The Importance of

Power Quality

A white paper written by **Greg Ehrhardt, Engineering Manager**
Richards Electric Motor Co.

Executive Summary

The Importance of Power and How it Effects your Equipment

Recent reports show power quality disturbances cost American manufacturers $26 billion annually in downtime, reduced capacity, production waste, premature equipment failure, utility penalties, and damaged machinery. This is up from $15 billion in 2015.

Within a manufacturing facility, 80% of all power quality problems originate on the customer's side of the meter and primarily involve surges (62%) and sags (29%), with the balance of quality issues being impulses, harmonics, and the loss of AC line voltage altogether. What does this mean for your plant production?

The good news is you have options. Power supplies at the point of use that are properly sized ensure the right voltages are getting to your equipment or controls, regardless of power quality disturbances. Also, the Internet of Things (IoT) can help capture power quality data in a cost-effective manner to monitor the effects on your equipment.

At MULTIVAC we do not claim to be power experts, but we are happy to share knowledge and put you in touch with a third-party resource who can help diagnose power quality issues. The following white paper was written to educate our valued customers and prevent production interruptions from power quality issues.

Sincerely,

MULTIVAC Customer Service Department

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Power Quality for Servo Drive | NVFD | HMI Applications

Reliable power is essential for sensitive electronic equipment in today's competitive business environment. Power quality issues, often hidden from regular utility bills and plant information systems, often lead to plant downtime, reduced capacity, production waste, premature equipment failure, and utility penalties. Alternative power sources such as solar and wind have created grid stability challenges in a rush to meet renewable energy portfolio standards. In addition, the increased use of electronic equipment in industrial facilities strains utilities, increasing power quality events. To minimize expensive repairs and downtime, production sites must be upfront when designing sensitive electronic equipment installations, thereby protecting themselves on the horizon.

Equipment efficiency has been a goal for servo drive/ VFD suppliers. Thus, switching speeds have dramatically increased along with the noise issues accompanying this speed. The increased capacitive coupling due to the effective frequency increase may cause noise-induced equipment failures.

QUALITY POWER INSTALLATIONS

One must have quality power supplying all Information Technology Equipment (ITE). When measuring the voltage to prove one has a quality installation, measuring the voltage at the input to the equipment with a slow sampling meter is not enough. Instead, facilities must monitor the power with a high-speed power recorder (5 MHZ sample rate) to ensure the power events fall within the CBEMA/ITIC curves.
These curves were generated to analyze 120V, 120/208V, and 120/240V systems. The curves are an excellent way to establish baseline power quality.

See Appendix 1 for CBEMA / ITIC curve discussion.
Keep in mind, the curves are more conservative than what Servo Drive manufacturers allow for 50-microsecond transients, but they are a great benchmark. We want to be more conservative as we have sensitive HMI screens in addition to Servo Drives fed by the power.

Appendix 2 shows page one of IEC 61800-1, the IEC standard for adjustable speed drive power systems. The Standard contains more details on damage curves for Servo drives and can be purchased from an authorized distributor.

A manufacturer has no control over the power quality supplying equipment sold to an end user. Power monitoring to ensure compliance with the CBEMA / ITIC curves is the only way to accomplish this task.

In addition, the OEM should stress that quality surge protection on the service entrance would protect against lightning-induced surges not seen during site power monitoring. The goal is to install a policy that protects sensitive electronics from all power disturbance scenarios. Therefore, all power systems need quality surge suppression at the service entrance and surge protection at the equipment itself, protecting against internal surges and let thru surges from the primary surge device at the service entrance. Changing the owner's power system to provide adequate power quality can be costly, depending on the electrical installation and the panel requirements. Therefore, it is best to perform power monitoring and look over the existing power system at the facility before making any recommendations.

Current Servo Drives are designed to meet surge requirements per IEC 61800-1. The surge allowances are slightly higher than the CBEMA/ITIC Curves at 50 microseconds.

Appendix 3, provided by Kollmorgen Servo Drives, displays the differences between the curves.

Looking at the Fluke event reports shown in Appendix 4, we can analyze acceptability for the very short transient exposures in the events log on Pages 5-7. The events can be plotted against the CBEMA / ITIC curves, as shown on Page 8 and will show status quo regarding power quality for sensitive electronic equipment. For a quality power system, all power events must be outside of the prohibited region and voltage sags must meet requirements. If additional voltage regulation is necessary, a determination can be made at this time. This type of reporting is essential to show if power quality is adequate.

Equipment can also be damaged by inrush currents caused by oversized supply transformers feeding the equipment. Servo drive manuals typically state that the owner must limit inrush current in a vague, general statement. Appendix 5 by SQD explains the role of source strength with input current levels and initial inrush. Appropriately sized line reactors are known to reduce the input currents and have been used for a long time. However, one must evaluate the system before blindly adding reactance to the circuit. Some EMC filters used in Europe provide the servo drives with an advantage here, as they will limit inrush.

NEW INSTALLATIONS

Key issues one should address to ensure a quality installation from a power quality perspective.

Step 1} Ensure there is correct fault current available for the equipment design. Too much fault current is a safety hazard and will increase the inrush / surge current to the Servo drives when power is applied.

Short circuit ratings for equipment installations are 5,000 Amps RMS Symmetrical Amps. Avoid issues with some simple calculations.

Example 1: 3-phase transformer supplying the equipment
480V 3-Phase primary 120/208 V Secondary
Size= 251<VA Impedance= 3.71%
Full load amps= 25000VA / (1.732 x 208V} = 69.4 Amps
Short circuit current= 69.4A (100)/3.71 = 1067.4 Amps 3 Phase RMS Symmetrical. "OK" as available short circuit current with infinite primary is less than the SCCR of the equipment.

Example 2: 1-Phase transformer supplying the equipment
480V 1 Phase primary 120/240V Secondary
Size= 25KVA Impedance= 3.71%
Full load Amps= 25000VA / 240V = 104.2A
Short Circuit L-L = 104.2A{100/3. 71) = 2808.6A
Short Circuit L-N = 150% L-L value (Conserv.) = 4212.9 A

Worst Case: Short circuit values are less than the assumed Panel Short Circuit Current Rating of SKA. This is considered OK.

Step 2} Calculate Source Impedance ratio. To reduce inrush current issues, ensure the power source impedance in reference to the servo drive impedance is at least .5%.

Example 1 (3-phase example above) would present the impedance of the source in reference to the Servo drive as follows:

9A (Drive input Amps) / 1067A (short circuit current) = .8% OK
Allen Bradley recommends a minimum of .5% Source impedance for Servo Drives as shown in Appendix 6.

Recommendation: Design for a source impedance of between 1 and 5 percent for VFDs / Servo Drives. If the Source impedance is too low, reduce the transformer size.

Caution: Complete a system analysis before resizing a transformer or adding reactance to an existing installation.

Sola Constant Voltage Power Conditioners are excellent choices when powering sensitive electronic equipment. They provide voltage regulation with surge protection and noise attenuation with little to no maintenance.
Many of the Servo Drive manuals allow Single phase input power as an option, but this would need to be run by Engineering if the standard setup is for three-phase power.

See Appendix 7 for details.

If 3-phase power is required, consider the Sola 3-phase power conditioners. They are much more expensive than the Sola Single phase power conditioners but will eliminate power problems. In addition, they keep the voltage in the window needed and provide proper surge protection. This option should have relatively low maintenance. Do a site walkthrough before heading down this road.

See Appendix 8 for details.

For no bigger than the loads are to the panels, robust 3-phase UPS power may also be the answer. This is the most expensive option, and one must compare costs to the 3-phase power conditioner. This option would require maintenance as batteries are involved.

See Appendix 9 for details.

Step 3} Quality surge protection/proper grounding at the main service equipment is essential in today's power environments and will absorb the bulk of the surge energy coming into the building. The transformers/power conditioners/UPS mentioned above will dissipate the remaining energy.

Note: Voltage transients are generated both inside and outside of plants. Protect against both.

The 3-phase power conditioners by Sola and 3-phase UPS systems are expensive. Evaluate these systems before going this route. UPS Systems are great but require battery maintenance and a clean-cool environment for extended battery life.

Suppose the site power monitoring indicates clean power and the owner has quality surge protection on the incoming power. In that case, the owner should be OK with the standard step-down transformer as sized above.

EXISTING INSTALLATIONS WITH A TROUBLED PAST

Begin by recording the power quality for one week and analyzing any issues. Next, demonstrate the power's true quality by comparing events to the CBEMA/ITIC curves. If power events do not reside in the correct parts of the curves, it is time for improvements to the power system supplying the equipment. When installing a power monitor, a power walkthrough should be performed to determine any weaknesses (lack of incoming surge protection, poor grounding, oversized power system, capacitors switching outside the plant, large motors regularly starting, to name a few).

SUMMARY

In summary, Rome wasn't built in a day. It was built with quality, and it lasted. The same goes for modern power quality. Perform quality power assessments on the front end and design accordingly.

Existing installations with problems need power analysis to determine the root cause and eliminate issues. In time, emergent calls will diminish.

Measure the problem to manage it properly. Gathering information about power quality allows efficient analysis of the issues. Complaints will diminish once equipment challenges start backing off.

Appendix 1

Voltage Disturbance
Power Engineering Study Resource

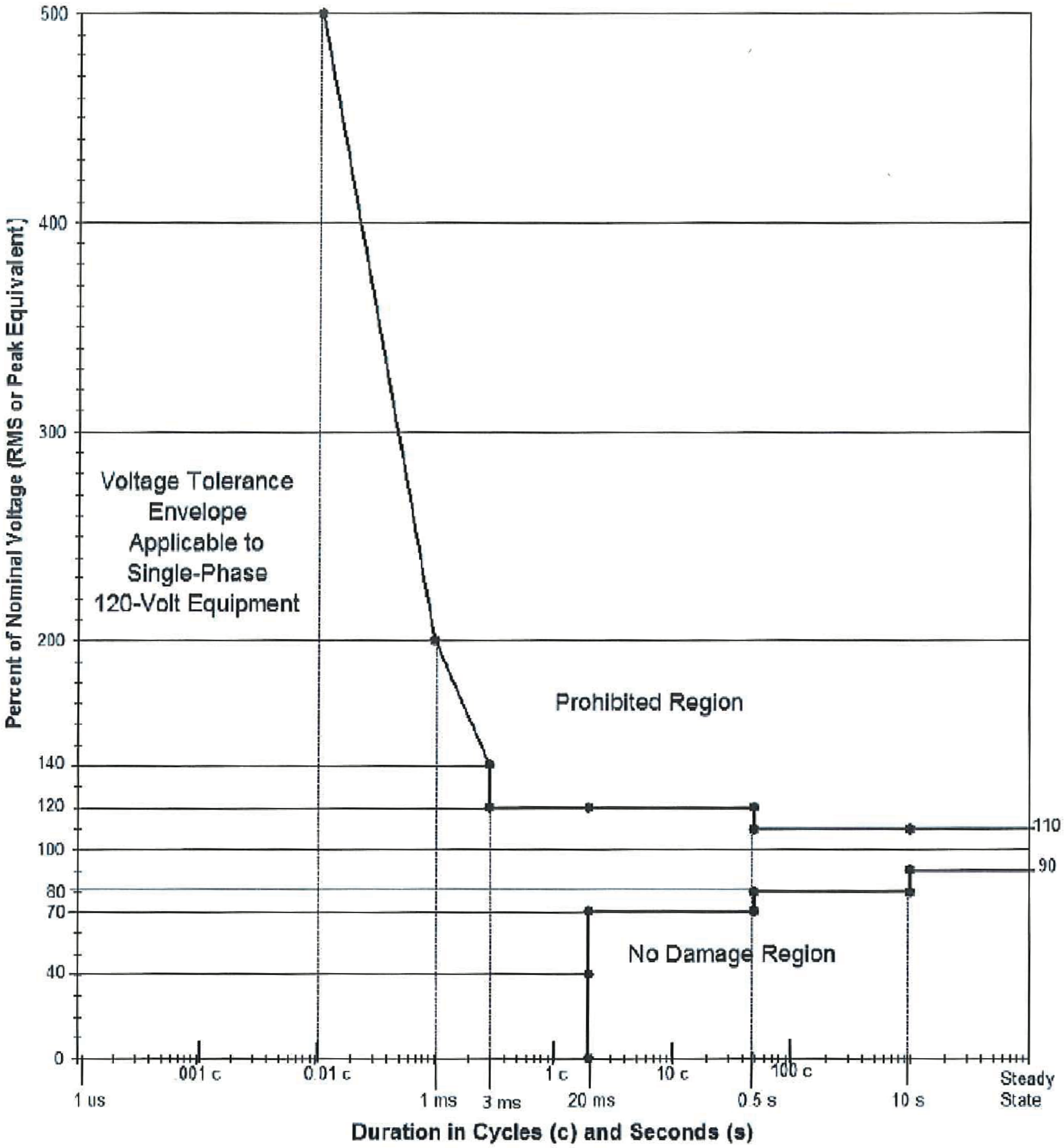
ITIC CURVE

HISTORY

ITIC Curve is published by Information Technology Industry Council (ITIC) formerly known as Computer & Business Equipment Manufacturer's Association (CBEMA). This curve provides an AC voltage boundary that most information technology equipment (ITE) can tolerate or ride through without experiencing unexpected shutdowns or malfunctions. Information technology equipment could include single phase computers, printers, scanners etc. The CBEMA curve is a precursor to ITIC curve and was published in the 1970's.

The origination of CBEMA curve goes back to 1977 when Computer and Business Equipment Manufacturers Association ESC-3 working group was asked to provide their input into an energy performance profile for computer equipment that was proposed for publication in IEEE Std 446. After some minor modifications to the proposal, the ESC-3 working group approved this initial version of the curve, which remained unchanged until early in 1996. Throughout the next 20 years that the original version was published, it grew in stature from a simple curve describing the performance of mainframe computer equipment (PCs were not available), to a curve that was used to define everything from specification criteria for electronic equipment to the basis of power quality performance contracts between electric utilities and large industrial customers. Obviously, this is quite an extension from the initial intent of describing the power quality performance of typical mainframe computers. [IEEE 1100]

Even though both ITIC and CBEMA names are used interchangeably there are subtle differences.



New ITI Curve (CBEMA) Curve (2000)

APPLICATION

The curve is primarily intended for 120V, 120/208V, and 120/240V 60 Hz systems. Other voltages are not specifically part of this, and it is the responsibility of the user to verify that the curve is applied correctly at other voltages. People tend to extrapolate these curves to 480V or even higher voltages and as a general metric of incoming power quality. While there is no harm in using this a reference to establish a baseline power quality. While there is no harm in using this as a reference to establish a baseline power quality, it is important to recognize that the original intent of the curve was for 120V single phase computer equipment. The curve describes an AC voltage envelope which can typically be tolerated by ITE equipment. The curve describes both steady state and transitory conditions.

INFORMATION TECHNOLOGY EQUIPMENT (ITE EQUIPMENT)

ITE Equipment includes common office equipment such as computers and its related peripheral equipment. Most modern ITE equipment are powered by a switched mode power supply. The front end of the switched mode power supply has a bridge rectifier that rectifies the incoming AC to DC. The rectified DC is stored in the bus capacitor. The DC voltage is further converted to the required voltage and is in turn used to power the various subsystems inside the ITE equipment.

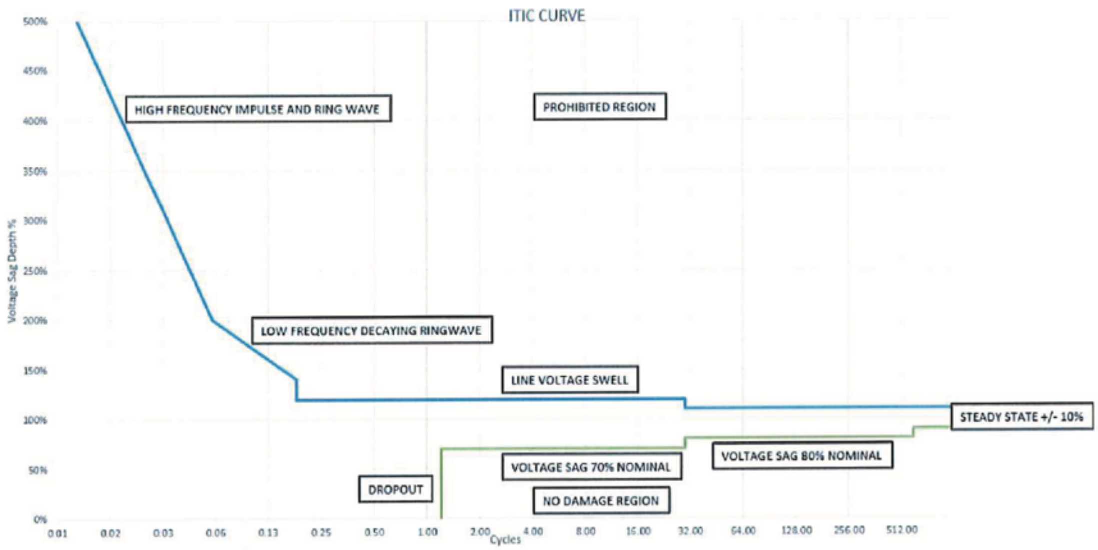
During a power system disturbance, like a voltage sag, swell or a transient voltage for example, the DC bus voltage could go very low or very high and in turn affect the reliable operation of the ITE equipment. The ITIC curve is essentially an input voltage vs. duration performance plot that covers sags, swells, transients, interruptions, and steady state voltage variation at the input terminals to the ITE equipment.

It should be noted that the individual manufacturers performance to input voltage fluctuation is difficult to quantify as each may use a different technology inside their switched mode power supply.

ITIC CURVE (NEW CBEMA CURVE)

Due to the importance of the previous CBEMA curve, a working group and several sponsors undertook the task of revising the curve based on actual test results. The basis of this curve is supported by tests that were conducted on a representative sample of eight PC power supplies supplied by eight different manufacturers.

The older CBEMA curve is very ‘smooth’ whereas the ITIC curve (new CBEMA Curve) has discrete steps and is relatively easier to program in power quality meters and in spreadsheet platforms.



ITIC CURVE

CONDITIONS

Nominal Voltage: Nominal voltage is considered to be 120V RMS, 60 Hz

Steady State Tolerance: +/- 10% from the nominal voltage. This is shown in the right portion of the curve.

Line Voltage Swell: Up to 120% of the RMS nominal voltage with duration of up to 0.5 seconds.

Low Frequency Decaying Ringwave: This region describes the decaying ringwave which results from capacitor banks switching. The frequency of transient may range from 200 Hz to 5KHz. The magnitude of transient is expressed as a percentage of the peak of 60Hz nominal voltage (not the RMS value). Transient is assumed to occur near the peak of the nominal voltage waveform. The transient is assumed to be completely decayed by the end of half-cycle in which it occurs. The amplitude of transient varies from 140% to 200%.

High Frequency Impulse and Ringwave: This region above 200% describes the transients that typically result from lightning strikes. Waveshape applicable to this transient and the general test conditions are described in ANSI/IEEE C62.41-1991.

Voltage Sag: Two different RMS voltage sags are described. Sags to 80% of nominal for up to 10 seconds (600 cycles) and sags to 70% of nominal for up to 0.5 seconds (30 cycles). Voltage sag is an RMS reduction in the AC voltage, at the power frequency, for duration from half cycle to few seconds [IEEE 1100]. The IEC terminology for this phenomenon is voltage dip. Voltage sags are most often caused by faults on the utility system although they may be caused by faults within the facility or by large motor starts. IEEE standard 1159 defines voltage sag as a decrease in RMS voltage at the power frequency for duration from 0.5 cycle to 1 minute, reported as the remaining voltage.

Dropout: Voltage dropout includes both sever RMS voltage sags and complete interruptions of the applied voltage, followed by immediate re-application of the nominal voltage. Interruption may last up to 20 milliseconds (1.2 cycles). This transient could occur during a temporary fault in the power system followed by clearing of the fault.

No Damage Region: Voltage sags, dropouts, and steady state voltages in this region are not expected to damage the ITE equipment. Normal functioning of the ITE equipment is also not expected in region.

Prohibited Region: Any surges or swell in this region could result in damage to the ITE equipment.

LIMITATION OF USING THE ITIC CURVE (NEW CBEMA CURVE)

Compatibility of the Information Technology Equipment to ITIC curves does not necessarily result in trouble free operation of the IT infrastructure. ITIC curves only address the quality of incoming power to the IT equipment. There are many other variables that could affect the reliable operation of IT equipment. Some of which are unequal ground potentials, Electromagnetic Noise Interference etc.

Other Voltage Ride Through Standards:

SEMI F47-0706 is the specification for Semiconductor Processing Equipment voltage sag immunity originally published in year 2000 and updated in 2006. The standard has been implemented by essentially all semiconductor fabs and has been a huge cost saver for the industry. Semiconductor wafer production is very sensitive to voltage sag (voltage dip) events and one voltage sag event could cost a facility hundreds of thousands of dollars per voltage sag event.

SEMI F47 sets out limits of voltage sag that the equipment needs to tolerate without creating any process upsets or shutdowns. SEMI F47 suggests that semiconductor manufacturers may use this standard in their specification whenever they purchase equipment. By doing so the manufacturer can make sure all the equipment used for semiconductor production has been tested and certified to SEMI F47 standard. Compared to other voltage sag immunity curves (CBEMA, ITIC), SEMI standard is more stringent on the tolerance limits.

SEMI F47 does not address product quality and the purpose of the standard is to keep the equipment running without any operator intervention when exposed to voltage sags above the tolerance curve.

Appendix 2

IEC 61800-1

Edition 2.0 2021-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Adjustable speed electrical power drive systems –
Part 1: General requirements – Rating specifications for low voltage adjustable speed DC power drive systems

Entraînements électriques de puissance à vitesse variable –
Partie 1: Exigences générales – Spécifications de dimensionnement pour systèmes d'entraînement de puissance à vitesse variable en courant continu et basse tension

INTERNATIONAL
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ICS 29.160.30; 29.200

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Appendix 3

AKD®, AKD® BASIC, AKD® PDMM

Installation Manual

Edition: AF, January 2022

Valid for AKD, AKD BASIC Hardware Revision E / F
Valid for AKD BASIC-I/O Hardware Revision EA / FA
Valid for AKD PDMM Hardware Revision EB / FB

Part Number 903-200003-00

Original Document

For safe and proper use, follow these instructions. Keep for future use.

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KOLLMORGEN

3.2 Use as Directed

The AKD drives are exclusively intended for driving suitable synchronous servomotors with closed-loop control of torque, speed, and/or position.

AKDs are components that are built into electrical plants or machines and can only be operated as integral components of these plants or machines. The manufacturer of the machine used with a drive must generate a risk assessment for the machine. When the drives are built into machines or plant, the drive must not be used until it has been established that the machine or plant fulfills the requirement of the regional directives.

Cabinet and Wiring

Drives must only be operated in a closed control cabinet suitable for the ambient conditions (→ #33). Ventilation or cooling may be necessary to keep the temperature within the cabinet below 40° C.

Use only copper conductors for wiring. The conductor cross-sections can be derived from the standard IEC 60204 (alternatively for AWG cross-sections: NEC Table 310-16, 75° C column).

Power Supply

The drives can be supplied by 1 or 3 phase industrial supply networks.

Drives in the AKD series can be supplied as follows:

Models with Hardware Revision F, FA, FB
- AKD-xzzz06: 1 or 3 phase industrial supply networks (100-240V).

Models with Hardware Revision A, C, D, E, DB, DA, EB or EA
- AKD-xzzz06: 1 or 3 phase industrial supply networks (120V/240V).
- AKD-xzzz07: 3 phase industrial supply networks (240V, 400V and 480V).

Connection to other voltage types of supply networks is possible with an additional isolating transformer (→ #105).

- AKD-x04807: In case of mains voltage asymmetry >3% a mains choke 3LO, 24-50-2 must be used.

Periodic overvoltage between phases (L1, L2, L3) and the housing of the drive must not exceed 1000V peak. In accordance with IEC 1800, voltage spikes (>50 µs) between a phase and the housing must not exceed 2000V.

EMC filter measures for AKD-xzzz06 must be implemented by the user.

For the cases of group installations and of DC powered drives
AKD has not been evaluated by Kollmorgen, UL, or TUV for group installations nor are ratings defined for DC input voltage.

Group installations must be reviewed and evaluated by the user for branch circuit protection*, wire size, wire voltage rating, fuse protection, system dielectric requirements, overvoltage, and input** current rating.

In case of DC supplied drives the built-in EMC filter will not work. The user is responsible to keep the conducted emissions and the immunity of the drive within the required noise levels.

* Special care must be taken in branch circuit design with mixed rating drives to avoid the smaller drives becoming the effective ‘fuse’ rather than the circuit protective fuse.

** The power supply system design must ensure inrush current protection by limiting input current during power up. DC supply polarity must be properly wired. Improper polarity of DC power will damage the drive and void warranty.

Appendix 4

Power Analysis Summary

INTRODUCTION

This is a summary of the power conditions measured with these setup parameters:

Measurement File:	C:\Richards Electric Project Files\NTN Screw Compressor Power
Start Time:	06/03/2021 09:44:44
End Time:	07/14/2021 07:39:37
Duration:	40 – 21:54:53

Power Configuration:	3-ph Wye
Nominal Voltage:	277V
Nominal Frequency:	60Hz

INSTRUMENT

The measurement was performed with a FLUKE 1750 with these characteristics:

Instrument:	1750 <2118028>

Voltage Inputs

A:	A-A, 1.00:1
B:	B-B, 1.00:1
C:	C-C, 1.00:1
N:	N-N, 1.00:1

Current Inputs

A:	A-A, 1.00:1
B:	B-B, 1.00:1
C:	C-C, 1.00:1
N:	N-N, 1.00:1
G:	G-G, 1.00:1

Current Probs

A:	Unidentified CT Defaults to 5A
B:	Unidentified CT Defaults to 5A
C:	Unidentified CT Defaults to 5A

N:	Unidentified CT Defaults to 5A
G:	Unidentified CT Defaults to 5A

EVENTS

The Events section is a summary of the voltage and current events that occurred at this location during the monitor period.
Events are defined as changes in the monitored voltage or current. These changes may be subtle or severe.

Tolerance curves provide a graphical representation of the likelihood of an event to disrupt equipment operations. Tolerance curves classify the event by magnitude and duration; there are standardized tolerance curves for voltage such a CBEMA or ITIC and for current, circuit breaker manufacturers supply curves of their equipment's operation.

LIMIT CONFIGURATION

Voltage Limits

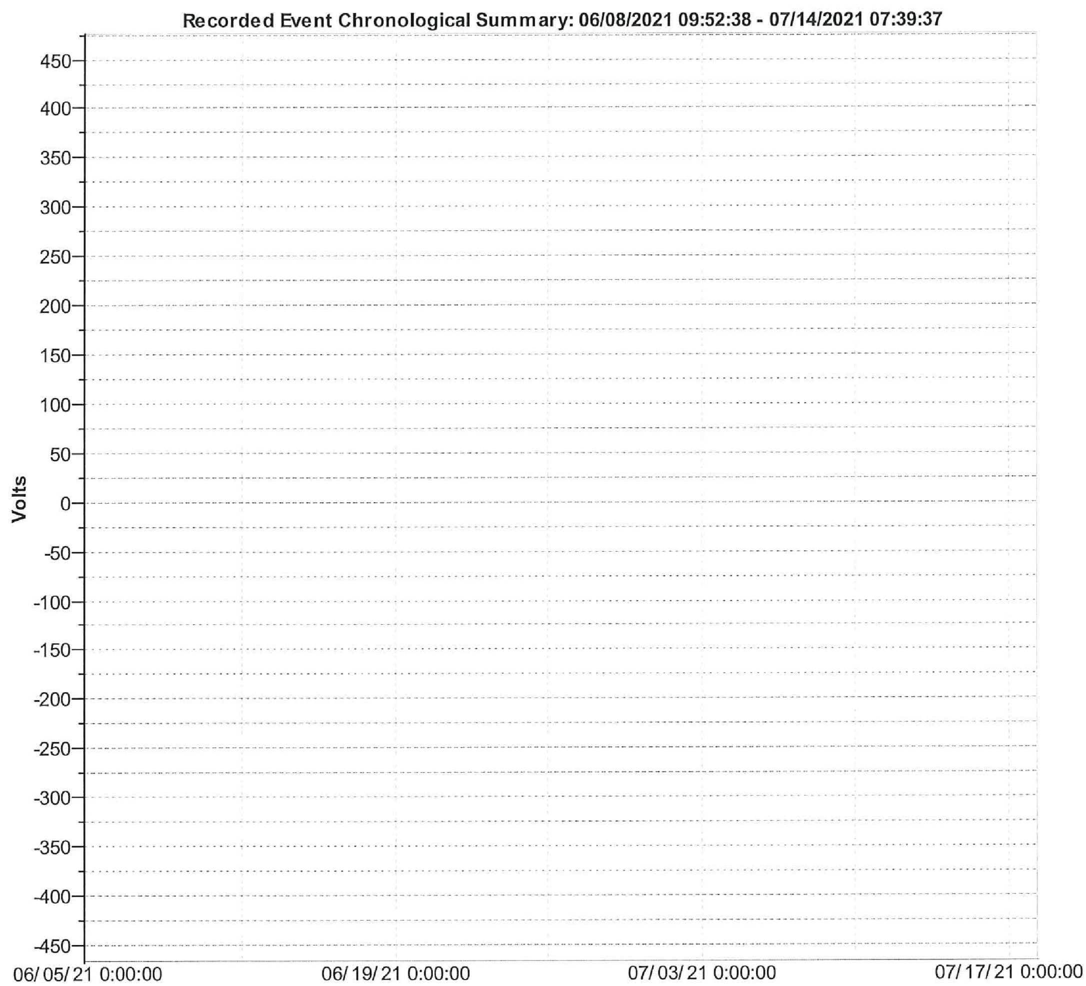
	<	>
AN	- 10.0% (249.3 v RMS)	+ 10.0% (304.7 v RMS)
BN	- 10.0% (249.3 v RMS)	+ 10.0% (304.7 v RMS)
CN	- 10.0% (249.3 v RMS)	+ 10.0% (304.7 v RMS)
NG	- 0.0% (0.0 v RMS)	+ 3.6% (10.0 v RMS)
Impulse	200.0 v PK	
Show events	Combined	
Aggregate events	0 s	

Current Limits

	>
A	1.5 A
B	1.5 A
C	1.5 A
N	0.5 A
Show events	Combined
Aggregate events	0 s

Events

Phase	Max	Time	Min	Time
V RMS Avg AN	378.79 V	06/17/2021 09:46:50	-388.50 V	06/17/2021 09:05:21
V RMS Avg BN	390.46 V	06/17/2021 11:38:28	-363.82 V	06/08/2021 14:11:35
V RMS Avg CN	379.52 V	06/08/2021 09:52:54	-386.36 V	06/08/2021 14:11:37
V RMS Avg NG	14.08 V	06/17/2021 11:38:28	14.08 V	06/17/2021 11:38:28



FLUKE

Events

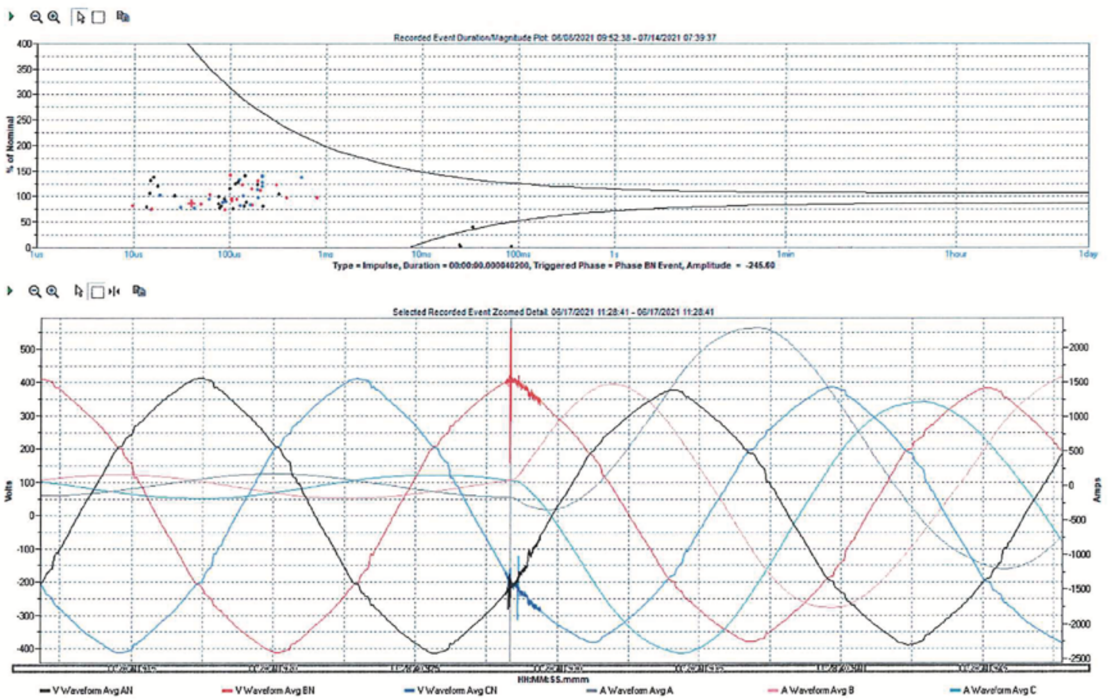
#	Date/Time	Type	Duration (d-h:mm:ss)	% of Nominal	Absolute	Phase
1	06/08/2021 09:52:38.430.280	Dip	0 - 00:00:15.402402700	0.02%	0.066 V	AN, BN,
2	06/08/2021 09:52:38.583.725	Interruption	0 - 00:00:15.238870400	0.02%	0.066 V	AN, BN,
3	06/08/2021 09:52:53.823.575	Impulse	0 - 00:00:00.000557600	137.01%	379.52 V	CN
4	06/08/2021 14:11:33.811.442	Dip	> 0 - 00:10:13.789968100	0.02%	0.063 V	AN, BN,
5	06/08/2021 14:11:35.436.410	Impulse	0 - 00:00:00.000199600	131.34%	-363.82 V	BN
6	06/08/2021 14:11:35.436.892	Impulse	0 - 00:00:00.000171800	82.76%	-229.25 V	BN
7	06/08/2021 14:11:35.437.372	Impulse	0 - 00:00:00.000106400	91.94%	-254.68 V	BN
8	06/08/2021 14:11:36.942.833	Impulse	0 - 00:00:00.000195800	113.29%	-313.82 V	CN
9	06/08/2021 14:11:36.944.522	Impulse	0 - 00:00:00.000216200	119.97%	-332.31 V	CN
10	06/08/2021 14:11:36.949.806	Impulse	0 - 00:00:00.000162800	84.15%	233.11 V	CN
11	06/08/2021 14:11:36.950.242	Impulse	0 - 00:00:00.000127000	81.68%	226.25 V	CN
12	06/08/2021 14:11:36.951.021	Impulse	0 - 00:00:00.000136800	100.74%	279.04 V	CN
13	06/08/2021 14:11:36.951.211	Impulse	0 - 00:00:00.000139400	81.31%	225.24 V	CN
14	06/08/2021 14:11:36.951.724	Impulse	0 - 00:00:00.000197400	98.24%	272.11 V	CN
15	06/08/2021 14:11:36.967.940	Impulse	0 - 00:00:00.000216400	118.95%	329.50 V	CN
16	06/08/2021 14:11:36.969.318	Impulse	0 - 00:00:00.000215800	119.40%	330.73 V	CN
17	06/08/2021 14:11:36.976.775	Interruption	0 - 00:00:00.024934900	0.03%	0.092 V	AN, BN,
18	06/08/2021 14:11:37.009.627	Impulse	0 - 00:00:00.000217800	137.80%	-381.71 V	CN
19	06/08/2021 14:11:37.018.376	Interruption	0 - 00:00:00.016666700	0.04%	0.099 V	AN, BN,
20	06/08/2021 14:11:37.043.175	Impulse	0 - 00:00:00.000216200	139.48%	-386.36 V	CN
21	06/08/2021 14:11:37.044.028	Impulse	0 - 00:00:00.000216400	126.93%	-351.61 V	CN
22	06/08/2021 14:11:37.051.645	Interruption	> 0 - 00:10:10.549765100	0.02%	0.063 V	AN, BN,
23	06/17/2021 09:01:28.413.650	Interruption	> 0 - 00:03:36.604008200	0.02%	0.069 V	AN, BN,
24	06/17/2021 09:01:28.413.650	Dip	> 0 - 00:03:52.941259500	0.02%	0.069 V	AN, BN,
25	06/17/2021 09:05:05.086.278	Interruption	0 - 00:00:00.041666700	0.03%	0.085 V	AN, BN,
26	06/17/2021 09:05:05.136.742	Impulse	0 - 00:00:00.000103600	93.84%	259.94 V	BN
27	06/17/2021 09:05:05.136.999	Impulse	0 - 00:00:00.000210600	111.34%	308.42 V	BN
28	06/17/2021 09:05:05.153.189	Impulse	0 - 00:00:00.000088400	74.11%	205.28 V	BN
29	06/17/2021 09:05:05.161.148	Interruption	0 - 00:00:00.124609400	0.03%	0.079 V	AN, BN,
30	06/17/2021 09:05:05.293.796	Impulse	0 - 00:00:00.000308600	122.93%	-340.51 V	BN
31	06/17/2021 09:05:05.294.250	Impulse	0 - 00:00:00.000061600	104.16%	-288.53 V	BN
32	06/17/2021 09:05:17.871.721	Impulse	0 - 00:00:00.000060600	94.46%	-261.65 V	CN
33	06/17/2021 09:05:17.888.764	Impulse	0 - 00:00:00.000091000	89.25%	-247.23 V	CN
34	06/17/2021 09:05:17.888.988	Impulse	0 - 00:00:00.000083400	87.87%	-243.41 V	CN
35	06/17/2021 09:05:17.889.212	Impulse	0 - 00:00:00.000125600	132.06%	-365.80 V	CN
36	06/17/2021 09:05:21.364.743	Impulse	0 - 00:00:00.000107800	75.75%	-209.82 V	AN
37	06/17/2021 09:05:21.365.237	Impulse	0 - 00:00:00.000140000	79.71%	-220.80 V	AN
38	06/17/2021 09:05:21.366.950	Impulse	0 - 00:00:00.000078600	77.82%	-215.56 V	AN
39	06/17/2021 09:05:21.367.181	Impulse	0 - 00:00:00.000119800	128.04%	-354.66 V	AN

FLUKE®

Events

#	Date/Time	Type	Duration (d-h:mm:ss)	% of Nominal	Absolute	Phase
40	06/17/2021 09:05:21.367.475	Impulse	0 - 00:00:00.000081200	80.16%	-222.05 V	AN
41	06/17/2021 09:05:21.367.756	Impulse	0 - 00:00:00.000075800	85.56%	-237.00 V	AN
42	06/17/2021 09:05:21.371.198	Dip	0 - 00:00:00.083385400	1.17%	3.237 V	AN
43	06/17/2021 09:05:21.383.319	Impulse	0 - 00:00:00.000076400	99.11%	-274.54 V	AN
44	06/17/2021 09:05:21.383.561	Impulse	0 - 00:00:00.000143000	140.25%	-388.50 V	AN
45	06/17/2021 09:05:21.383.925	Impulse	0 - 00:00:00.000026200	100.49%	-278.37 V	AN
46	06/17/2021 09:05:21.449.330	Impulse	0 - 00:00:00.000099200	114.59%	-317.40 V	AN
47	06/17/2021 09:05:21.496.185	Dip	0 - 00:00:00.033368900	39.47%	109.35 V	AN
48	06/17/2021 09:05:21.517.767	Impulse	0 - 00:00:00.000114600	124.39%	-344.56 V	AN
49	06/17/2021 09:05:21.542.437	Impulse	0 - 00:00:00.000324000	104.48%	289.41 V	AN
50	06/17/2021 09:05:21.543.088	Impulse	0 - 00:00:00.000149400	87.49%	242.34 V	AN
51	06/17/2021 09:05:21.546.116	Dip	0 - 00:00:00.025054800	1.15%	3.179 V	AN
52	06/17/2021 09:05:21.566.630	Impulse	0 - 00:00:00.000086800	93.76%	-259.71 V	AN
53	06/17/2021 09:05:21.566.759	Impulse	0 - 00:00:00.000223800	80.63%	-223.35 V	AN
54	06/17/2021 09:46:49.708.271	Impulse	0 - 00:00:00.000013600	79.01%	218.85 V	AN
55	06/17/2021 09:46:49.708.372	Impulse	0 - 00:00:00.000017600	120.28%	333.18 V	AN
56	06/17/2021 09:46:49.708.594	Impulse	0 - 00:00:00.000016200	136.75%	378.79 V	AN
57	06/17/2021 09:52:09.836.154	Impulse	0 - 00:00:00.000014600	105.12%	-291.18 V	AN
58	06/17/2021 10:06:36.821.038	Impulse	0 - 00:00:00.000015400	75.28%	-208.53 V	BN
59	06/17/2021 10:09:53.671.142	Impulse	0 - 00:00:00.000030800	78.31%	-216.93 V	CN
60	06/17/2021 10:18:52.243.920	Impulse	0 - 00:00:00.000009800	81.88%	226.80 V	BN
61	06/17/2021 10:46:33.086.144	Impulse	0 - 00:00:00.000042600	77.83%	-215.60 V	CN
62	06/17/2021 10:53:52.992.904	Impulse	0 - 00:00:00.000018800	102.73%	-284.57 V	CN
63	06/17/2021 10:56:38.640.608	Impulse	0 - 00:00:00.000015200	73.99%	-204.95 V	CN
64	06/17/2021 10:57:17.736.568	Impulse	0 - 00:00:00.000015000	130.82%	-362.37 V	AN
65	06/17/2021 11:28:40.928.302	Impulse	0 - 00:00:00.000040200	88.66%	-245.60 V	BN
66	06/17/2021 11:38:26.617.882	Dip	> 0 - 00:04:52.384607700	0.02%	0.066 V	AN, BN,
67	06/17/2021 11:38:28.111.037	Swell	0 - 00:00:00.024686800	5.08%	14.084 V	NG
68	06/17/2021 11:38:28.114.415	Impulse	0 - 00:00:00.000394000	97.20%	-269.26 V	BN
69	06/17/2021 11:38:28.116.474	Impulse	0 - 00:00:00.000118800	94.81%	-262.61 V	BN
70	06/17/2021 11:38:28.116.870	Impulse	0 - 00:00:00.000105200	96.17%	-266.39 V	BN
71	06/17/2021 11:38:28.117.321	Impulse	0 - 00:00:00.000050400	85.72%	-237.45 V	BN
72	06/17/2021 11:38:28.123.503	Impulse	0 - 00:00:00.000101400	140.96%	390.46 V	BN
73	06/17/2021 11:38:28.123.668	Impulse	0 - 00:00:00.000809600	97.60%	270.35 V	BN
74	06/17/2021 11:38:28.124.989	Impulse	0 - 00:00:00.000134000	123.47%	342.02 V	BN
75	06/17/2021 11:38:28.125.359	Impulse	0 - 00:00:00.000169800	114.41%	316.91 V	BN
76	06/17/2021 11:38:29.279.983	Impulse	0 - 00:00:00.000195200	123.47%	342.02 V	AN
77	06/17/2021 11:38:29.308.466	Interruption	> 0 - 00:04:49.694024500	0.02%	0.066 V	AN, BN,
78	07/14/2021 07:35:05.406.747	Dip	> 0 - 00:04:31.802175000	0.03%	0.069 V	AN, BN,
79	07/14/2021 07:35:05.406.747	Interruption	> 0 - 00:04:31.802175000	0.03%	0.069 V	AN, BN,

400HP Y-Delta Start with CBEMA Curve / All Events Marked



Event #	65
Event View	Tolerance
Event Trigger	Voltage
RMS Overlay	Off
Annotations	Shown

Appendix 5

8800DB0801
11/2008
Raleigh, NC, USA

DATA BULLETIN

The Effects of Available Short-Circuit Current on AC Drives

Class Number 8800
Retain for future use.

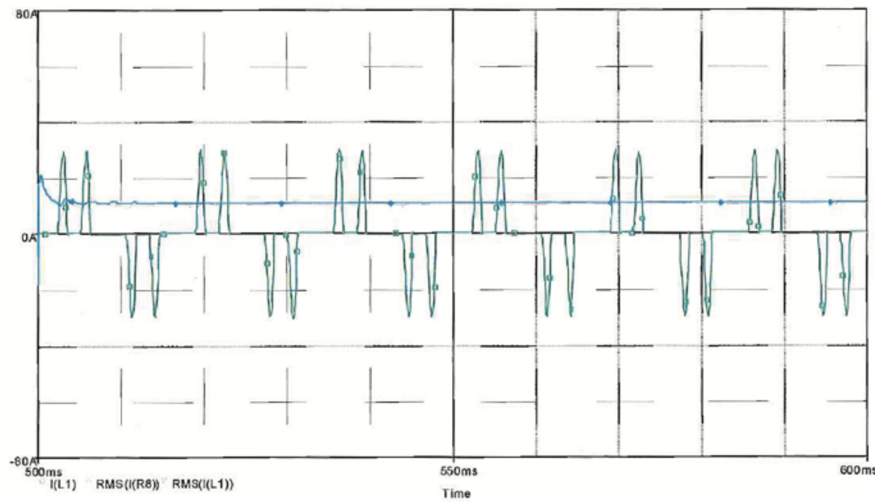
INTRODUCTION

This document explores the effects of short-circuit current rating (SCCR) values with respect to potential equipment damage. In particular, what happens to the line current when a drive with a 6-diode rectifier section is inductance.[1] This application note applies to Altivar ® 61 drives and Altivar ® 71 drives, as well as other variable frequency drives with a 6-pulse rectifier circuit. It does not apply to Altivar ® 21 devices as they have a greatly reduced amount of DC bus capacitance.

5 kA SHORT-CIRCUIT POWER SYSTEM

This example uses an ATV71HU40N4 (the largest Altivar ® 71 drive rated for a 5 kA system) running at the full 5 hp output load (Figure 1). The input power system impedance is modeled with 104 µH and 39.2 mOhms, resulting in 5 kA available short current with a power factor of 0.7.

Figure 1: 5 kA Short-Circuit Power System



- Vertical Scale = -80 to 80 A, 20 A/Div
- Peak Input Current = 28.4 A (green)
- RMS Input Current = 10.6 A (red)
- RMS AC Current in the DC Bus Capacitors = 10.4 A (blue)

---

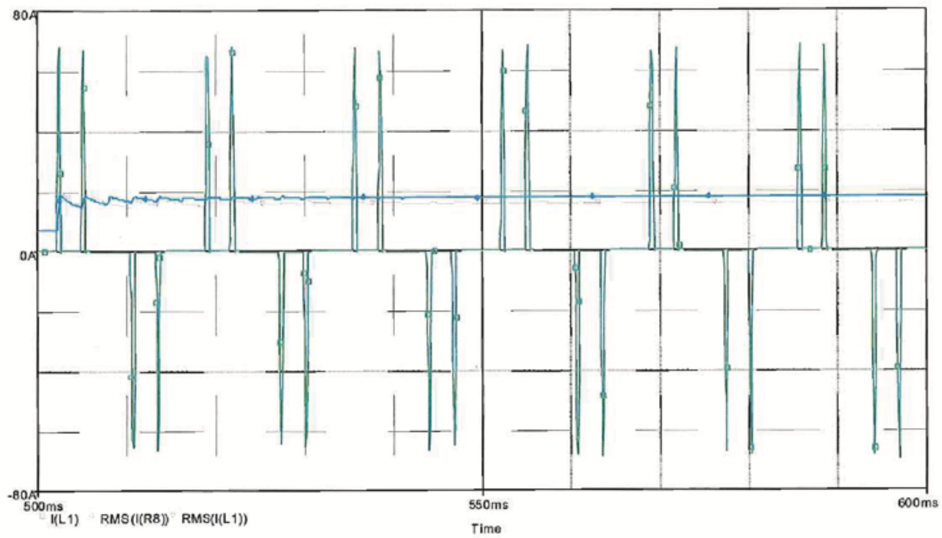
[1] The word "drive" as used in this document refers to the controller portion of the adjustable speed drive according to the NEC (NFPA70).

100 kA SHORT-CIRCUIT POWER SYSTEM

The double hump input current waveform is typical of all drives due to the diode and capacitor rectification of the input line power. The RMS current in the DC bus capacitors is caused by alternate charges and discharges during the cycle.

In Figure 2 the same model drive and output load are used as in Figure 1, but the input power system impedance is modified to provide 100 kA available short-circuit current at a power factor of 0.2. The input power system impedance parameters were 7.2 µH and 0.54 mOhms.

Figure 2: 100 kA Short-Circuit Power System



- Vertical Scale = -80 to 80 A, 20 A/Div
- Peak Input Current = 68 A (green)
- RMS Input Current = 16.3 A (red)
- RMS AC Current in the DC Bus Capacitors = 18 A (blue)

The peak input currents increased by 139%, from 28.4 to 68 A. This increase of input current causes premature diode failure, which may occur within minutes. RMS input currents increased by 54%, from 10.6 to 16.3 A, rising above the current listed on the nameplate. This causes additional heating in the input wiring, which may result in damage to the installation.

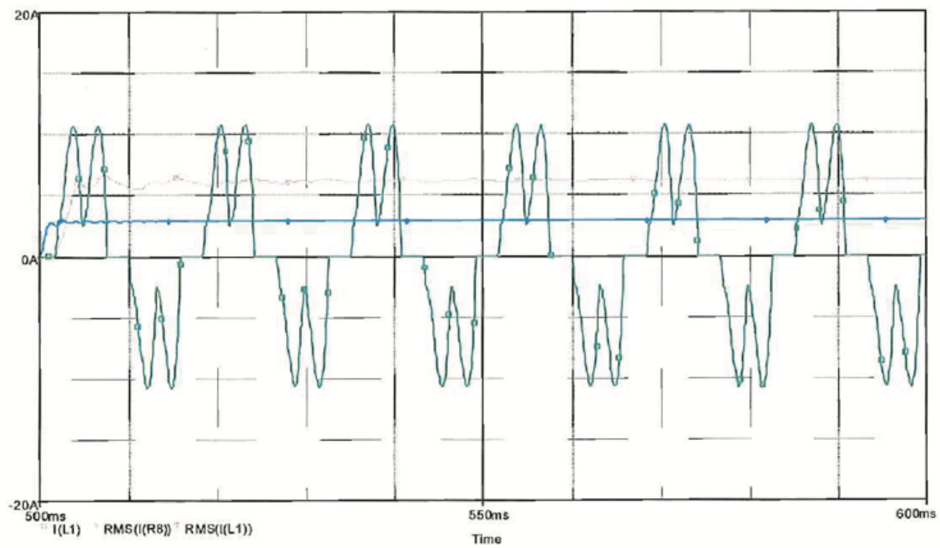
The increase in RMS currents in the DC bus capacitors is 73% (18 ÷ 10.4 = 1.73). Since temperature rise is proportional to the square of the current, there will be up to 3 times the heating in the DC bus capacitors causing the expected life cycle to be reduced from 20,000 hours to a few hundred hours.

ADDING A 3% LINE REACTOR

Adding a 3% line reactor greatly reduces the input current peaks (Figure 3). A line reactor for 5 hp and 480 V with an inductance of 3 mH is used in this example. The input power system line impedance was set to provide 100 kA of short-circuit current at a power factor of 0.2. The input power system inductance plus the input line reactor inductance results in a total input inductance of 3.007 mH.

NOTE: The addition of a line reactor does not, by itself, allow the installation of the drive on a mains supply with an SCCR higher than that of the drive. A higher rating may be published in the drive's instruction bulletins for tested combinations of overcurrent protective devices (OCPD), line reactors, drives, and enclosures. Contact the manufacturer for the latest ratings.

Figure 3: Adding a 3% Line Reactor



- Vertical Scale = -20 to 20 A, 5 A/Div
- Peak Input Current = 10.7 A (green)
- RMS Input Current = 6.1 A (red)
- RMS AC Current in the DC Bus Capacitors = 2.8 A (blue)
- DC Bus Voltage = 639 V (not shown on graph)

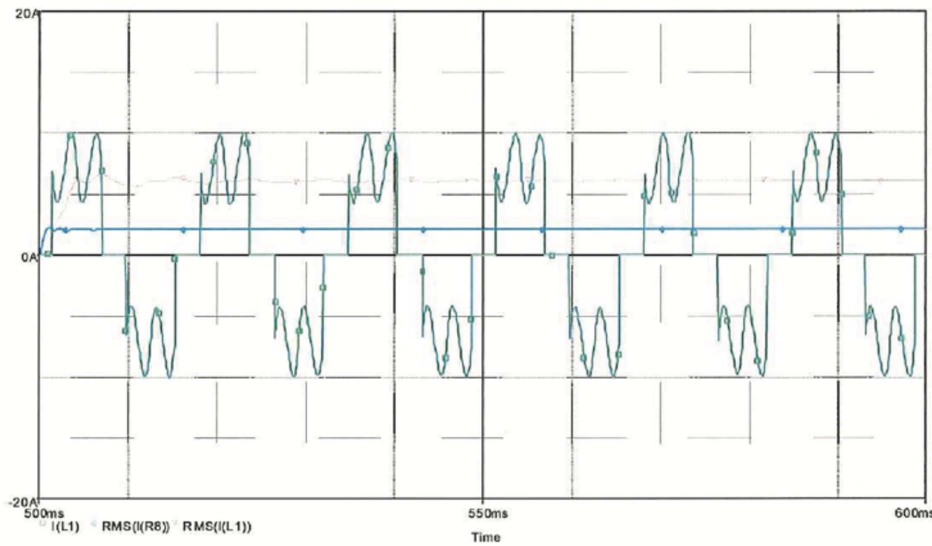
The large impedance provided by the line reactor dominates the input power system impedance. For this reason, virtually identical results are achieved with this line reactor on a 5 kA input line as on a 100 kA input line.

ADDING A DC CHOKE WITH AN IMPEDANCE EQUIVALENT TO THE 3% LINE REACTOR

The input power system line impedance was set to provide 100 kA of short-circuit current at a 0.2 power factor. A 6 mH DC choke was added between the diode bridge and the DC bus capacitors. This value for the DC choke gives a similar effect as the 3% line reactor used earlier, with a lower ripple current in the capacitors and a higher DC bus voltage (Figure 4).

NOTE: The addition of a DC choke does not allow the installation of the drive on a mains supply with an SCCR higher than that of the drive. A higher rating may be published in the drive's instruction bulletins for tested combination of OCPD, line reactors, drives and enclosures. Contact the manufacturer for the latest ratings.

Figure 4: Adding a DC Choke with an Impedance Equivalent to the 3% Line Reactor



- Vertical Scale = -20 to 20 A, 5 A/Div.
- Peak Input Current = 10 A (green)
- RMS Input Current = 6.0 A (red)
- RMS AC Current in the DC Bus Capacitors = 2.0 A (blue)
- DC Bus Voltage = 647 V (not shown on graph)

The waveshape of the input current is slightly different with the DC choke as compared to an AC line reactor. For a system with balanced three-phase voltage, the current in the DC choke never goes to zero, unlike the AC line reactor which has the current reversing at a 60 Hz rate. An advantage of the DC choke is that it has a slightly lower voltage drop as compared to an AC line reactor. However, the AC line reactor can help protect the input diodes from voltage spikes on the line.

CONCLUSION

Running a drive, without additional inductance, on a power system with a short-circuit current greater than the published SCCR of the drive severely reduces the life of the drive. Using an appropriately sized input line reactor or DC choke reduces both the input line current peaks and the heating in the DC bus capacitors, bringing the drive's life expectancy back to specified levels. Attention must be paid to the manufacturer's specified OCPD and the enclosure type used with the recommended reactor or choke at the UL Listed higher SCCR to properly apply the adjustable speed drive power converter.

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Appendix 6

AC Line Impedance Considerations

DC-bus power supplies do not require an isolation transformer for three-phase input power. Regenerative bus supplies also do not require an isolation transformer for three-phase input power unless they are connected to corner-grounded or ungrounded facility power. See Input Power Configurations for Kinetix 5700 Power Supplies on page 121 for example configurations.

IMPORTANT: These recommendations are advisory and do not address all situations. Site-Specific conditions must be considered for proper installation.

A transformer can be required to match the voltage requirements of the power supply to the available service. For the AC input voltage requirements, refer to the Kinetix 5700 power specifications in the Kintetix 5700, 5500, 5300 and 5100 Servo Drives Specifications Technical Data, publication KNX-TD003.

IMPORTANT: When using an autotransformer, make sure that the phase to neutral/ground voltage does not exceed the input voltage ratings of the power supply.

Use a safety factor of 1.5 for three-phase power (where safety factor is used to compensate for transformer, drive modules, motor losses, and to account for utilization in the intermittent operating area of the torque speed curve).

EXAMPLE: Sizing a transformer to the voltage requirements of this power supply: 2198-P141: 31kW x 1.5 = 46.5 kVA transformer.

In the following use cases, an additional transformer or line reactor is required due to faults or potential damage associated with AC line disturbances:

• Installation site has switched power-factor correction capacitors.
• Installation site has lightning strikes or voltage spikes in excess of 6000ν peak.
• Installation site has power interruptions or voltage dips in excess of 200ν AC.
• The transformer kVA is more than 10 times larger than the drive kVA, or the percent source impedance relative to each converter is less than 0.5%.

In the following use cases, a line reactor is required due to faults associated with sharing AC line-input on multiple converters:

• Repetitive AC input line-voltage notching is present. For example, if silicon-controlled rectifier drive is connected to the same AC input-power source.
  + In drive systems that include the regenerative bus supply, repetitive AC line voltage notching can cause the integrated AC line filter to overheat and result in FLT S18 converter overtemperature fault.
• Powering multiple (two or more) regenerative bus supplies from the same AC input-power source.
  + Switching ripple from each regenerative bus supply can interfere with other regenerative bus supplies on the same AC input power source.
• Powering 2198-*Pxxx* DC-bus power supply and 2198-*RPxxx* regenerative bus supply from the same AC input-power source.
  + Switching ripple from the regenerative bus supply can impact the temperature of DC-bus capacitors in the DC-bus power supply. In this use case, a line reactor is required in the AC input-power string leading to the regenerative bus supply.
  + Line reactor in the AC input-power string is not required for the DC-bus power supply in this use case but is recommended for the prevention of issues caused by other use cases.
• Powering two or three 2198-P208 DC-bus power supplies from the same AC input-power source that share the same DC-bus.
  + In this use case, a line reactor is required for each 2198-P208 DC-bus power supply to make sure that they share current more evenly.

Use these equations to calculate the impedance of the DC-bus power supply, regenerative bus supply, or transformer to check the percent source-impedance relative to the power supply to make sure it is not less than 0.5%. An additional transformer or line reactor is required in this use case.

EXAMPLE: DC-bus Power Supply or Regenerative Bus Supply Impedance (in ohms)

$$Z_{drive} = \frac{V_{line\text{-}line}}{\sqrt{3} \bullet I_{input\text{-}rating}}$$

EXAMPLE: Transformer Impedance (in ohms)

$$Z_{xfmr} = \frac{V_{line\text{-}line}}{\sqrt{3} \bullet I_{xfmr\text{-}rated}} \bullet \text{\% Impedance}$$

Or

$$Z_{xfmr} = \frac{(V_{line\text{-}line})^2}{VA} \bullet \text{\% Impedance}$$

% impedance is the nameplate impedance of the transformer.

EXAMPLE: Transformer Impedance (in ohms)

$$Z_{xfmr} = \frac{V_{line\text{-}line}}{\sqrt{3} \bullet I_{xfmr\text{-}rated}} \bullet \text{\% Impedance}$$

% impedance is the nameplate impedance of the transformer.

EXAMPLE The DC-bus power supply or regenerative bus supply is rated 1 Hp, 480V, 2.7 A input.

The supply transformer is rated 50,000 VA (50 kVA), 5% impedance.

$$Z_{drive} = \frac{V_{line\text{-}line}}{\sqrt{3} \bullet I_{input\text{-}rating}} = \frac{480V}{\sqrt{3} \bullet 2.7} = 102.6 \text{ Ohms}$$

$$Z_{xfmr} = \frac{(V_{line\text{-}line})^2}{VA} \bullet \text{\% Impedance} = \frac{480^2}{50{,}000} \bullet 0.05 = 0.2304 \text{ Ohms}$$

The percent (%) impedance has to be in per unit (5% becomes 0.05) for the formula.

$$\frac{Z_{xfmr}}{Z_{drive}} = \frac{0.2304}{102.6} = 0.00224 = 0.22\%$$

0.22% is less than 0.5%. Therefore, this transformer is too large for the DC-bus power supply or regenerative bus supply. Consider adding either a line reactor or isolation transformer.

Table 8 - Bulletin 1321 Line Reactor Selection

Kinetix 5700 Power Supply	Power Supply Cat. No.	Number of Power Supplies in a Bus Group	Bulletin 1321 Line Reactor Cat. No.	Status
DC-bus Power Supply	2198-P031	1	1321-3R12-B	Recommended
	2198-P070	1	1321-3R35-B	Recommended
	2198-P141	1	1321-3R55-B	Recommended
	2198-P208	1	1321-3R80-B	Recommended
		2		Required
		3		Required
Regenerative Bus Supply	2198-RP088	1	1321-3R35-A	Recommended
	2198-RP200	1	1321-3R100-A	Recommended
	2198-RP263	1	1321-3R160-B	Recommended
	2198-RP312	1	1321-3R200-A	Recommended

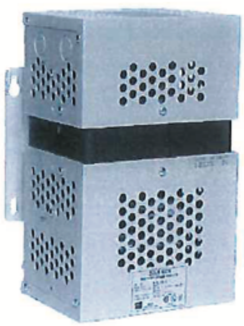
See Power Wiring Examples on page 321 for AC input-power interconnect diagrams. For Bulletin 1321 line reactor specifications, see the 1321 Power Conditioning Products Technical Data, publication, 1321-TD001.

IMPORTANT: You can group multiple 2198-*Pxxx* DC-bus power supplies on one line reactor if they do not share same DC bus. However, the line reactor percent impedance must be large enough when evaluated for each DC-bus power supply separately, not evaluated for all loads connects at once.

Appendix 7

CR Hardwired Series – Power Line Conditioning with Voltage Regulation

The MCR Hardwired Series provides excellent noise filtering and surge suppression to protect connected equipment from damage, degradation or misoperation. Combined with the excellent voltage regulation inherent to Sola/Hevi-Duty's patented ferroresonant design, the MCR can increase the actual Mean Time Before Failure (MTBF) of protected equipment. The MCR is a perfect choice where dirty power, caused by impulses, swell, sags, brownouts and waveform distortion can lead to costly downtime because of damaged equipment.



Related Products

- On-line UPS (S4K Industrial)
- Surge Suppression
- Three Phase Power Conditioners

Features

- ±3% output voltage regulation
- Noise attenuation
  - 120 dB common mode
  - 60 dB transverse mode
- Surge suppression tested to ANSI/IEEE C62.41 Class A & B Waveform:
  - <10 V let through typical
- Acts as a step-up or step-down transformer
- Harmonic filtering
- Hardwired
- Galvanic isolation provides exceptional circuit protection.
- 25 year typical MTBF
- No maintenance required

Applications

- Industrial automation and control equipment PLCs
- Machine tools
- Computer loads and electronic equipment
- Robotics
- Semiconductor fabrication equipment

Selection Tables: Single Phase

Group 2 – MCR Series, 60 Hz Only

cULus

VA	Catalog Number	Voltage Input	Voltage Output	Height (inch)	Width (inch)	Depth (inch)	Ship Weight (lbs)	Design Style	Elec Conn
120	63–23–112–4	120, 208, 240, 480	120	9	4	5	15	1	D
250	63–23–125–4	120, 208, 240, 480	120	10	6	8	27	1	D
500	63–23–150–8	120, 208, 240, 480	120, 208, 240	13	9	7	37	1	E
750	63–23–175–8	120, 208, 240, 480	120, 208, 240	14	9	7	52	1	E
1000*	63–23–210–8	120, 208, 240, 480	120, 208, 240	17	9	7	62	1	E
1500*	63–23–215–8	120, 208, 240, 480	120, 208, 240	17	13	9	95	1	E
2000*	63–23–220–8	120, 208, 240, 480	120, 208, 240	18	13	9	109	1	E
3000*	63–23–230–8	120, 208, 240, 480	120, 208, 240	19	13	9	142	1	E
5000*	63–23–250–8	120, 208, 240, 480	120, 208, 240	28	13	9	222	1	E
7500**	63–28–275–8	208, 240, 480	120, 208, 240	27	26	9	362	2	F
10000**	63–28–310–8	208, 240, 480	120, 208, 240	28	26	9	446	2	F
15000**	63-28-315-8	208, 240, 480	120, 208, 240	28	38	10	710	3	F

Selection Tables: Single Phase

Group 3 – MCR Series, 60 Hz Only

VA	Catalog Number	Voltage Input	Voltage Output	Height (inch)	Width (inch)	Depth (inch)	Ship weight (lbs)	Design Style	Elec Conn
500	63-31-150-8	600	120, 208, 240	13	9	7	38	1	B
1000	63-32-210-8	600	120, 208, 240	17	9	7	62	1	B
2000	63-32-220-8	600	120, 208, 240	18	13	10	109	1	B
3000	63-32-230-8	600	120, 208, 240	19	13	10	142	1	B
5000	63-29-250-8	208, 240, 480, 600	120, 208, 240	28	13	10	221	1	A
7500	63-29-275-8	208, 240, 480, 600	120, 208, 240	27	25	10	360	2	A
10000	63-29-310-8	208, 240, 480, 600	120, 208, 240	28	25	10	441	2	A
15000	63-29-315-8	208, 240, 480, 600	120, 208, 240	28	38	10	706	3	A

Group 4 – MCR Series, 50 Hz Only (±5% output voltage regulation)

VA	Catalog Number	Voltage Input	Voltage Output	Height (inch)	Width (inch)	Depth (inch)	Ship weight (lbs)	Design Style	Elec Conn
120	63-23-612-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	9	6	8	24	1	C
250	63-23-625-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	11	6	8	27	1	C
500	63-23-650-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	13	9	7	40	1	C
1000	63-23-710-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	18	9	7	64	1	C
2000	63-23-720-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	18	13	10	113	1	C
3000	63-23-730-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	27	13	10	162	1	C
5000	63-23-750-8	110, 120, 220, 240, 380, 415	110, 120, 220, 240	30	13	10	266	1	C
7500	63-28-775-8	220, 240, 380, 415	110, 120, 220, 240	28	26	10	393	2	C1
10000	63-28-810-8	220, 240, 380, 415	110, 120, 220, 240	30	26	10	490	2	C2
15000	63-28-815-8	220, 240, 380, 415	110, 120, 220, 240	30	38	10	776	3	C2

Specifications

Parameter	Condition	Value
	Input	
Voltage	Continuous at full load (lower input voltage possible at lighter load)	+10% to -20% of nominal
	For temporary surge or sags	+20% to -35% of nominal
Current[1]	at Full Load & 80% of nominal input voltage	$I_{in} \cong (VA/.89)/(V_{in} \times 80\%)$
Frequency	See Operating Characteristics section for details.	50 Hz or 60 Hz depending on model
	Output	
Line Regulation	V_{in} >80% and <110% of nominal	± 5% for 50 Hz units, ± 3% for 60 Hz units
Overload Protection	At Nominal Input Voltage	Current limited at 1.65 times rated current
Output Harmonic Distortion	At full load within input range	3% total RMS content
Noise Attenuation	-Common Mode -Transverse Mode	120 dB 60 dB
	General	
Efficiency	At Full Load	Up to 92%
Storage Temperature	Humidity <95% non-condensing	-20° to +85°C
Operating Temperature	Humidity <95% non-condensing	-20° to 50°C
Audible Noise	Full Resistive Noise	35 dBA to 65 dBA
Approvals	60 Hz Models	UL1012, CSA evaluated by UL
	50 Hz Models	CE (EMC & LVD)
Warranty	See General Information section for details	10 + 2 Years

Notes:
1 - Consult user manual for fuse sizing.

/S Hardwired Series – Constant Voltage Transformers

Superior voltage regulation of ±1% sets the CVS series apart from other power conditioning technologies on the market. Extremely tight regulation is accomplished by SolaHD's ferroresonant transformer technology. The CVS recreates a well regulated sinusoidal waveform that is well isolated from input disturbances including:

- Impulses
- Brownouts
- Severe waveform distortion
- Swells
- Sags

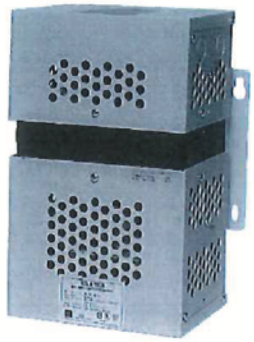
No other power conditioning technology provides as complete a solution against these power quality disturbances. The CVS series is ideal for applications where even a small change in voltage level can lead to unscheduled downtime, misoperation, incorrect data or scrapped production.

Applications

- Industrial automation and control equipment PLCs
- Analytical laboratory and factory automating equipment
- Photo processing equipment
- Sound/recording systems
- Photographic enlargers
- Broadcast equipment

Features

- Superior voltage regulation of ±1%
- Surge protection tested to ANSI/IEEE C62.41, Class A & B waveform
- Harmonic filtering



c UL us E47379 RoHS

- Hardwired
- Acts as a step-up/step-down transformer
- Galvanic isolation provides exceptional circuit protection
- 25 year typical mean time between failure
- No maintenance required

Certifications and Compliances

- cULus Listed
  - UL 1012
  - CSA C22.2 No. 66
- RoHS Compliant

Related Products

- On-line UPS (S4K Industrial)
- Surge Protection
- Three Phase Power Conditioners
- Active Tracking® Filters

Selection Tables: Single Phase

Group 1 – CVS Series, 60 Hz

VA	Catalog Number	Voltage Input	Voltage Output	Height in (mm)	Width in (mm)	Depth in (mm)	Ship Weight lbs (kg)	Design Style	Elec Conn
30	23-13-030-2	120	120	7.00 (177.8)	4.00 (101.6)	5.00 (127.0)	9.0 (4.08)	1	J
60	23-13-060-2	120	120	7.00 (177.8)	4.00 (101.6)	5.00 (127.0)	9.0 (4.08)	1	J
120	23-22-112-2	120, 240	120	8.00 (203.2)	4.00 (101.6)	5.00 (127.0)	13.0 (5.90)	1	J
250	23-23-125-8	120, 240, 480	120	11.00 (279.4)	6.00 (152.4)	8.00 (203.2)	29.0 (13.15)	1	G
500	23-23-150-8	120, 208, 240, 480	120, 240	13.00 (330.2)	9.00 (228.6)	7.00 (177.8)	42.0 (19.05)	1	H
1000	23-23-210-8	120, 208, 240, 480	120, 240	17.00 (431.8)	9.00 (228.6)	7.00 (177.8)	65.0 (29.48)	1	H
2000	23-23-220-8	120, 208, 240, 480	120, 240	18.00 (457.2)	13.00 (330.2)	10.00 (254.0)	111.0 (50.35)	1	H
3000	23-23-230-8	120, 208, 240, 480	120, 240	19.00 (482.6)	13.00 (330.2)	10.00 (254.0)	142.0 (64.41)	1	H
5000	23-23-250-8	120, 208, 240, 480	120, 240	28.00 (711.2)	13.00 (330.2)	10.00 (254.0)	222.0 (100.70)	1	H
500 *	23-28-275-6	240, 480	120, 240	27.00 (685.8)	25.00 (635.0)	9.00 (228.6)	365.0 (165.56)	2	J

* This unit is UL Listed only.

Contact **Technical Services** at (800) 377-4384 with any questions.
Visit our website at www.solahd.com.

odel Comparison

Description	Hardwired CVS	Hardwired MCR	Portable MCR
VA Ratings	30 to 7500 VA	120 to 15000 VA	70 to 3000 VA
Input Voltage Range	+10/-20% of nominal		
Voltage Regulation	±1% for an input line variation of +10/-20%. No loss of output for line loss of 3 msec.	±3% for an input line variation of +10/-20% (50 Hz hardwired units ±5%.) No loss of output for complete line loss of 3 msec.	
Overload	Limits output current to 1.65 x rated current at nominal input.		
Output Harmonic Distortion	3% total RMS content at full load.		
Noise Isolation	40 dB common and normal code.	120 dB common mode and 60 dB normal mode.	
Surge Protection	Up to 6000 Volt surges are suppressed to a let through of less than 1% per ANSI/IEEE C62.41 Class A & B waveforms.	ANSI/IEEE C62.41 Class A & B 6000 waveforms are suppressed to a let-through of less than 0.2%.	
Efficiency	Up to 92% at full load		Up to 90% at full load
Operating Temperature	-20°C to 50°C		-20°C to 40°C
Audible Noise	32 dB to 65 dB	35 dB to 65 dB	34 dB to 49 dB
Conformance	Listed to UL 1012. CSA Certified	UL Listed and CSA Certified. 50 Hz models in compliance with Low Voltage Directive Specification EN60950.	Listed to UL 1012. CSA Certified on all models except 3000 VA.
Warranty	10 years		

Note: All values are typical and may vary based on VA ratings of actual units.

BTU Output Chart for CVS and MCR Series

VA Ratings	120	250	500	750	1000	1500	2000	3000	5000	7500	10000	15000
Total BTU's	136	225	280	444	519	686	1229	1331	2117	2407	3209	4813

Note: Ratings are for a 40°C ambient temperature.

Operating Characteristics of the CVS & MCR Series

Regulation

SolaHD's CVS power conditioners will hold output voltages to ±1.0% or less with input variations as great as ±15% (115V ±15% or 120 V +10%/-20%). Units operated at less than rated load will maintain approximately ±1% regulation over a wider input line voltage variation. Output meets NEMA voltage specifications even when input voltage drops to 65% of nominal. The output versus input voltage relationship for a typical CVS is show in Figure A.

CVS Conditioner Rating – VA	Increase in Output Voltage due to Load Removal
30	3%
60 & 120	2%
250 & over	1%

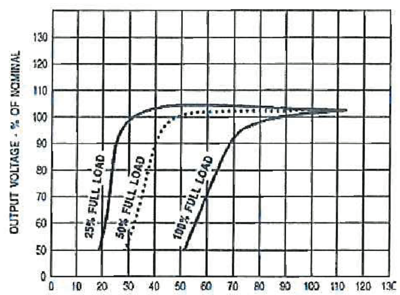


Figure A: Load Variation

Note: MCR line regulations: ±3% for 60 Hz; ±5% for 50 Hz. The typical performances shown in Figure B indicate that most of the residual changes take place near the lower (95 V) and upper (130 V) ends of the input range. It is possible to improve output regulation if line variations remain within a restricted range near the center of the nameplate range (for example, 100-120 V).

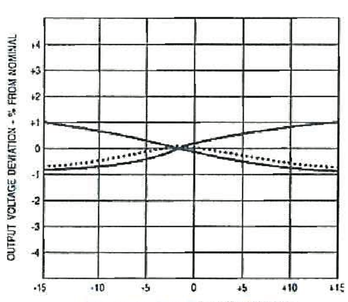


Figure B: Line Regulation

Normally, the output voltage will rise as the load is decreased. Typical percentages for changes in resistive load from full to zero load as shown below.

Except as noted, all characteristics of Sola/HD's CVS products also apply to the MCR series.

Input Characteristics

SolaHD power conditioners include a resonant circuit that is energized whether or not it is serving load. The input current at no load or light load may run 50% or more of the full primary current. As a result, the temperature of the unit may rise to substantially full-load level, even at light or no load. Input power factor will average 90-100% at full load, but may drop to about 75% at half load and 25% at no load. In any case, the current is always leading. The input no load watts are about 12.5% of the VA rating.

Frequency

Output voltage varies linearly with a change of frequency of the input voltage. This change is about 1.5% of the output voltage for each 1% change in input frequency and in the same direction as the frequency change.

Power Factor

SolaHD power conditioners regulate any power factor load. Output voltage is a function of load current and load power factor (see Figure C). If lower voltage under lagging power factor is objectionable, correction may be made with capacitors at the load. "Median" value of output voltage will vary from the nameplate rating if the load has a power factor other than that for which the transformer was designed. Load regulation will also be relatively greater as the inductive load power factor is decreased (see Figure C). However, the resulting median values of output voltage will be regulated against supply line changes at any reasonable load or load power factor.

)perating Characteristics of the CVS & MCR Series

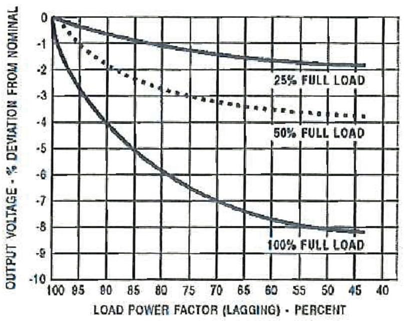


Figure C: Power Factor

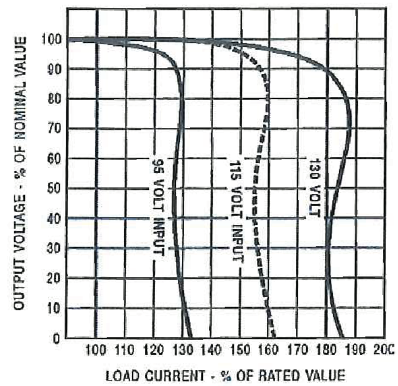


Figure D: Overload Performance

Efficiency

The copper magnet wire and lamination material used in SolaHD ferroresonant products are selected to achieve efficiencies of 90% or higher. Whether or not an external load is being served, current will be drawn from the line whenever the primary is energized, since the capacitor remains connected in the circuit.

Overload and Short Circuits

Vhen the load is increased beyond the regulator's rated .alue, a point is reached where the output voltage suddenly collapses and will not regain its normal value until the load is partially released. Under direct short circuit, the load current is limited to approximately 150-200% of the rated full load value and the input watts to less than 10% of normal.

A constant voltage regulator will protect both itself and its load against damage from excessive fault currents. Fusing of load currents may not be necessary. The actual value of short-circuit current varies with the specific design and rating. Units may be operated indefinitely at short-circuit. This characteristic protects the unit itself as well as the load and load circuit being served. Typical overload performance is shown in Figure D.

Motor Loads

Because of the fast response time of the SolaHD circuit, any current-limiting characteristic must be taken into account for transient overloads such as motor starting and solenoid operation. In general, the SolaHD constant voltage regulator must have a capacity nearly equal to the maximum demand made on it, even for an instant. To determine the power rating of the regulator, peak motor-starting current or solenoid inrush current should be measured or power factor correcting capacitors should be used to reduce the starting VA of the load.

Response Time

An important advantage of SolaHD's ferroresonant transformer is its fast response time compared with other types of AC regulators. Transient changes in supply voltage are usually corrected within 1½ cycles or less; the output voltage will not fluctuate more than a few percent, even during this interval.

Operating Characteristics of the CVS & MCR Series

Temperature

SolaHD's ferroresonant power conditioners are very stable with respect to temperature. The change in output voltage is only 0.025%/°C. Units are factory adjusted to +2%/-0% of nominal, with full load and nominal input voltage. This adjustment to the high side of nominal is to compensate for the natural temperature drift of about 1% that takes place during initial turn-on or warm-up. When the unit warms up to operating temperature, the voltage typically falls about 1%.

At a stable operating temperature, the output voltage will change slightly with varying ambient temperatures. This shift is equal to approximately 1% for each 40°C of temperature change. The normal maximum temperature rise of a SolaHD power conditioner may fall anywhere in the range of 40°C to 110°C depending on the type and rating. The nominal design ambient range is between -20°C and +50°C (-20°C to +40°C for 70 - 1000 VA, 60 Hz portable models).

External Magnetic Field

In almost all applications, this effect may be disregarded.The exclusive SolaHD "wide outside leg" construction reduces stray magnetic fields to a practical minimum. On critical applications, care should be taken in orientation of the core with respect to critical circuits to minimize the effect of the field.

Phase Shift

The phase difference which exists between input and output voltages is in the range of 120 degrees to 140 degrees at full load. This phase difference varies with the magnitude and power factor of the load, and to a lesser extent, with changes in line voltage and load power factor.

Transient Protection

Ferroresonant power conditioners protect input transients (caused by lightning and load switching) from damaging the sensitive electronic load. A typical surge protective device (SPD) tries to 'clamp' a transient by diverting it to ground. A ferroresonant power conditioner "blocks" the transient. This 'blocking' action is achieved by total physical separation from input (primary) to output (secondary). Because of this difference in operation, it is difficult to apply the same specifications to a ferroresonant power conditioner. Some parallels can be made however.

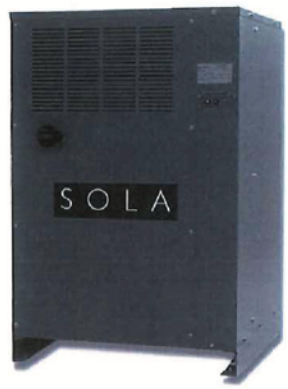
One, is that under load, the let-through voltage of a ferroresonant power conditioner (SPD refers to "clamping voltage") is less than 10 V above the point where the sine wave would normally be at any given time. The ferroresonant power conditioner is an 'active tracking' suppressor with several advantages. The Ferro power conditioner will not shunt the transient to the ground line as SPD devices typically do. Shunting the transient to ground can cause the disturbance to be transmitted to other sensitive loads within a facility. This can pose serious problems with electronic or microprocessor-based equipment, especially if there is poor grounding within a facility. Other advantages provided by ferroresonant power conditioners include noise filtering, filtering of harmonic distortion and protection against voltage fluctuations such as sags or swells. These features are not provided by standard surge protection devices but are often misrepresented or misused by SPD manufacturers trying to market their product as a "Do All" power quality device.

Appendix 8

SOLATRON™ Plus Series - Three Phase Power Conditioners

Features

- Rugged, industrial design
- High overload capability
- High MTBF - No fans used
- No power factor restriction on loads
- Tight regulation for protection against sag (-25%) and swell (+15%) conditions
- Fail-safe, no-break, auto-bypass
- Status indicating lights
- Shielded, copper wound isolation transformer
- Surge protection to ANSI/IEEE and IEC Standards
- High efficiency (96%) microprocessor controlled tap switcher
- Automatic under voltage protection
- UL1012, UL1449-2, $_{c}UL_{US}$ Listed
- Two Year Limited Warranty



Related Products

- STV 100K
- Isolation Transformers

Applications

- Automatic Packaging Machinery
- Large Machine Tool Equipment
- UPS Bypass Circuits
- Retail Store
- Process Equipment

Electrical Specifications

Power Ratings	20, 30, 50, 75 KVA, Three Phase*
Nominal Voltages	See Selection Table
Input Voltage Range	-25% to +15% of nominal rated voltage
Output Voltage Range	Regulated to a max of ± 5% (3% typical) of nominal voltage with an input voltage range of –25% to +15%.
Response Time	Responds to any line variation in <1.5 cycles typical.
Technology	Enhance Voltage Regulation (EVR), Microprocessor controlled electronic tap switching. 6 taps switched at zero current crossing with no output interruption.
Operating Frequency	57-63 Hz
Load Power Factor	No Restriction
Insulation Resistance	100 megohms from winding to core measured at 500 Vdc
Efficiency	96% typical
Overload Capability	1000% of rated load for 1 second 200% of rated load for 1 minute
EMI	Less than 0.2 gauss at a distance of 3 ft.

* Contact Technical Services for other ratings.

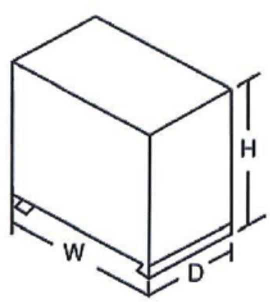
Mechanical Specifications

Indicators	Indicating Lamps: 2 amber (over temperature and bypass mode), 1 green (regulated output present)			
Connections	Field wired, terminal blocks			
Size		H	W	D
	in	42	28	26
	mm	1016	712	661
Safety Agency Approvals	UL1012 and UL1449-2 cUL (Canadian Standard C22.2 No 125) Complies with Part 15 Subpart J of FCC rules for a Class A computing device.			

Environmental Specifications

Audible Noise	Less than 50 dBA at 3 feet
Ambient Temperature	0° to 40°C Operating, 0° to 80°C Storage
Operating Altitude	10,000 feet without derating
Operating Humidity	95% relative (non-condensing)

Design Style



Contact **Technical Services** at **(800) 377-4384** with any questions.
Visit our website at www.solaheviduty.com.

Protection Specifications

Under Voltage	Output voltage will switch to bypass mode when input is less than 50% of nominal. Regulated output voltage will be re-established once input voltage is with specifications.
Short Circuit Protection	Input circuit breaker
Over Temperature Protection	Amber lamp indication of over temperature at approximately 180°C. Unit switches to by-pass mode until internal temperature is reduced to specified values.

Noise Suppression Performance Specifications

Common Mode Noise Attenuation	150 dB at 100 kHz
Normal Mode Noise Attenuation	65 dB at 100 kHz
Surge Protection	Tested to ANSI/IEEE standard C62.41 A&B

Selection Table

Output KVA	Catalog Number	Vac Input	Vac Output	Ship Weight (lbs/kg)
208 Vac Input, 208Y/120 Vac Output, 60 Hz				
20	**63TAA320**	208	208Y/120	600/273
30	**63TAA330**	208	208Y/120	750/341
50	**63TAA350**	208	208Y/120	950/432
75	**63TAA375**	208	208Y/120	1200/545
480 Vac Input, 208Y/120 Vac Output, 60 Hz				
20	**63TCA320**	480	208Y/120	600/273
30	**63TCA330**	480	208Y/120	750/341
50	**63TCA350**	480	208Y/120	950/432
75	**63TCA375**	480	208Y/120	1200/545
480 Vac Input, 480Y/277 Vac Output, 60 Hz				
20	**63TCC320**	480	480Y/277	600/273
30	**63TCC330**	480	480Y/277	750/341
50	**63TCC350**	480	480Y/277	950/432
75	**63TCC375**	480	480Y/277	1200/545
600 Vac Input, 208Y/120 Vac Output, 60 Hz				
20	**63TDA320**	600	208Y/120	600/273
30	**63TDA330**	600	208Y/120	750/341
50	**63TDA350**	600	208Y/120	950/432
75	**63TDA375**	600	208Y/120	1200/545
Custom Voltages	**240 Vac Input, 240Y/139 Vac Output, 60 Hz** **480 Vac Input, 240Y/139 Vac Output, 60 Hz** **600 Vac Input, 240Y/139 Vac Output, 60 Hz**			
Contact Technical Services for custom voltages.				

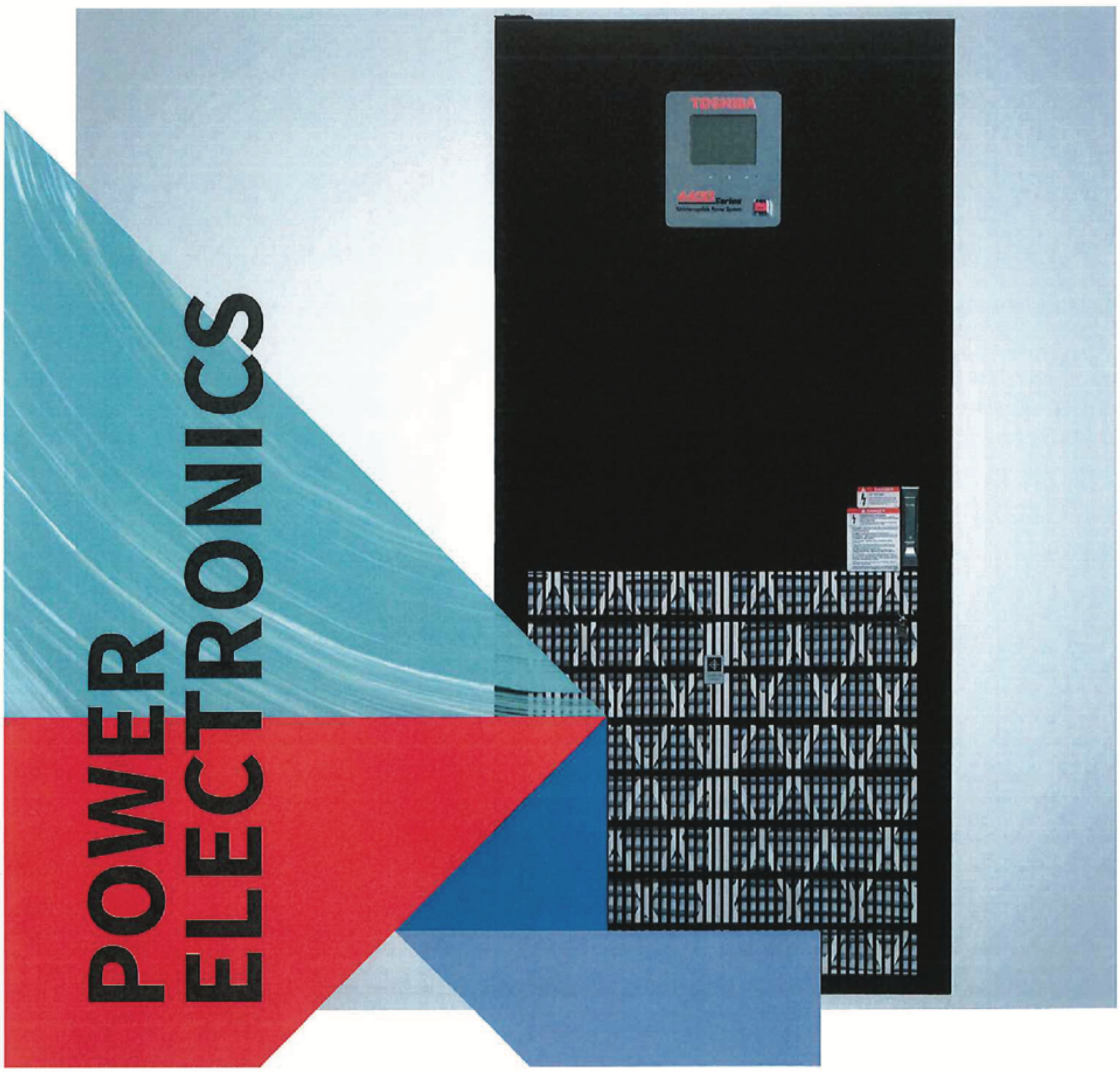
Appendix 9

TOSHIBA

TOSHIBA INTERNATIONAL CORPORATION

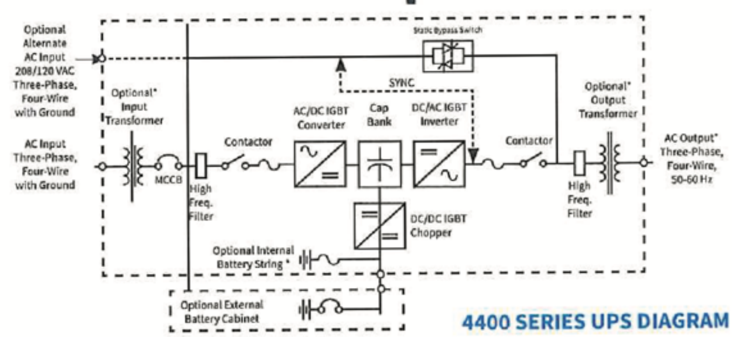
UNINTERRUPTIBLE POWER SYSTEMS

4400 Series



NEXT GENERATION TECHNOLOGY

The Toshiba 4400 Series Uninterruptible Power Supply (UPS) is the next-generation three-phase UPS. The double-conversion, all insulated-gate bipolar transistor (IGBT) 4400 Series UPS features a digitally controlled IGBT input rectifier; an intelligent, low harmonic, pulse-width modulation (PWM) IGBT output inverter; state-of-the art, IGBT battery isolation circuitry; and an easy to navigate local touchscreen interface. The small footprint and total front access mechanical design requires zero rear clearance and includes features such as top, bottom, and side cable entry, standard sized air filters included, and lockable keyed doors. Customization is available through a number of options, such as internal battery backup, internal maintenance bypass, internal transformers for specific voltage applications, and remote monitoring with the Toshiba RemotEye® 4 multi-protocol UPS monitoring solution.



4400 SERIES UPS DIAGRAM

Multi-Application Ready	UPS models available for any application; everything from internal energy storage, internal maintenance bypass, frequency conversion, Power Conditioning (no batteries) or any voltage / power distribution configuration, all in a sleek standardized line up.
Time-Tested Topology	Utilizes a Toshiba established true-online, double conversion all IGBT topology to meet the highest industry standards of reliability and power quality.
Over Design Protection	15 year design life components with long MTBF require minimal service for long lasting use in the toughest of environments.
Bad Utility Responsive, Tough Load Ready	Superior Design features Low Harmonic Distortion, wide input Voltage and frequency window, 100% Load Step and 100% unbalanced load capabilities, with up to 109% continuous overload without compromising voltage regulation.
Value-Generating Construction	Save on power and space with the 4400 Series, rugged industrial all front access, zero rear or side clearance, seismic ready design that minimizes footprint while maximizing power efficiency.
Toshiba End-to-End Solution	Configurable UPS options with wide range of run time Battery cabinets ensure the 4400 Series can represent a turnkey solution for a wide variety of applications.
Made in USA	Manufactured in Houston, Texas. Meets BAA and ARRA requirements.

OPTIONS & ACCESSORIES

BATTERY CABINETS

Matching battery cabinets with Valve-Regulated Lead Acid (VRLA) batteries provide uniform installation appearance with various run times. The Toshiba 4400 Series UPS works equally well with either VRLA or flooded-cell battery backup.

AUXILIARY CABINETS

Matching auxiliary cabinets are available for uniform installation appearance. Options include:

- Maintenance Bypass Switch (MBS)
- Power Distribution
- Subfeed Breakers
- Input Step Down Transformer
- Slim MBS

UPS MONITORING

RemotEye® 4 offers real-time control, monitoring, and analysis of UPS operation. The quick and easy-to-use software can automatically initiate an orderly shutdown to connected servers to minimize any risk of data loss. RemotEye® 4 also features a first-ever mobile website for monitoring UPS status updates on-the-go. Universal communications protocols compatible with RemotEye® 4 include:

- Modbus TCP & RTU
- BACnet IP & MSTP
- HTTP/HTTPS
- SNMP
- IPv6 Compatible

Battery Cabinet

50-100 kVA UPS

Slim MBS

One Cabinet Solution: UPS, MBS, & Batteries

EMERGENCY LIGHTING (UL924)

4400 Series UPS Systems may be ordered in a pre-designed and certified configuration to meet the rigorous UL924 Standard for emergency lighting applications. The end-to-end solution includes the 90-minute runtime and battery test function required by the UL924 Standard. The 4400 Series' centralized approach for emergency lighting is ideal for a world moving towards the utilization of LED lights which demand the power quality that only a UPS system like the 4400 Series can provide. Optional matching 4400 Series Distribution cabinets are available for multi branch circuitry of an Emergency Lighting System.

INDUSTRIES SERVED

- Data Center
- Emergency/Healthcare
- Commercial/Retail

4400 SERIES APPLICATIONS

- Computer Systems
- Medical Labs
- Small Scale Server Rooms
- Voice/Data Network Closets
- Edge Data Centers
- Point of Sale Equipment
- Banking Systems
- Retail Office Systems
- School System Computer Rooms
- Light Industrial

TOSHIBA
TOSHIBA INTERNATIONAL CORPORATION

4400
Series

3 THREE YEAR WARRANTY

MODEL NUMBER	4400X3X150XA	4400X3X200XA	4400X3X250XA	4400X3X300XA	4400X3X500XA	4400X3X800XA	4400F3F10KXA
Capacity	15 kVA (13.5 kW)	20 kVA (18 kW)	25 kVA (22.5 kW)	30 kVA (27 kW)	50 kVA (45 kW)	80 kVA (72 kW)	100 kVA (90 kW)
Topology	True On-Line, Double-Conversion, All-IGBT Technology						
INPUT							
Voltage (Standard)	208/120V Three-Phase, Four-Wire + Ground Single or Dual Input*						
Voltage Range	-15% to +10% (Without Using Battery)**						-10% to +10% (Without Using Battery)**
Power Factor	>0.98						
Current THD	<5% at 100% Load						
Frequency	50 +/- 5 Hz; 60 +/- 5 Hz						
OUTPUT							
Voltage (Standard)	208/120V Three-Phase, Four-Wire + Ground Output***						
Frequency	50/60 Hz, +0.1% Auto-Sensing Standard. (50/60 Hz Selectable, for use as Frequency Converter)						
Voltage Regulation	+/-2% at 0-100% Balanced Load						
Power Factor	0.9 Lagging						
Inverter Overload Capacity	109% Continuous, 110-124% for 6 Minutes, 125-149% for 90 Seconds, 150% for 30 Seconds;						104% Continuous, 105-125% for 6 Minutes, 125-149% for 60 Seconds, 150% for 30 Seconds
Bypass Overload Capacity	125% for 10 Minutes, 150% for 2 Minutes, 1000% for 1 Cycle						
BATTERY							
DC Link	288 VDC						
Ripple Voltage	<0.5% DC						
ENVIRONMENT							
Temperature Range	32° to 104°F (0° to 40°C)						
Relative Humidity	5% to 95% Non-Condensing						
Heat Rejection	4556 BTUs/Hour	6074 BTUs/Hour	7395 BTUs/Hour	9111 BTUs/Hour	15,286 BTUs/Hour	24,297 BTUs/Hour	30,372 BTUs/Hour
Full-Load Efficiency	91.0%						
25% Load Efficiency	88.0%						
Altitude	3300 ft. (1000 m) Maximum Without Derating						
Air Filtration	Airflow Front-to-Top, Front-Located Filters Included						
Audible Noise	<65dBA @ 1 m Typical						<70dBA @ 1 m Typical
DIMENSIONS							
Dimensions	20.12 in. (W) x 37.40 in. (D) x 65.06 in. (H)				32.10 in. (W) x 37.20 in. (D) x 73.80 in. (H)		
Weight****	725 lbs. (329 kg)	730 lbs. (331 kg)	750 lbs. (340 kg)	760 lbs. (345 kg)	965 lbs. (438 kg)	1550 lbs. (612 kg)	1650 lbs. (748 kg)
COLOR							
	Powder Coat, DuPont O'Brien Black						
MONITORING							
	Touchscreen Operator Interface, UPS Status N/O Dry Contacts, RS232C Interface (Optional RemotEye® 4 Intelligent Monitoring System)						
OPTIONS							
	Internal Batteries (15-50kVA), Internal Isolation & Voltage Conversion Transformers, Dual-Input Feed, RemotEye® 4 Intelligent Monitoring System, Remote Status Alarm Panel, External Matching & Non-Matching Battery Cabinets, Matching MBS/Transformer/Distribution Cabinets. UL924 Certified Emergency Lighting System (15-20kVA), Internal 3-Breaker MBS (15-30kVA)						
STANDARDS							
	UL 1778, CUL, ISO9001, ISO14001:2004, ANSI C62.41 (IEEE 587), NEMA/PET-1993, CE, IBC, & CBC (OSHPD)						UL 1778, CUL, ISO9001, ISO14001:2004, ANSI C62.41 (IEEE 587), NEMA/PET-1993
WARRANTY							
	3-Year On-Site Warranty; 10+ Year Service Agreements Available; See Toshiba Warranty Policy for Full Details						
SERVICE							
	24-Hour, 365-Day Technical Support: 1-877-867-8773						

* Isolation and Auto Transformer Options for Input Voltage Conversion. 15-50kVA Units can support 2 internal transformers. 80kVA Units can support 1 internal transformer. Not available for 100kVA
** For loads less than 50% of total UPS output capacity, input voltage within -30% to +10% of Standard value is sufficient for operation
*** Auto Transformer Options for Output Voltage Conversion. 15-50kVA Units can support 2 internal transformers. 80kVA Units can support 1 internal transformer. Not available for 100kVA
**** Unit Weight Not Including Internal Battery and Transformers
Specifications subject to change without notice.

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Power Electronics
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