$$

$$I_{RMS} = \sqrt{I_1^2 + \sum_{h=2}^{\infty} I_h^2}$$

$$KW\,(\text{Motor Input}) = \frac{Hp \times .746}{\%Eff}$$

Handy formulas

For Δ-Connected Capacitors:

$C_{TOT} = 3 \times C_{ph}$

$V_L = V_\phi$

$I_L = \sqrt{3} \times I_\phi$

For Y-Connected Capacitors:

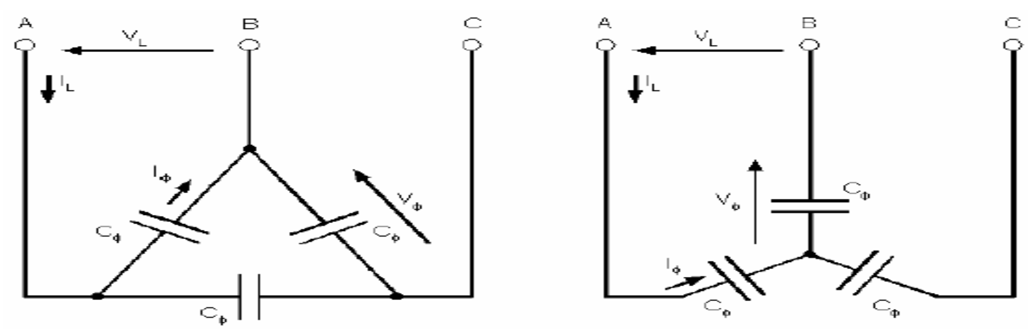
$C_{TOT} = 3 \times C_{ph}$

$V_L = \sqrt{3} \times V_\phi$

$I_L = I_\phi$

Legend

V_ϕ	- Phase voltage
V_A	- Applied line voltage
V_R	- Rated line voltage
I_L	- Line current
I_ϕ	- Phase current
I_h	- Harmonic current of order h
I_1	- Current at fundamental frequency
I_{RMS}	- Root-mean-square value of current
f	- Frequency
f_A	- Applied frequency
f_R	- Rated frequency
C_{TOT}	- Total capacitance in μF
C_{ph}	- Phase capacitance in μF
HP	- Horsepower
PF_0	- Initial power factor
PF_T	- Target power factor
η	- Motor efficiency
THD	- Total harmonic distortion
Xc	- Capacative Reactance
Z	- Transformer Impedance



Delta Connection

Wye Connection

Panel fabrication

- ***Dimension:***
  - Non standard
- ***Approval:***
  - CSA & UL
- ***Enclosure type:***
  - NEMA 1, 12, 3R, & 4
- ***Type of material***
  - Steel,
  - Stainless steel (304 & 316)
  - Aluminium

www.custom-metalinc.com