

A MAGNETIC DEVICE FOR IMPROVING POWER QUALITY

by

Mohan L. Ray, M.S.E.E., P.E.
Northrop Grumman Corporation, ESSS
Baltimore, Maryland

and

Robert T. Emmet, PhD
Pure Powers Systems, Inc.
Annapolis, Maryland

ABSTRACT

Power Quality can be described as the best quality power to operate specific equipment or process with the lowest level of operating problems.

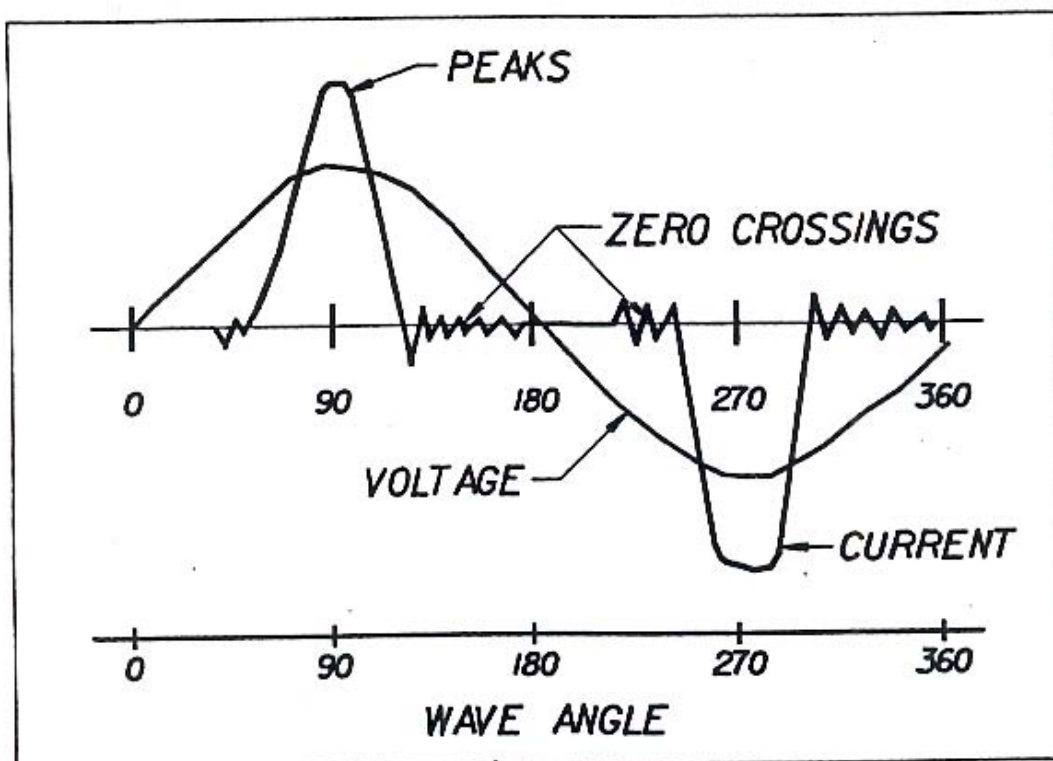
Several techniques such as providing harmonic mitigation, power factor improvement, and transient suppression devices are available for power quality improvement. Reduction of L.C. resonance, the phase balancing of voltages and load currents also enhances power quality. A circuit comprised of symmetrical wrap-around magnetic chokes between all three(3) phases, simultaneously accomplishes all the above improvements to various degrees. Basic understanding of Power Quality, Device Overview, and Test Data of this simple and rugged device are presented.

BASIC UNDERSTANDING OF POWER QUALITY

It is necessary to understand non-linear loads, harmonics, power factor, sags, surges, and transients.

Non-Linear Load - The Current Waveform does not look like the Voltage Waveform.

Note: this document is being redistributed by POWERGEN Systems, please contact them via phone or email (info@powergensystem.com) if you have any questions concerning this document or if require additional information.



Harmonics - Harmonics are currents or voltages with frequencies that are integer multiples of fundamental power frequency. If the fundamental is 60Hz, the second harmonic is 120Hz, the third harmonic is 180Hz, etc.. Harmonics are created by non-linear pulses that draw current in abrupt pulses rather than in a smooth sinusoidal manner. These pulses cause distorted current wave shapes which in turn cause harmonic currents to flow back to other parts of the Power System.

Each harmonic has a name, frequency, and sequence. The sequence refers to phasor rotation with respect to fundamental (F); i.e., in an induction motor, a positive sequence harmonic would generate a magnetic field that is rotated in the same direction as the fundamental. A negative sequence harmonic would rotate in the reverse direction.

The first nine(9) harmonics, along with the effects, are listed below:

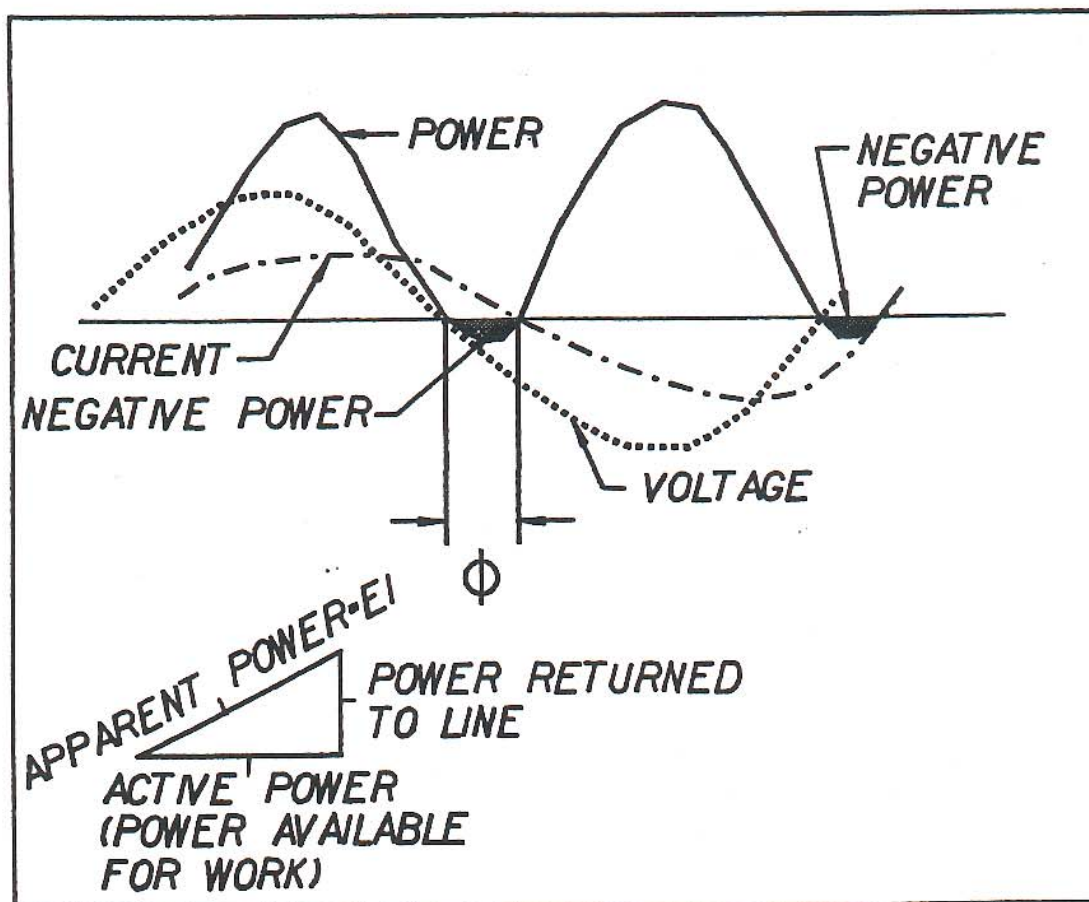
Name	First	2nd*	3rd	4th*	5th	6th*	7th	8th*	9th
Frequency	60	120	180	240	300	360	420	480	540
Sequence	+	-	0	+	-	0	+	-	0

* Even harmonics disappear when waves are symmetrical.

Sequence	Rotation	Effects (From skin effects, eddy currents, etc...)
Positive	Forward	Heating of Conductors and Breakers, etc.
Negative	Reverse	Heating as above + Motor problems
Zero	None	Heating + add on Neutral of 3-Phase, 4-wire system

Zero Sequence Harmonics and Odd Multiples of the 3rd are called "Triplens".

Power Factor: - Power Factor is defined as the "active" power divided by the "apparent" power.* During the part of each cycle, when the voltage is negative but the current is positive, their product is negative. This is negative power and it is not available for work. It is actually the power returned to the line.

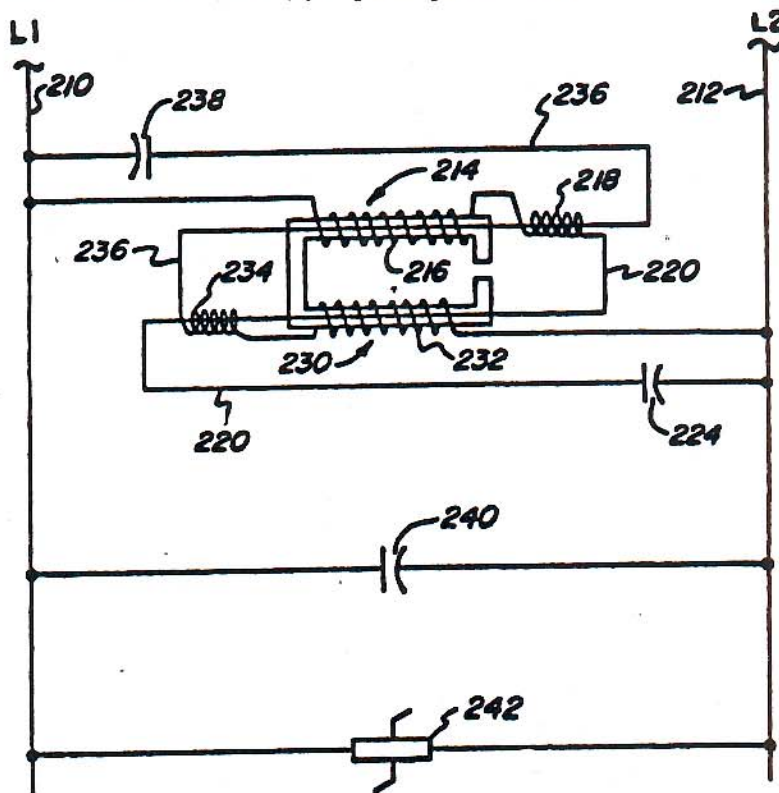


Sags and surges can be described as current and voltage fluctuations in milliseconds or more. Sags and surges are caused by severe weather - lightning, power line switching, large motors and inductive loads

turning off / on, short circuits, copiers / printers, fault / fuse clearing. Sags and surges cause data disruptions, damage to sensitive electronic devices, damage to power supplies, and total system failures. Transients are high-speed and high energy electrical noise. Transients relate to voltage or current excursions of microseconds and nanoseconds duration. Atmospheric lightning represents the most dangerous transients in transmission and distribution networks. Bolts of lightning have voltages between 500kv and 1000kv, durations between .5 and .20 microseconds and amperages 1,000 and 50,000 amps. If lightning strikes a transmission line, disturbances can travel from 10 to 20 miles within an electrical distribution system.

DEVICE OVERVIEW

The magnetic device for power quality improvement is called "USES" unit. "USES" units are installed at electrical panels supplying inductive load or at the disconnect links for large motors, i.e. elevators, air-conditioning units, heavy-duty machinery, etc. Units are also recommended for any panel at which surge protection is a major concern.. The "USES" is a single phase or three-phase passive line conditioner that functions to (a) reduce demand from the power system, (b) provide transient surge protection, (c) reduce harmonics, and (d) improve power factor.



The USES Circuit in Single Phase System

FIGURE 1

In FIGURE 1, two(2) chokes designated as 214 and 230 are used. Choke 214 comprises a first winding 216 in series with second winding 218. The choke terminates in a line 220 that is passed through the windings 232, 234 of choke 230. Line 220 is coupled to a capacitor 224 and the series combination of

choke 214 and capacitor 224 is coupled across an AC power source comprising line 210 and line 212. Similarly, choke 230 with the line 236 passing through the windings of choke 214, is coupled in series with a capacitor 238. The series combination of choke 230 and capacitor 238 is coupled across AC power source. A capacitor 240 and surge suppressor 242 are also coupled across the power source.

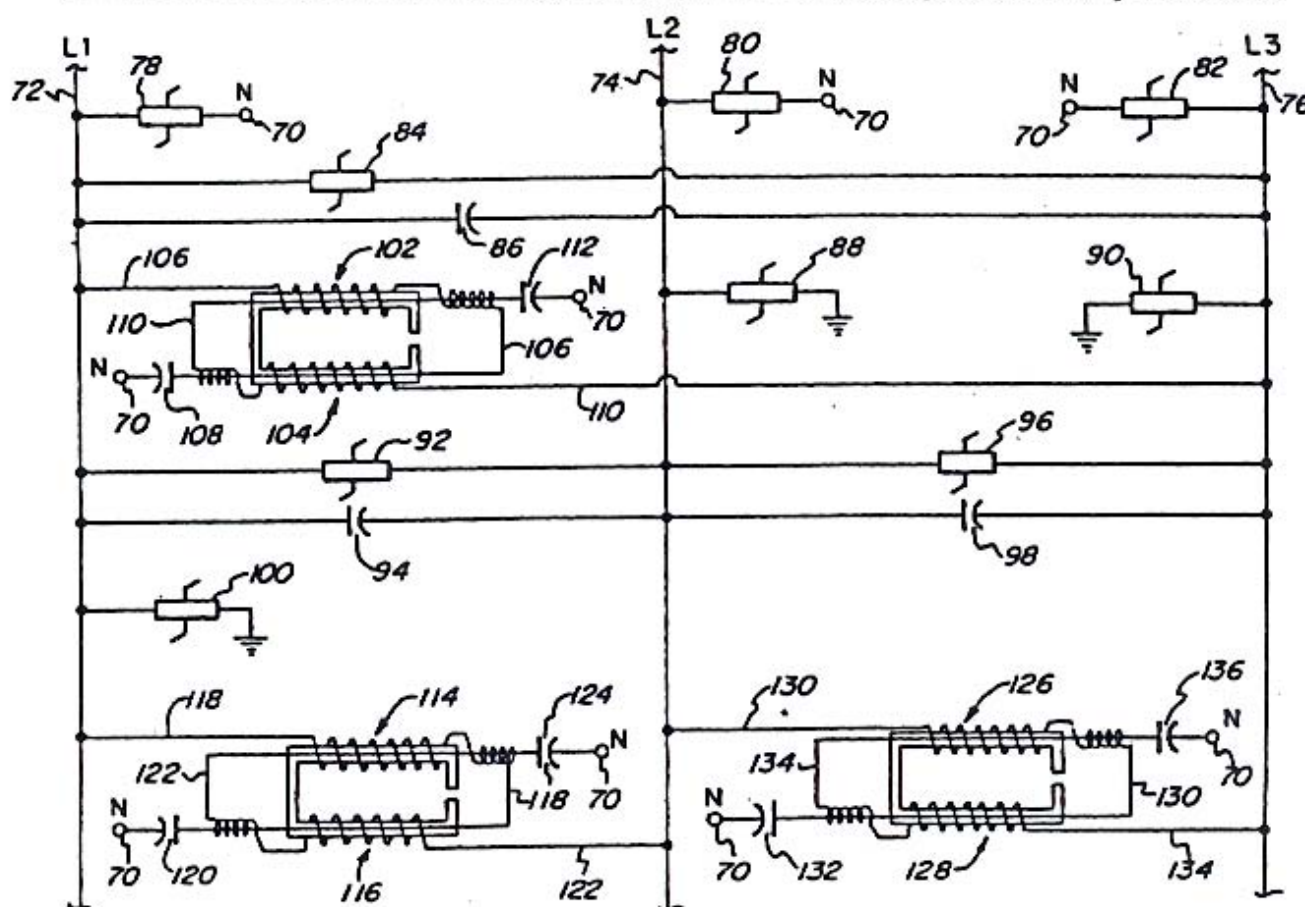


FIGURE 2

A three-phase embodiment of the power conditioner is illustrated in **FIGURE 2**. Again, the power conditioner can be placed at the service panel where incoming power is received from a utility. Additional power conditioners can also be placed at or near significant loads. The power conditioner is coupled to the three(3) incoming power lines **L1, L2, L3** represented by reference numerals 72, 74, and 76, respectively, and also to neutral as represented at terminal 70. MOV devices 78, 80, and 82 provide transient suppression from each line to neutral. MOV devices 84, 92, and 96 provide transient suppression between the various power lines. MOV devices 88, 90, and 100 provide transient suppression from each respective line to ground. Capacitors 86, 94, and 98 are coupled between respective power lines to provide filtering and power factor correction.

Chokes 114 and 116 are coupled between lines 72 and 74. Choke 114 and series capacitor 120 provide a first path 118 from line 72 to neutral. Choke 116 and series capacitor 124 provide a second path 122 from line 74 to neutral.

In a similar fashion, two other pairs of chokes couple lines 74 and 76 and lines 72 and 76. The three sets of wrap-around chokes provide magnetic coupling between the three electric phases: **L1, L2** and **L3**.

Chokes 102 and 104 are coupled between lines 72 and 76. Choke 102 and series capacitor 108 provide a fifth path 106 from line 72 to neutral. Choke 104 and series capacitor 112 provide a sixth path 110 from line 76 to neutral.

TESTING

The USES unit is connected to a 150 HP compressor motor, identified at Northrop Grumman, Sykesville, Maryland facility as "Chiller 2A". The motor is a 460 volt induction motor started across-the-line. The USES unit under test is Model # CMES3D480, as noted on the Installation picture on page 8.

The Chiller 2A is rated 150 HP at 460 v, with full load current (running load amperes, RLA) equal to 182A. The USES unit is connected in parallel to the 3-phase motor feed on the line side of the motor starter contactor. The USES unit has its own 30A molded case breaker for switched isolation.

The one-line diagram on page 7 shows the electrical configuration of Chiller 2A and its feed from Substation #4, 225A molded case breaker. Also shown on this one-line diagram are the connection points of both the USES and the power monitoring.

Motor / Compressor Data

Manufacturer: McQuay International, Inc.

460 V, 3-phase, 60 Hz, 182 FLA (RLA), 409 LRA (Wye), 1,228 LRA (Delta), 0.882 rated power factor (FLA)

Power Analyzer Description

The Power Platform PPI, manufactured by Dranetz-BMI, Inc., Edison, NJ, was used as the primary recording device for this project. The PPI, when used with the Task 8000 Task card, allows the meter to measure and record power parameters for both single phase and three phase systems. These parameters include : voltage, current, real power, reactive power, apparent power, power factor and voltage and current harmonics.

In conjunction with the PPI, two(2) other power meters were used as comparable data measurements. These were the ACE 2000, manufactured by CPM, Inc., Toronto, Canada, and the Fluke 41B. Data from these units are not included in this report; however, verification of recorded parameters of these units compared very closely with the Dranetz PPI data.

Test Procedure

The overall purpose of this testing was to measure and record power parameters of Chiller 2A under various load conditions both with and without the USES unit connected to the feeder. The power analyzer (PPI) was connected to the load side of the 225A feeder breaker. Power measurements were recorded by manual initiation as opposed to threshold triggering during specific loading conditions and USES operation. For instance, with Chiller 2A running at 100% RLA, and the USES unit breaker closed, measurements were initiated. At the same loading, the USES breaker was opened, and a new set of measurements was recorded. Load was changed on the chiller by varying the programmable chilled

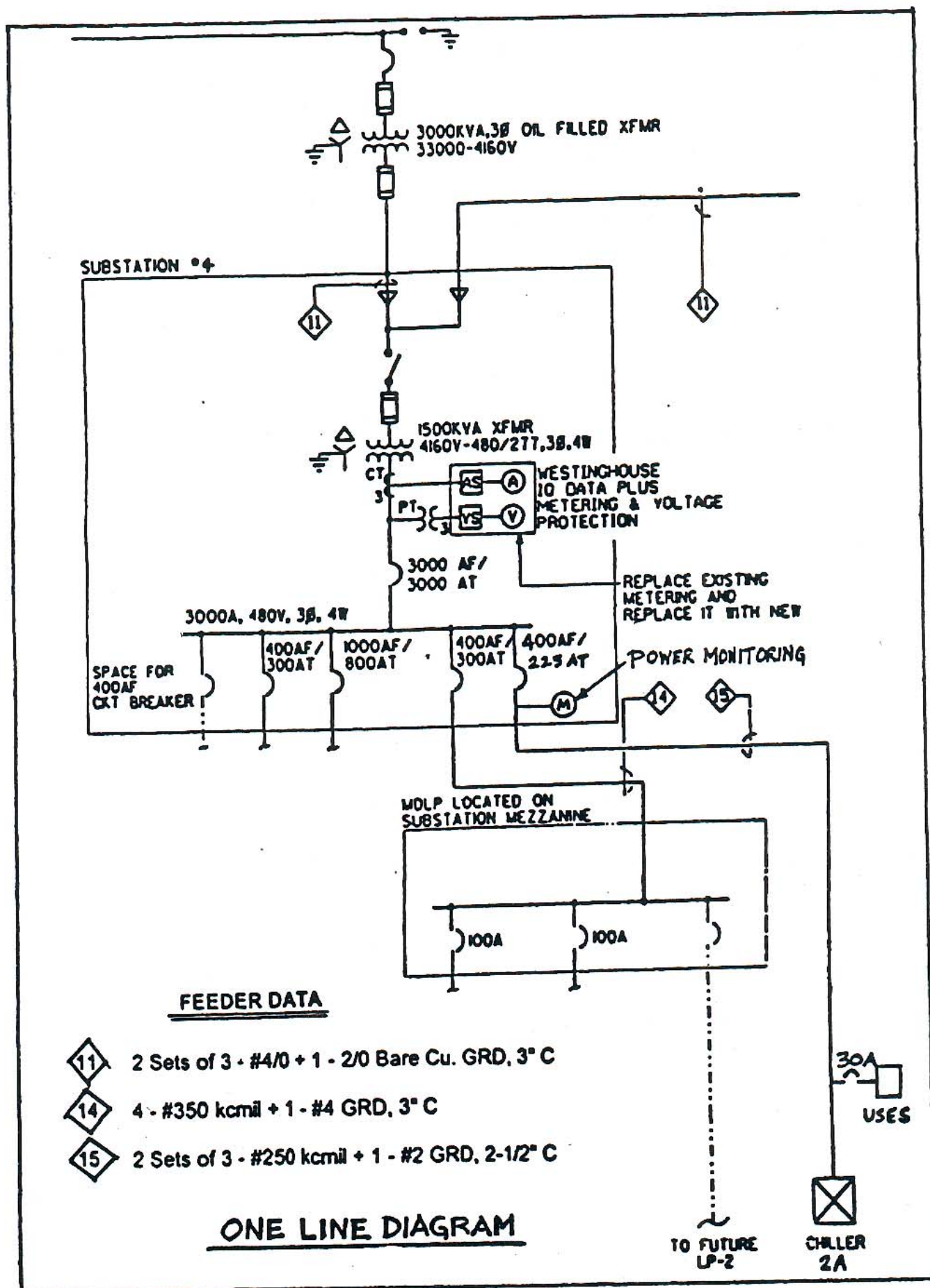
water temperature point. This adjustment allowed for a load range from 100% to 50% RLA. Consequently, power measurements were recorded under 100%, 90%, 75% and 50% load conditions for the USES connected and disconnected to the feeder.

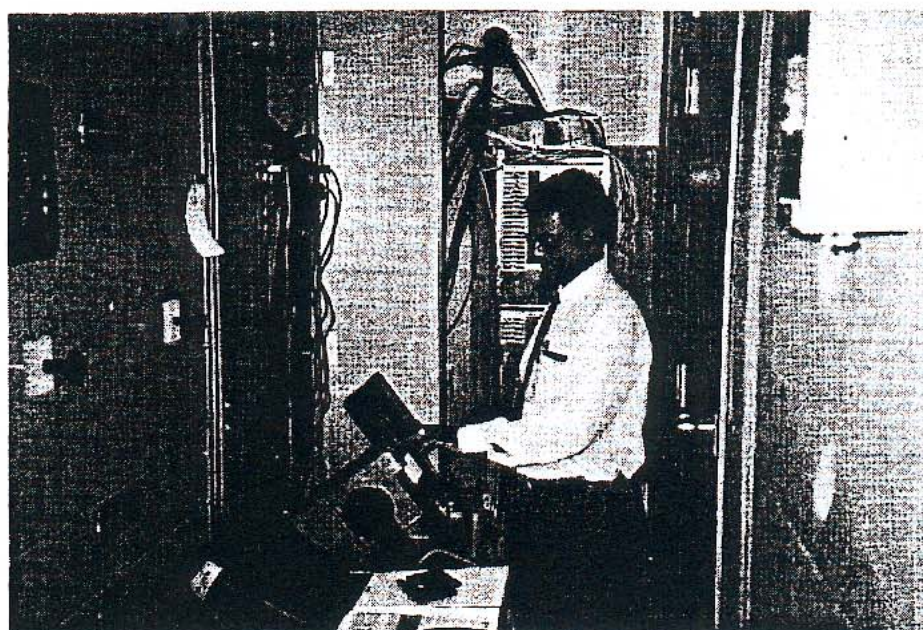
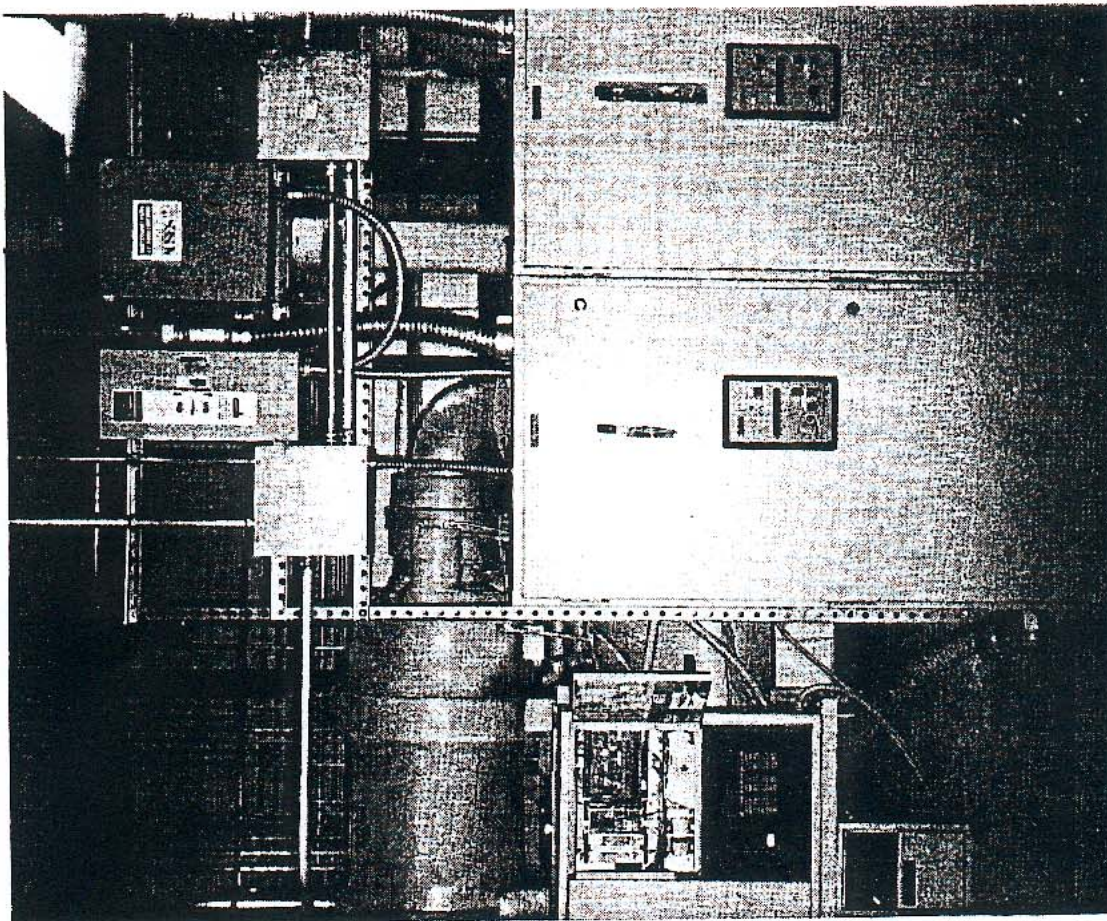
Test Results

Pointed results from the PPI recorded measurements are provided on pages 10 through 13 for 75% loading. These data sheets contain power measurements, voltage, current phases diagrams, sinusoidal waveforms, and harmonic data. For ease of comparison, these measurements are summarized in the Data Summary Table below for each load condition and with the USES unit switched on and off.

DATA SUMMARY TABLE

	100% RLA		90% RLA		75% RLA		50% RLA	
	ON	OFF	ON	OFF	ON	OFF	ON	OFF
V_{LL}	495.3	495.5	497.2	495.8	496.1	497.3	497.9	495.8
Abs.Chg.	-0.2		1.4		-1.2		2.1	
I_L	170.6	188.6	143.1	162.4	115.4	131.2	69.9	93.2
% Chg.	-9.5%		-11.9%		-12.0%		-25.0%	
PF	0.998	0.996	1.000	0.991	0.997	0.968	0.915	0.836
% Chg.	0.20%		0.90%		2.90%		7.90%	
kW	84.3	93.1	71.1	79.8	57.1	63.1	31.8	38.6
% Chg.	-9.5%		-10.9%		-9.5%		-17.6%	
kVARS	-5.1	8.1	0.6	10.9	4.1	16.3	14.1	25.4
% Chg.	-163.0%		-94.5%		-74.8%		-44.5%	
kVA	84.5	93.5	71.0	80.5	57.2	65.2	34.8	46.2
% Chg.	-9.6%		-11.8%		-12.3%		-24.7%	
V_{THD}	1.965	1.949	2.084	1.932	2.026	1.965	2.119	2.033
% Chg.	0.8%		7.9%		3.1%		4.2%	
I_{THD}	1.938	2.844	2.372	3.310	2.884	4.206	3.990	4.911
% Chg.	-31.9%		-28.3%		-31.4%		-18.8%	





75% RLA - USES ON

75% RLA - USES OFF

DRANETZ PPI-8000 N-G 2R 14:25:46 Apr-08-99
ALL CHANNELS SUMMARY REPORT f= 60.00hz (A)
--R-- --B-- --C-- --O-- --ABC--
495.6 497.0 495.8 0.038 0.038
111.7 115.5 118.9 0.000 0.000
55.27k 57.10k 58.84k 0.000 0.000
0.998 0.995 0.998 0.000 0.000
3.185k 3.664k 3.584k 0.000 0.000
1.481 1.396 1.394 0.000 0.000
1.448 1.447 1.418 0.000 0.000
2.026 1.865 1.885 0.000 0.000
2.884 2.792 2.845 0.000 0.000
7.235k 7.844k 5.980k 0.000 0.000
5.886k 7.384k 6.415k 0.000 0.000
0.997 0.996 0.997 1.000 1.000
0.999 0.996 0.999 0.000 0.000
859.6 859.8 858.5
PRESENT DEMAND: 171.2kW
ACCU ENERGY: 1.458MWHR
PROJ. DEMAND: 190.5kW

DRANETZ PPI-8000 N-G 2R 14:33:39 Apr-08-99
ALL CHANNELS SUMMARY REPORT f= 59.99hz (A)
--R-- --B-- --C-- --O-- --ABC--
496.5 498.6 496.8 0.038 0.038
126.3 132.0 135.2 0.000 0.000
60.99k 63.09k 65.34k 0.000 0.000
0.972 0.959 0.973 0.000 0.000
62.72k 65.79k 67.15k 0.000 0.000
14.65k 18.64k 15.49k 0.000 0.000
1.398 1.396 1.394 3.402 3.402
1.427 1.405 1.393 0.000 0.000
1.965 1.825 1.853 0.000 0.000
4.206 3.934 3.841 0.000 0.000
4.115k 4.182k 3.906k 0.000 0.000
2.096k 1.958k 2.115k 0.000 0.000
0.997 0.997 0.997 1.000 1.000
0.974 0.968 0.974 0.000 0.000
861.8 862.1 860.2
PRESENT DEMAND: 189.4kW
ACCU ENERGY: 1.481MWHR
PROJ. DEMAND: 178.1kW

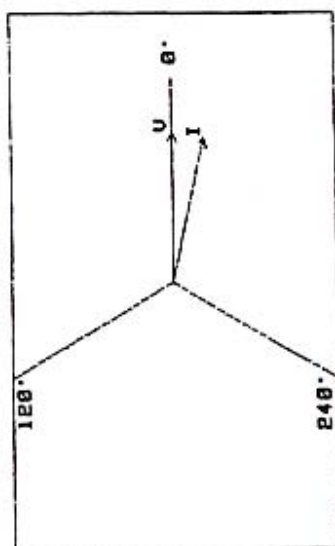
75% RLA - USES OFF

14:34:28 Apr-08-99

DRANETZ PPI-8000 N-G 2R

PHASOR: A

VOLTAGE:
497 ± 888°
CURRENT:
126 ± 345°

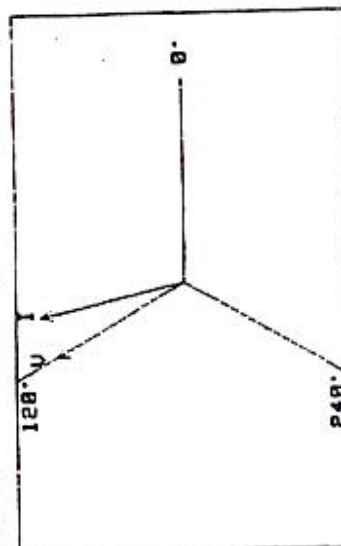


14:34:33 Apr-08-99

DRANETZ PPI-8000 N-G 2R

PHASOR: B

VOLTAGE:
499 ± 120°
CURRENT:
132 ± 183°

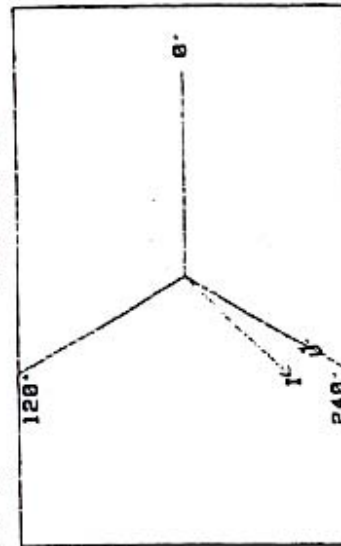


14:34:37 Apr-08-99

DRANETZ PPI-8000 N-G 2R

PHASOR: C

VOLTAGE:
497 ± 240°
CURRENT:
135 ± 227°



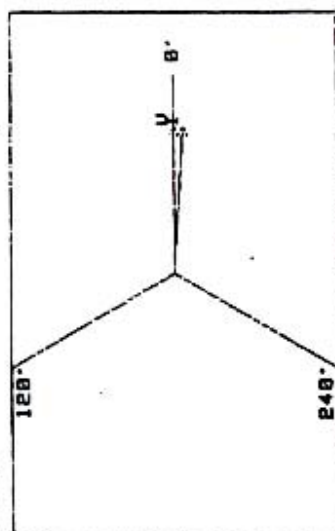
75% RLA - USES ON

14:27:58 Apr-08-99

DRANETZ PPI-8000 N-G 2R

PHASOR: A

VOLTAGE:
497 ± 888°
CURRENT:
186 ± 356°

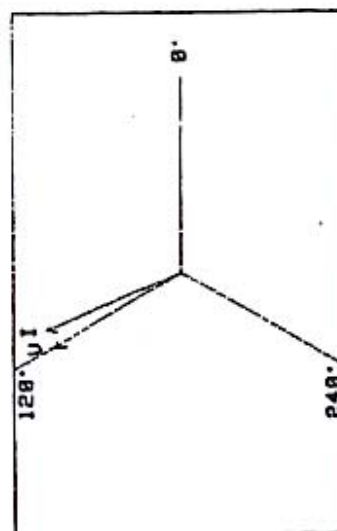


14:28:05 Apr-08-99

DRANETZ PPI-8000 N-G 2R

PHASOR: B

VOLTAGE:
498 ± 120°
CURRENT:
111 ± 113°

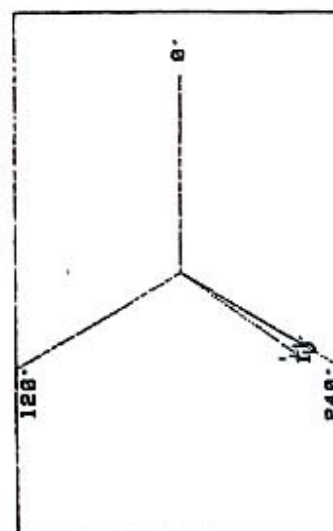


14:28:18 Apr-08-99

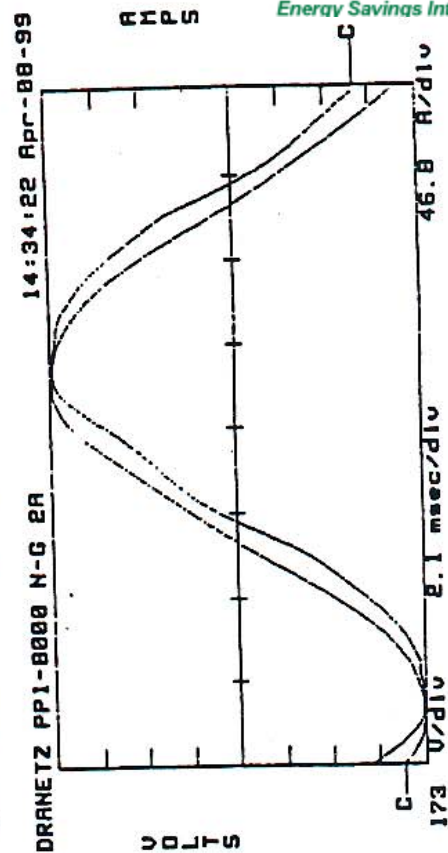
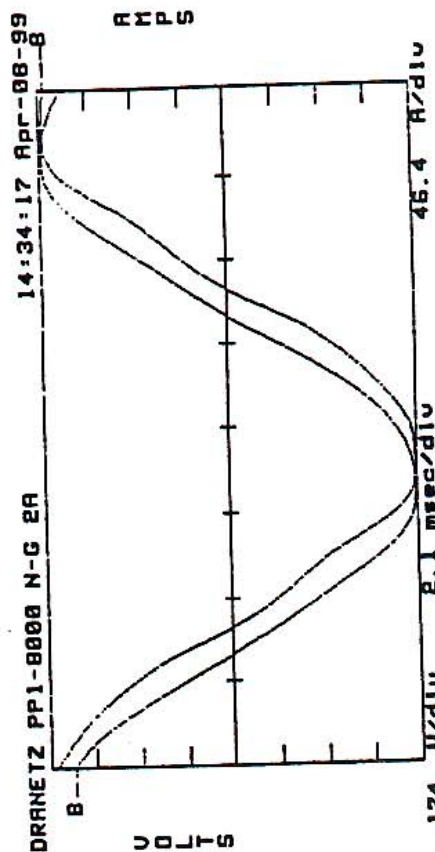
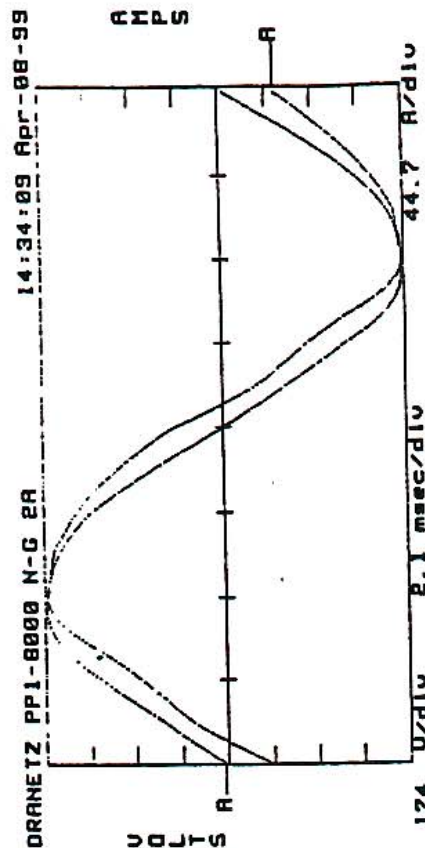
DRANETZ PPI-8000 N-G 2R

PHASOR: C

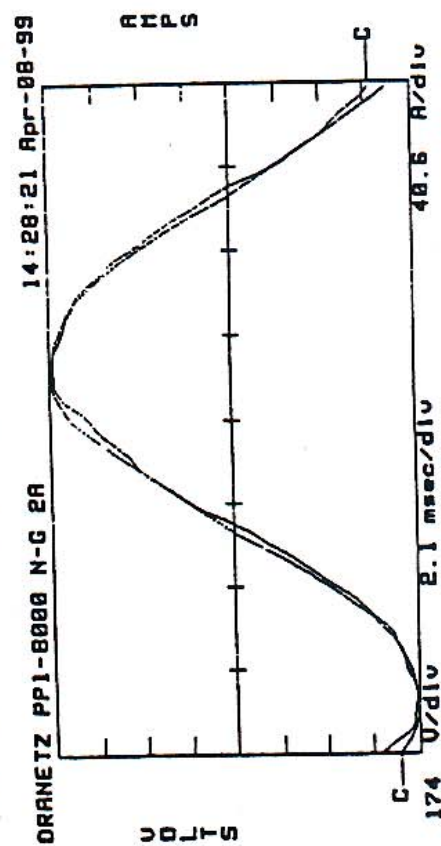
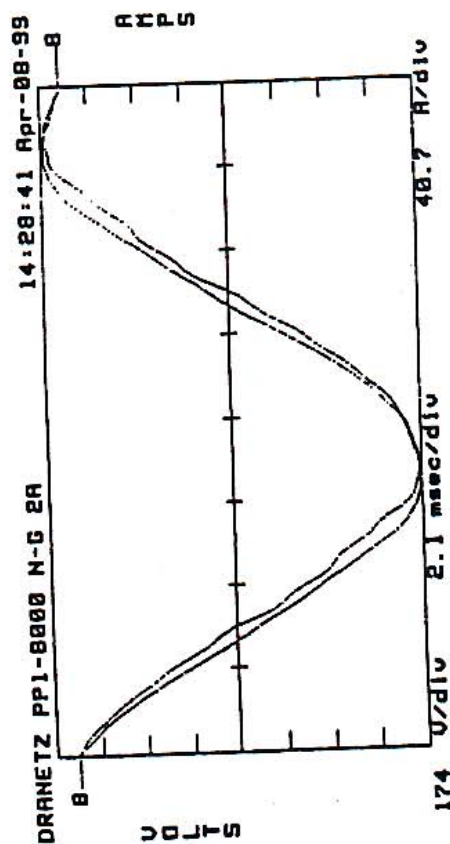
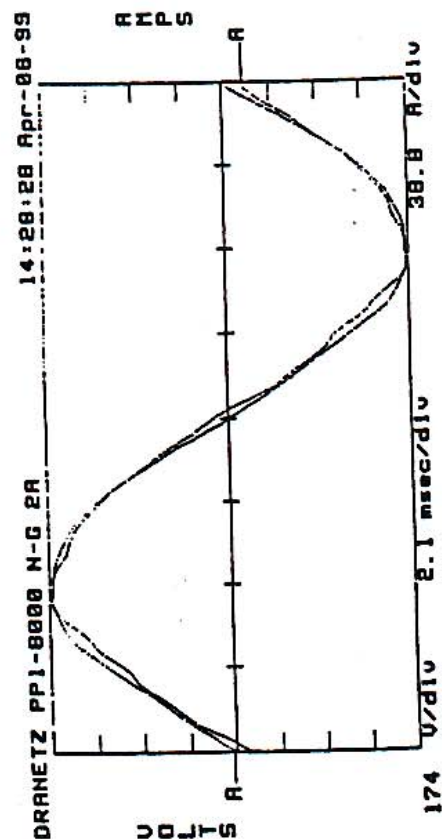
VOLTAGE:
497 ± 240°
CURRENT:
114 ± 236°



75% RLA - USES OFF



75% RLA - USES ON



75% RLA - USES OFF

75% RLA - USES ON

DRANETZ PPI-8000 N-G 2A									
HARMONICS:CH A									
APR-08-99 14:35:41									
126.0 A, 60.0Hz									
XFUND	ITHD	4.172 %	REF	MAGX	H#	MAGX	H#	MAGX	H#
02	0.142	263	0.057	0.000	36	0.000	169	0.000	336
03	0.091	123	0.000	0.000	37	0.000	336	0.000	336
04	0.057	66	0.000	0.000	38	0.000	336	0.000	336
05	0.041	41	0.000	0.000	39	0.000	336	0.000	336
06	0.028	28	0.000	0.000	40	0.000	336	0.000	336
07	0.020	20	0.000	0.000	41	0.000	336	0.000	336
08	0.014	14	0.000	0.000	42	0.000	336	0.000	336
09	0.010	10	0.000	0.000	43	0.000	336	0.000	336
10	0.007	7	0.000	0.000	44	0.000	336	0.000	336
11	0.005	5	0.000	0.000	45	0.000	336	0.000	336
12	0.004	4	0.000	0.000	46	0.000	336	0.000	336
13	0.003	3	0.000	0.000	47	0.000	336	0.000	336
14	0.002	2	0.000	0.000	48	0.000	336	0.000	336
15	0.001	1	0.000	0.000	49	0.000	336	0.000	336
16	0.001	1	0.000	0.000	50	0.000	336	0.000	336
17	0.000	0	0.000	0.000					
18	0.000	0	0.000	0.000					

DRANETZ PPI-8000 N-G 2A									
HARMONICS:CH A									
APR-08-99 14:29:22									
109.4 A, 60.0Hz									
XFUND	ITHD	2.943 %	REF	MAGX	H#	MAGX	H#	MAGX	H#
02	0.155	229	0.264	0.000	36	0.000	169	0.000	336
03	0.091	123	0.000	0.000	37	0.000	336	0.000	336
04	0.057	66	0.000	0.000	38	0.000	336	0.000	336
05	0.041	41	0.000	0.000	39	0.000	336	0.000	336
06	0.028	28	0.000	0.000	40	0.000	336	0.000	336
07	0.020	20	0.000	0.000	41	0.000	336	0.000	336
08	0.014	14	0.000	0.000	42	0.000	336	0.000	336
09	0.010	10	0.000	0.000	43	0.000	336	0.000	336
10	0.007	7	0.000	0.000	44	0.000	336	0.000	336
11	0.005	5	0.000	0.000	45	0.000	336	0.000	336
12	0.004	4	0.000	0.000	46	0.000	336	0.000	336
13	0.003	3	0.000	0.000	47	0.000	336	0.000	336
14	0.002	2	0.000	0.000	48	0.000	336	0.000	336
15	0.001	1	0.000	0.000	49	0.000	336	0.000	336
16	0.001	1	0.000	0.000	50	0.000	336	0.000	336
17	0.000	0	0.000	0.000					
18	0.000	0	0.000	0.000					

DRANETZ PPI-8000 N-G 2A									
HARMONICS:CH B									
APR-08-99 14:35:47									
133.4 A, 60.0Hz									
XFUND	ITHD	3.880 %	REF	MAGX	H#	MAGX	H#	MAGX	H#
02	0.108	216	0.108	0.000	36	0.000	304	0.000	304
03	0.069	138	0.000	0.000	37	0.000	304	0.000	304
04	0.046	92	0.000	0.000	38	0.000	304	0.000	304
05	0.033	66	0.000	0.000	39	0.000	304	0.000	304
06	0.024	48	0.000	0.000	40	0.000	304	0.000	304
07	0.018	36	0.000	0.000	41	0.000	304	0.000	304
08	0.013	26	0.000	0.000	42	0.000	304	0.000	304
09	0.010	20	0.000	0.000	43	0.000	304	0.000	304
10	0.007	14	0.000	0.000	44	0.000	304	0.000	304
11	0.005	10	0.000	0.000	45	0.000	304	0.000	304
12	0.004	8	0.000	0.000	46	0.000	304	0.000	304
13	0.003	6	0.000	0.000	47	0.000	304	0.000	304
14	0.002	4	0.000	0.000	48	0.000	304	0.000	304
15	0.001	3	0.000	0.000	49	0.000	304	0.000	304
16	0.001	2	0.000	0.000	50	0.000	304	0.000	304
17	0.000	1	0.000	0.000					
18	0.000	0	0.000	0.000					

DRANETZ PPI-8000 N-G 2A									
HARMONICS:CH B									
APR-08-99 14:29:27									
113.8 A, 60.0Hz									
XFUND	ITHD	2.729 %	REF	MAGX	H#	MAGX	H#	MAGX	H#
02	0.252	126	0.568	0.000	36	0.000	249	0.000	249
03	0.158	79	0.000	0.000	37	0.000	249	0.000	249
04	0.105	53	0.000	0.000	38	0.000	249	0.000	249
05	0.073	37	0.000	0.000	39	0.000	249	0.000	249
06	0.052	26	0.000	0.000	40	0.000	249	0.000	249
07	0.038	19	0.000	0.000	41	0.000	249	0.000	249
08	0.028	14	0.000	0.000	42	0.000	249	0.000	249
09	0.020	10	0.000	0.000	43	0.000	249	0.000	249
10	0.015	7	0.000	0.000	44	0.000	249	0.000	249
11	0.011	5	0.000	0.000	45	0.000	249	0.000	249
12	0.008	4	0.000	0.000	46	0.000	249	0.000	249
13	0.006	3	0.000	0.000	47	0.000	249	0.000	249
14	0.004	2	0.000	0.000	48	0.000	249	0.000	249
15	0.003	1	0.000	0.000	49	0.000	249	0.000	249
16	0.002	1	0.000	0.000	50	0.000	249	0.000	249
17	0.001	0	0.000	0.000					
18	0.000	0	0.000	0.000					

DRANETZ PPI-8000 N-G 2A									
HARMONICS:CH C									
APR-08-99 14:35:52									
135.9 A, 60.0Hz									
XFUND	ITHD	3.867 %	REF	MAGX	H#	MAGX	H#	MAGX	H#
02	0.108	216	0.106	0.000	36	0.000	370	0.000	370
03	0.069	138	0.000	0.000	37	0.000	370	0.000	370
04	0.046	92	0.000	0.000	38	0.000	370	0.000	370
05	0.033	66	0.000	0.000	39	0.000	370	0.000	370
06	0.024	48	0.000	0.000	40	0.000	370	0.000	370
07	0.018	36	0.000	0.000	41	0.000	370	0.000	370
08	0.013	26	0.000	0.000	42	0.000	370	0.000	370
09	0.010	20	0.000	0.000	43	0.000	370	0.000	370
10	0.007	14	0.000	0.000	44	0.000	370	0.000	370
11	0.005	10	0.000	0.000	45	0.000	370	0.000	370
12	0.004	8	0.000	0.000	46	0.000	370	0.000	370
13	0.003	6	0.000	0.000	47	0.000	370	0.000	370
14	0.002	4	0.000	0.000	48	0.000	370	0.000	370
15	0.001	3	0.000	0.000	49	0.000	370	0.000	370
16	0.001	2	0.000	0.000	50	0.000	370	0.000	370
17	0.000	1	0.000	0.000					
18	0.000	0	0.000	0.000					

DRANETZ PPI-8000 N-G 2A									
HARMONICS:CH C									
APR-08-99 14:29:33									
118.0 A, 0.0Hz									
XFUND	ITHD	2.844 %	REF	MAGX	H#	MAGX	H#	MAGX	H#
02	0.122	148	0.519	0.000	36	0.000	261	0.000	261
03	0.074	89	0.000	0.000	37	0.000	304	0.000	304
04	0.056	63	0.000	0.000	38	0.000	339	0.000	339
05	0.038	46	0.000	0.000	39	0.000	363	0.000	363
06	0.028	34	0.000	0.000	40	0.000	393	0.000	393
07	0.020	25	0.000	0.000	41	0.000	419	0.000	419
08	0.015	18	0.000	0.000	42	0.000	437	0.000	437
09	0.011	13	0.000	0.000	43	0.000	455	0.000	455
10	0.008	9	0.000	0.000	44	0.000	467	0.000	467
11	0.006	6	0.000	0.000	45	0.000	476	0.000	476
12	0.004	4	0.000	0.000	46	0.000	485	0.000	485
13	0.003	3	0.000	0.000	47	0.000	495	0.000	495
14	0.002	2	0.000	0.000	48	0.000	504	0.000	504
15	0.001	1	0.000	0.000	49	0.000	510	0.000	510

DISCUSSION OF THE DATA

To study the effects of the USES Unit over a range of motor amperage, the power parameters were recorded at four (4) load levels, 50%, 75%, 90% and 100% rated load amperage (RLA). The Data Summary Table, at all load levels, shows that the USES Unit decreases the amperage and power demand and increases the motor voltage and power factor. KVAR is reduced considerably and the amperage THD is reduced by about 30 %. The data summary predicts that the motor operation will use less power and will be cooler and smoother both mechanically and electrically. To gain insight into the USES mechanism however, we must compare the individual phase data.

For each on/off measurement condition, the average deviation of the three (3) phase amperages and voltages were calculated. The average deviations between phases with USES are uniformly smaller by 0.3 A and 0.2 V at the three upper load levels, but not at 50%. The regular pattern of convergence demonstrates that USES balances, through the magnetic chokes, the phase amperages and voltages. Within the induction motor, improved phase balance would result in more symmetrical magnetic fields and reduced eddy currents. At 50% load level where motor operation is less efficient, although USES caused greater reduction in amperage, other factors cause the phase conditions to diverge slightly. Through this phase balancing of amperage and voltage, USES would attenuate both amperage and voltage transients that appear on only one phase. The balancing would also capture and distribute energy between phases, thus making it available to 3-phase machinery. We have given the complete 3-phase data for the 75% load level. The data for the other load levels can be found in the Cutler Hammer Report.

During the testing, measurements were also made with the motor off but with USES on. Each phase drew 27 amps at 498 volts. From the 3-phase USES Circuit Diagram in Figure 2, it is apparent that the wrap-around magnetic chokes co-generate the 27 amp signals from the adjacent phases, and that each signal would be 120 degrees out-of-phase with respect to the main phase amperages. At the points of connection of the USES leads, there is vectorial addition of the 27 amp signal to the main phase amperage. In each phase, the 27 amp signal is capacitive reactive current which seeks to cancel inductive reactive current produced by the inductive loads. This cancellation causes the amperage demand reduction up line from the point of USES connection and is the mechanism for displacement power factor correction. USES is a superior method of power factor correction because only a small, out-of-phase current does the job. Traditional power factor correction capacitors, because of the large currents involved, must be located near the motors or at the service entrance where the cables are heavy-duty. Eliminating the capacitors reduces RCL resonance and other motor-related problems. Also, USES does not heat up or fail in high harmonic environments.

By comparing the harmonic data in the Summary Data Table and in the phase data tables, it is seen that with USES the current harmonic distortion, ITHD, is reduced by 30% while the VTHD is increased by 4%. The harmonic distortion is generated within the motor, and the 30% decrease in ITHD is evidence of smoother electrical and mechanical operation, which leads to higher efficiency and longer motor life. Study of the effects of USES on transient attenuation, and on ITHD and VTHD will be the goals of future testing.

CONCLUSION

This Study provides conclusive evidence that by providing passive magnetic linkage between electrical phases, the USES Unit does reduce amperage demand and power demand for inductive loads. The USES Circuit and the Testing are precisely described. Analysis of the data in three (3) phases suggests mechanisms by which USES attenuates transients, improves displacement power factor and balances electrical phases. The USES Unit reduces inductive circuit current harmonics by 30% which suggests that the power quality is significantly improved. The other pronounced functions of harmonic distortion reduction and transient voltage suppression are to be further tested separately in the future.

References:

1. The USES Unit - The Inductive Solution to the Inductive Circuit Efficiency Problem -
March 24, 1999 By: Robert T. Emmet, PhD
2. Power Measurement Report of USES for Northrop Grumman Corporation Facility at
at Sykesville, Maryland By: Alton W. Baum, P.E. -
CUTLER-HAMMER
3. USES Manufacturing, Inc. - "An A-C Power Conditioning System", U.S. Patent # 5,105,327,
April 1992. By: E. B. Wohlforth