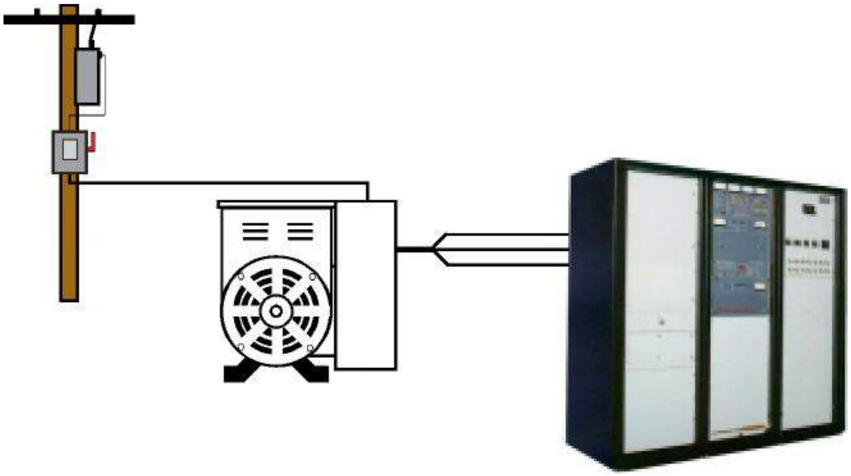
No Three-Phase Power?
No Problem!



AM FM DTV 5 – 500 KW

Operate <u>any</u> 3-phase transmitter from a 1-phase power supply.

The Phasemaster® converter turns any location into a 3-phase site within hours!

- True 3-phase output
- Efficiency >95%
- Highly reliable
- Low maintenance
- Installs in a few hours
- Coordinates with backup supplies
- More stable than utility open-delta
- 2-5% voltage regulation
- Transient suppression & ride-through

The LEAST expensive alternative to utility 3-phase service

Eliminates utility line extension charges

Make your own 3-phase when you need it

Avoid demand charges

Recommended by utilities, consultants and leading transmitter manufacturers

Kay Industries
PHASEMASTER®
Rotary Phase Converters

WORLD LEADERS IN SINGLE TO 3–PHASE POWER CONVERSION

"We thought we had found an outstanding transmitter site. It was affordable, had excellent access and no interference. But it did not have 3-phase power and the utility wanted a fortune to bring it in."

Sound familiar? It happens all the time! But you don't have to be a prisoner of the utility! The **Phasemaster® Type T** Rotary Phase Converter produces the true equivalent of utility 3-phase from any existing 1-phase supply, and at tremendous savings.

"Thanks to the Phasemaster® converter, we were able bring 3-phase power to the site for less than 5% of what the power company was going to charge us."

Claude F. Jones, VP and General Manager
WSLW White Sulphur Springs, West Virginia

Now you can expand your site selection options and save money too! **Phasemaster®** is recommended by broadcast consultants, utility companies and most major transmitter manufacturers.

But don't take *our* word for it. Talk to the people who own and operate some of the nearly 1000 radio and TV stations worldwide who have been running reliably on **Phasemaster** converters for as long as 30 years. Contact us for a complete list of references before you write that check to the utility or pay a premium for a less efficient 1-phase transmitter!

Kay Industries
PHASEMASTER®
Rotary Phase Converters

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South Bend, IN 46624
800-348-5257 574-289-5932 *fax*

Western Region Office
Fremont, CA
510-656-8766

www.kayind.com
info@kayind.com

PHASEMASTER® ROTARY PHASE CONVERTER FOR BROADCAST TRANSMITTER SERVICE

TYPE T

The World Leader in Single to Three-Phase Electric Power Conversion

Converters offer the most economical way to operate your three-phase transmitter from a single-phase supply

The Phasemaster Rotary Converter is specially engineered for use with all makes and designs of radio and television broadcast transmitters. It produces 3-phase power from any single-phase line wherever utility three-phase is unavailable or cost prohibitive. It is low in initial cost and high in performance and efficiency.

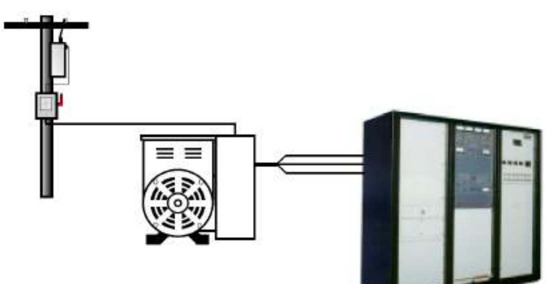
Phasemaster boasts an operating experience record of more than forty years and is successfully operating more than 1,500 radio and television stations throughout North and South America and the Pacific Rim.

Phasemaster converters have been approved by the major transmitter manufacturers and are recommended extensively by consultants and utility companies.
Further, Kay Industries maintains extensive compatibility application and test data on most makes of commercial transmitters.

Phasemaster Expands Siting Options and saves money

The Phasemaster Rotary Converter solves a very common problem. An otherwise near perfect transmitter site turns out to be unsuitable because the utility does not have a nearby 3-phase line and it cost too much to extend one. The solution is a Phasemaster converter. It's low installed cost makes it the most economical alternative when compared to costly single-phase transmitters, or high maintenance diesel engine generators.

Documented savings of $100,000 by using a Phasemaster converter are not uncommon. In certain cases, a converter may even reduce power bills by eliminating the demand charges which are very common on three-phase services but much less prevalent on single-phase service.



Performance

The Phasemaster converter produces a true three-phase output with each phase shifted by 120 degrees just like the utility line. In addition it provides may other performance benefits:

- Immediate power availability - A phase converter can be connected in a few hours compared to weeks or months for utility service extensions.
- Low maintenance trouble-free operation Phasemaster converters requires very little attention. It can operate 24 hours a day for years at a time.
- High efficiency design - the Kay Industries' patented construction minimizes noise and vibration and keeps losses to less than 5% of total system load. The output voltage is regulated to keep AM noise to a minimum
- Reduced outages from line noise - The converter's stored energy buffers the line and rides through short term disturbances.
- Integral lightning and surge protection guards against switching and other line transients.

Choose a transmitter site without worrying about 3-phase power availability. Phasemaster converters have helped thousands of broadcasters operate from single phase lines and saved them millions in three-phase installation

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Superior Construction

Phasemaster converters are built with high quality components to meticulous manufacturing standards consistent with the requirements of its CSA/NRTL listing. It contains no brushes, commutators, slip rings or other maintenance prone components. The large terminal compartment facilitates fast and easy installation.

Accessories and Options

A broad range of optional accessories are also offered to make Phasemaster fit with any station design. Automatic controls allow remote shutdown and easy coordination with transfer switches to back-up power supplies. Load range controls enable the converter output to be adjusted for variable loads.

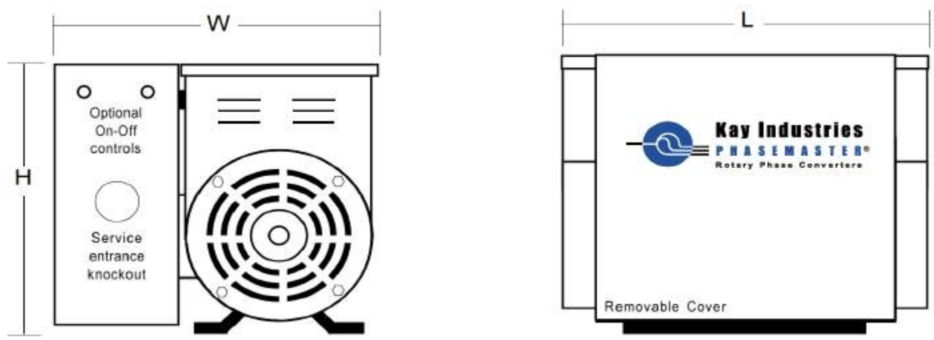
Selection and Ordering Information

The following data is essential to selecting the correct converter for your application:

- Transmitter type, AM FM or TV
- Manufacturer's model number and KW power rating
- Operating Voltage
- Type and size of incoming utility service
- Transmitter input power consumption in KW at full load or 100% modulation
- Operating load variations
- Other three-phase loads
- Size of utility service (Amps)

PHASEMASTER® ROTARY PHASE CONVERTER FOR BROADCAST TRANSMITTERS

TYPE T



Model No. Without Controls	Model No. With Auto Controls	Max. KW Out	Dimensions (Inches) L	W	H	Weight (LBS.) Manual	Weight (LBS.) Auto
T-1300	T-1300-A	6	14	17	18	225	245
T-2000	T-2000-A	8	17	20	22	280	305
T-2500	T-2500-A	10	19	20	22	330	355
T-4000	T-4000-A	16	20	22	26	380	425
T-5000	T-5000-A	20	22	24	27	430	480
T-7500	T-7500-A	25	25	24	27	497	560
T-8000	T-8000-A	30	25	27	33	640	705
T-10000	T-10000-A	38	26	27	33	788	865
T-12000	T-12000-A	45	27	29	35	905	980
T-14000	T-14000-A	55	30	29	35	950	1030

OPERATING SPECIFICATIONS (All Ratings):

Input Voltage:	230 or 460V single-phase, 50 or 60 Hertz
Output Voltage:	230 or 460V single-phase, 3-wire closed delta
Output Regulation:	2-5% at rated output
Harmonic Content:	<1%
Power Factor:	.95 or greater at full load
Operating Efficiency:	>95% at full load
Operating Reliability:	MTBF 50,000 hours
Surge Arrestors:	175V line-ground, Clamping Voltage @1500A: 600V

- This converter requires a separately mounted OR factory built-in disconnect switch and fuses for on-off control and short circuit protection.
- See Drawings 0302-T or 0302-TA for complete connection details including switch, fuse and feeder sizes.
- Actual dimensions will not exceed those shown.

What Our Customers Are saying…

"The Phasemaster certainly got us out of a real bind in that three-phase power was over a mile away. The cost to get it here was outrageous. The Phasemaster solved our problems and works for us 24 hours a day 7 days a week. I can recommend Phasemaster to anyone."
- VP/GM, Texas AM-FM Station

"We have used a Phasemaster Model T-7500 with our 10KW Continental Transmitter at our mountain top site for over one year now. It has been in continuous duty since we signed on, providing uninterrupted service."
- President.GM, California FM Station

"...this year we began operation from a new transmitter location on top of Greenbrier Mountain (elevation 3,000ft.). This move was made possible because of the availability of Phasemaster converters ... The cost of constructing a three phase power line to accomplish the same end would have been in excess of $25,000.00"
- VP/GM West Virginia AM Station

" I am happy to report that both the Phasemaster and transmitter have operated flawlessly ... running 24 hours a day, seven days a week"
- Chief Engineer, College Television Station

WARRANTY - Kay Industries, Inc. (the manufacturer) guarantees all products of our manufacture against faulty material or workmanship for a period of five years from date of installation or 61 months from date of shipment from factory, whichever period first expires. In addition Kay Industries will replace all defective bearings regardless of cause for the life of the converter. Any part that you return to us within this warranty period showing unmistakable defect in material or workmanship will be renewed or replaced at our option F.O.B. factory without charge. The final decision that an original defect existed shall rest with the manufacturer. The liability of is limited to the renewal or replacement of the defective part. In no case will Kay Industries be liable for damage or loss incurred because of interruption of service or for consequential damages, transportation, labor or expense required to repair or replace defective parts or units. Kay Industries will not be responsible if its products have been improperly installed in any way. This warranty shall not apply to any of the manufacturer's products that must be replaced because of normal wear, that have been subjected to misapplication, misuse, neglect, accident or that have been repaired or altered outside of the manufacturer's factory unless expressly authorized by the manufacturer.

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RADIO AND TELEVISION STATIONS OPERATING ON PHASEMASTER® ROTARY PHASE CONVERTERS

KAAA	Kingman	AZ
KAAR	Spokane	WA
KABF	Little Rock	AR
KADE	Boulder	CO
KAEN	Little Eagle	SD
KAHM	Prescott	AZ
KAOD	Babbitt	MN
KAPT	Austin	TX
KARO	Boise	ID
KARX	Amarillo	TX
KASH	Anchorage	AK
KAYO	Aberdeen	WA
KAYY	Fairbanks	AK
KBBI	Homer	AK
KBBZ	Whitefish	MT
KBBO	Yakima	WA
KBCO	Boulder	CO
KBDI	Broomfield	CO
KBHA	Deer River	MN
KBJQ	Bronson	KS
KBLG	Billings	MT
KBZR	Scottsdale	AZ
KCBI	Frederick	OK
KCFA	Eagle River	AK
KCFO	Eugene	OR
KCHY	Ayr	ND
KCIR	Twin Falls	ID
KCKK	Kanab	UT
KCWC	Riverton	WY
KCWN	Hutchinson	KS
KCYN	Wheatland	WY
KCYT	Anchorage	AK
KDFM	Durango	CO
KDNO	Thermopolis	WY
KDSJ	Deadwood	SD
KDTA	Delta County	CO
KDUK	Eugene	OR
KDWY	Diamondville	WY
KENO	Las Vegas	NV
KENT	Odessa	TX
KESP	Scottsdale	AZ
KESS	Irving	TX
KEXT	Albuquerque	NM
KEYF	Cheney	WA
KEZA	Fayetteville	AR
KFMF	Chico	CA
KFMF	Paradise	CA
KJUL	Las Vegas	NV
KROG	Medford	OR
KFMM	Stafford	AZ
KFSH	Hilo	HI
KFXJ	Abilene	TX
KGAS	Carthage	TX
KGCB	Prescott	AZ
KGLP	Gallup	NM
KGRD	Page	NE
KGVA	Harlem	MT
KIKO	Globe	AZ
KHGI	Kearney	NE
KHWY	Las Vegas	NV
KIRX	Kirksville	MO
KISY	Pineville	LA
KIVA	Albuquerque	NM
KJCT	Lacey	WA
KJNP	North Pole	AK
KJUL	Las Vegas	NV
KJZY	Denton	TX
KKDS	Salt Lake City	UT
KKEG	Fayetteville	AR
KKJR	Litchfield	MN
KKLL	Webb City	MO
KKOR	Gallup	NM
KKTZ	Mountain Home	AR
KLAD	Klamath Falls	OR
KLCO	Poteau	OK
KLCX	Eugene	OR
KLER	Orofido	ID
KLFD	Sauk Rapids	MN
KLJT	Tyler	TX
KLLR	Faribault	MN
KLO	Ogden	UT
KLRA	England	AR
KLSC	Tahoka	TX
KMAL	Parma	MO
KMMM	Muskogee	OK
KMCM	Miles City	MT
KMSO	Missoula	MT
KMTI	Manti	UT
KMTN	Jackson	WY
KMXK	St. Cloud	MN
KNAZ	Flagstaff	AZ
KNBZ	Wasilla	AK
KNFL	Salt Lake City	UT
KNUU	Las Vegas	NV
KNXN	Quincy	CA
KOGA	Ogallala	NE
KOLD	Tucson	AZ
KOMP	Las Vegas	NV
KONY	St. George	UT
KOOO	Colorado Springs	CO
KOTD	Omaha	NE
KOZE	Lewiston	ID
KPAW	Pineville	LA
KPCO	Quincy	CT
KPFM	Midway	AR
KPRN	Grand Junction	CO
KQMS	Redding	CA
KQNG	Lihue	HI
KQNM	Gallup	NM
KQQK	Hitchcock	TX
KQST	Phoenix	AZ
KQUL	Grand Junction	CO
KQXR	Boise	ID
KRBD	Ketchican	AK
KRIM	Payson	AZ
KRIT	Badger / Ft. Dodge	IA
KRMS	Osage Beach	MO
KROK	Merryville	LA
KROZ	Tyler	TX
KRRZ	Billings	MT
KRSE	Yakima	WA
KRTZ	Cortez	CO
KRVL	Kerrville	TX
KRXL	Kirksville	MO
KSHA	Redding	CA
KSNM	Truth or Conseq	NM
KSOX	Raymondville	TX
KSTR	Grand Junction	CO
KSXO	Redding	CA
KTCL	Fort Collins	CO
KTCX	Beaumont	TX
KTFI	Twin Falls	ID
KTOE	Mankato	MN
KTRA	Farmington	NM
KTXT	Beaumont	TX
KTYN	Minot	ND
KUBC	Montrose	CO
KUDA	Las Vegas	NV
KUGR	Green River	WY
KULU	Seaside	OR
KUOO	Spirit Lake	IA
KUSK	Prescott	AZ
KUUY	Cheyenne	WY
KUWR	U. of WY	WY
KVFM	Logan	UT
KVIM	Coachella	CA
KVMD	W. Los Angeles	CA
KVSF	Santa Fe	NM
KVSL	Show Low	AZ
KWBI	Morrison	CO
KWDC	Dallas	TX
KWHT	Pendleton	OR
KWK	St. Louis	MO
KWN	Stockholm	WI
KWQQ	Las Cruces	NM
KWRK	Window Rock	AZ
KWRL	Lagrande	OR
KXAX	St. James	MN
KXDR	Missoula	MT
KXGR	Grand Rapids	MN
KXLT	Clinton	LA
KXTC	Gallup	NM
KXTE	Las Vegas	NV
KYBS	Livingston	MT
KYCN	Wheatland	WY
KYGO	Denver	CO
KYOO	Bolivar	MO
KYUK	Bethel	AK
KZOC	Osage City	KS
KZDX	Burley	ID
KZRX	Phoenix	AZ
KZUL	Lake Havasu	AZ
KZWA	Ragley	LA
WADS	New Haven	CT
WAMV	Amherst	VA
WAQE	Peoria	IL
WAQX	Syracuse	NV
WARK	Hagerstown	MD
WATC	Marietta	GA
WAVL	Apollo	PA
WAVV	Naples	FL
WAYZ	Waynesboro	PA
WAZA	Liberty	MS
WBGL	Champaign	IL
WBQB	Fredericksburg	VA
WBRJ	Clayton	IL
WBTQ	Buckhannon	WV
WBTU	Ft. Wayne	IN
WBUC	Buckhannon	WV
WBYO	Boyertown	PA
WCCS	Bangor	ME
WCMS	Virginia Beach	VA
WCOZ	Lexington	KY
WCRM	Fort Myers	FL
WCUP	Baraga	MI
WCWV	Summerville	WV
WDCS	Portland	ME
WDER	Derry	NH
WDFM	Sherwood	OH
WDJX	Xenia	OH
WDNE	Elkins	WV
WEDH	Hartford	CT
WEFT	Champaign	IL
WELC	Welch	WV
WERN	Winamac	IN
WERT	Van Wert	OH
WEUX	Altoona	WI
WEYS	Institute	WV
WFGH	Fort Gay	WV
WFGM	Fairmont	WV
WFLR	Dundee	NY
WFVA	Fredericksburg	VA
WGET	Hanover	PA
WGGS	Taylor	SC
WGNE	Oak Hill	FL
WGSF	Bartlet	TN
WGSK	Lexington	KY
WGUL	New Port Richey	FL
WHBM	Xenia	OH
WHCF	Bangor	ME
WHDG	Claremont	NH
WHDZ	Erie	PA
WHRY	Saco	ME
WHEW	Fort Myers	FL
WHRY	Saco	ME
WIFL	Tavernier	FL
WJDY	Salisbury	MD
WJGS	Houghton Lake	MI
WJLW	DePere	WI
WJMJ	Burlington	CT
WJMW	Athens	AL
WJSL	Houghton	NY
WJSO	Jonesboro	TN
WJTO	Montfort	WI
WJTS	Jupiter	FL
WJYJ	Spotsylvania	PA
WKCY	Harrisonburg	VA
WKIN	Kingsport	TN
WKIT	Hendersonville	NC
WKJC	Tawas City	MI
WKLT	Traverse City	MI
WKSO	Columbia	SC
WKSQ	Ellsworth	ME
WKYN	N. Huntington	PA
WLAX	Altoona	WI
WLJC	Beattyville	KY
WLCQ	South Boston	VA
WLEM	Emporium	PA
WLSW	White Sulphur Sp	WV
WLXG	Lexington	KY
WMEF	Fort Kent	ME
WMLG	Eastman	GA
WMMQ	Charlotte	MI
WMOH	Coca	FL
WMPR	Jackson	MI
WMRA	Harrisonburg	VA
WMRS	Laconia	NH
WMTC	Vancleve	OH
WMTW	Auburn	ME
WNLB	Rockymount	VA
WNXR	Iron River	WI
WPSX	University Park	PA
WPVM	Bangor	ME
WOJB	Hayward	WI
WQCB	Brewer	ME
WQLR	Kalamazoo	MI
WQTK	Dewitt	MI
WQWM	Kaukauna	WI
WRKD	Rockland	ME
WRNY	Kirkland	NY
WRQT	Manistee	MI
WRUM	Rumford	ME
WRVA	San Antoino	TX
WRXS	Berlin	MD
WRYZ	Jupiter	FL
WSBA	Hellam	PA
WSBP	Chattahoochee	FL
WSCM	Cobleskill	NY
WSGB	Sutton	WV
WSHU	Fairfield	CT
WSPL	LaCrosse	WI
WSPY	Lockport	IL
WTID	Tuscaloosa	AL
WTKO	Ithaca	NY

WTOS	Showhegan	ME
WTWR	Monroe	MI
WTUG	Tuscaloosa	AL
WTUV	Rome	NY
WTXT	Tuscaloosa	AL
WULA	Eufaula	AL
WVCM	Charleston	WV
WVCN	Baraga	MI
WVMJ	Radford	VA
WVNS	Portsmouth	VA
WVOD	Manteo	NC
WWDX	Holt	MI
WWIZ	Sharon	PA
WWOW	Conneaut	OH
WWRX	Westerly	RI
WWSF	Ft. Walton Bch.	FL
WWTR	Roxanna	DE
WWTR	Ocean City	MD
WWWL	Lynchburg	VA
WXLO	Fitchburg	MA
WXUS	Lafayette	IN
WXZR	New London	CT
WYCO	Shelbyville	TN
WYDN	Paxton	MA
WYE	Miami	FL
WYFL	Henderson	KY
WYKM	Rupert	WV
WYRV	Cedar Bluff	VA
CKCO	Truro NS	CN
CKYK	Alma PQ	CN
DWBM	Manilla	Philippines
KCNM		Saipan
KUAM	Agana	GM
WJKC	St. Croix	VI
WEUC	Ponce	PR
WNRT	Manati	PR
WVID	Mayaguez	PR
C B C	Prince George	BC
Ch 4	San Jose	Costa Rica
Ch 9	San Jose	Costa Rica
Ch 9	Lima	Peru

OTHER PURCHASERS OF PHASEMASTER® T-SERIES PHASE CONVERTERS

AGPAL Broadcasting	Pendleton	OR
Acrodyne Industries	Phoenixville	PA
Advanced Broadcast Engng	Westernport	MD
Alem Engineering	Winston-Salem	NC
Allied Broadcast	Richmond	IN
All-Phase Electric	Logansport	IN
American Family Radio	Tupelo	MS
Applielec	Panama City	Panama
Armstrong Transmitter Co.	Syracuse	NY
Audio Broadcast Group	Grand Rapids	MI
AudioMedia Associates	Covington	LA
Bee Broadcasting	Whitefish	MT
BESCO International	Dallas	TX
Bennet Engineering	Bellevue	WA
Benson Broadcasting	Greenville	PA
Broadcast Electronics	Quincy	IL
Broadcast Richardson	Lafox	IL
CCA Electronics	Cherry Hill	NJ
Cache Valley Radio	Logan	UT
Camp Titus Radio	Pittsburg	TX
Canadian Broadcasting Corp.	Montreal PQ	Canada
Chapparal Broadcasting	Kemmerer	KY
Christian Friends Broadcasting	Elkhart	IN
Church of Christ 1430 AM	Santiago	Dom Rep
Clear Channel Communications	San Antonio	TX
CONTEL Federal Systems	Chantilly	VA
Continental Electronics	Dallas	TX
CORDINSA	Santo Domingo	Dom Rep
Corp. Panama de Radio	Panama City	Panama
Crouse-Kimsey Company	Dallas	TX
Daystar TV	Bedford	TX
Diversified Communications	Cranesville	PA
Educational Media Foundation	Sacramento	CA
Equico Lessons Inc.	Birmingham	MI
Equity Broadcasting	Little Rock	AR
Flannigan Electric Company	Jackson	MS
Flinn Broadcasting	Memphis	TN
Fort Belknap College	Harlem	MT
Granite City Electric Supply	Quincy	IL
Harris Corporation	Quincy	IL
High Plains Power	Riverton	WY
Hoffman Communications	Chester	VA
Holliday Broadcasting	Salt Lake City	UT
Independent Radio Ltd.	Kingston	Jamaica
Intercomp, Inc.	Miami	FL
Interior Broadcasting	Fairbanks	AK
Joy Public Broadcasting	Spotsylvania	VA
Legacy Communications	Salt Lake City	UT
Mareco Broadcasting	Manilla	Philippines
Marcom	Scotts Valley	CA
Meadowlark Group	Mt. Pleasant	SC
Metal Products	Eugene	OR
Minnesota Electric Supply	Willmar	MN
Norris Public Power District	Beatrice	NE
Northeast Broadcast Labs	Glens Falls	NY
Northern Virginia Bcst'g.	Warrenton	VA
Pennsylvania State University	University Park	PA
R F Specialties	Amarillo	TX
Radio Jamaica	Kingston	Jamaica
Range Telecommunications	Marquette	MI
Red Tronix Inc.	Medford	OR
Regent Broadcasting	St. Cloud	MN
Repuestos De Radio Y Television	Santo Domingo	Dom Rep
Rex Jensen Broadcasting	Cortez	CO
Roberts Broadcasting	Spokane	WA
S & S Broadcasting	Ontonagon	MI
SCMS	Pineville	NC
Sierra Linda Broadcasting	Montrose	CO
Southerland Corporation	Penn Yan	NY
Sunbrook Communications	Spokane	WA
Television Nationale du Haiti	Gonaives	Haiti
Thales Corporation	Southwick	MA
Teewindt Broadcasting	Jackson	WY
The World in Music	Billings	MT
Transcom Corporation	Elkins Park	PA
Venture Technologies	Los Angeles	CA
Watts Communications	Brownwood	TX
Western Cities Broadcasting	Westminster	CO
Woodstone Broadcasting	Ada	OK
XM Satellite Radio/LCC Int'l	McLean	VA

This list includes known installations of **Phasemaster**® rotary phase converters on AM, FM, and TV broadcast transmitters since 1971. It is based upon information provided to Kay Industries at the time of original purchase of the phase converter. It does not include known installations of used converters nor converters placed into service prior to 1971. Kay Industries regrets any errors contained herein and would be pleased to correct this listing to reflect omissions or changes in call letters or location.

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Rotary Phase Converters

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info@kayind.com

Phasemaster® Type T Rotary Phase Converters
Broadcast Transmitter Service
Confidential Reference List

The individuals on this list have extensive background history in the application, operation, sales and service of Type T converters. They have agreed to take calls from parties interested in discussing their experience and assessment of converters. They are independent of Kay Industries.

Joe Sands	Chief Engineer KJUL & KXTE Las Vegas, NV	702-868-7222 702-595-2281 Cell joesands@joesands.com
Lonnie Shurtleff	Capps Broadcast Group Chief Engr Pendleton, OR	541-276-1511 shurleffmusicandelectronics@hotmail.com
Lynn Deppen	Owner/Engr Keymarket Communications Pittsburgh, PA 15205	412-489-1001 ldeppen@aol.com
Mark Persons	M.W. Persons & Associates Brainerd, MN	218-829-1326 mark@mwpersons.com
Lloyd Mintzmyer	Praise Network KGRD President Hays, KS	758-628-3412 lmintz@ruraltel.net
Mike McFadden	Kemp Communications KMZQ Nautel 50KW AM Las Vegas, NV	702-658-0102
Bob Spain	Engineering Director Wyoming PTV KCWC-TV Riverton, WY	307-856-6944 bspain@cwc.edu
Richard Garrett	Continental Electronics Corp. Field Service Manager Dallas, TX	214-381-7161 rgarrett@contelec.com
Quin Morrison	Engineer KAVD Limon, CO	970-988-6354 qmorrison@regent.com
Leo Sullivan	Engineer WLIE Islandia, NY	781-879-0998 leo sullivan@post.harvard.edu
Corey Meyer	Audio Media Associates President Covington, LA 70434	985-892-8146 sales@am -fm.biz
Kurt Jackson	Hampden Communications Paxton, MA	508-791-7065
Christopher Kreger	RF Specialties Vice President & Secretary Kearney, MO	816-506-7473 rfmo@uniteone.net
Martin Cooper	Transcom Corporation President Elkins Park, PA	215-938-7304 transcom@fmam tv.com
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About Kay Industries

Kay Industries, Inc., is the worldwide industry leader in designing, manufacturing, and marketing single-phase to three-phase electrical power converters. A privately held corporation since 1946, Kay Industries sells phase converters nationwide through a select network of electrical wholesalers, equipment dealers and manufacturers. It also exports to Central and South America, Europe and the Pacific Rim. Kay Industries, Inc., markets under the registered trademark Phasemaster® and is headquartered in South Bend, Indiana, with offices in Fremont, California.

Kay Industries, Inc., was the first converter manufacturer to commercially offer:

- Rotary converters (1960)
- Automatic controls (1972)
- Money-back performance guarantee (1975)
- Independent agency approval (CSA/NRTL) (1979)
- National toll-free lines (1980)
- Extended warrantees (1986)

www.kayind.com

INSTALLATION MANUAL

TYPE T — Converter for Broadcast Transmitter Service
TYPE T-A — Type T Converter with automatic controls

CONTENTS

WARRANTY

Kay Industries, Inc. (the manufacturer) guarantees all products of our manufacture against faulty material or workmanship for a period of five years from date of installation or 61 months from date of shipment from factory, whichever period first expires.

Any part that you return to us within this warranty period showing unmistakable defect in material or workmanship will be renewed or replaced at our option F.O.B. factory without charge. The final decision that an original defect existed shall rest with the manufacturer.

The liability of the Company is limited to the renewal or replacement of the defective part. In no case will the Company be liable for damage or loss incurred because of interruption of service or for consequential damages, transportation, labor or expense required to repair or replace defective units.

Kay Industries will not be responsible if its products have been improperly installed in any way. This warranty shall not apply to any of the manufacturer's products that must be replaced because of normal wear, that have been subjected to misapplication, misuse, neglect, accident or that have been repaired or altered outside of the manufacturer's factory unless expressly authorized by the manufacturer.

I. BEFORE YOU START

Kay Industries has designed the **Phasemaster®** Rotary Phase Converter for ease of installation by anyone having basic electrical knowledge and mechanical skills. If you are unsure of how to proceed or do not thoroughly understand these instructions, we strongly recommend that you obtain the assistance of a licensed electrician.

These instructions are based upon Article 455 of the National Electric Code. Although we present a practical set of guidelines for converter installation, we do not intend to supersede or modify the requirements of the National Electric Code or any applicable local codes. We suggest that you consult these references to determine whether your particular installation complies with applicable regulations.

Verify that the load does not exceed the "Largest Motor" or KW rating on the converter nameplate. We also suggest that you ***temporarily connect the phase converter and the load*** to verify performance before proceeding with the permanent installation.

Whether this is your first phase converter installation or your one-hundredth, there are a few do's and don'ts that you should observe:

DO:	DON'T:
DO: Fuse the converter separately from all other loads. Use only properly sized dual element time delay fuses sized according to the Selection Chart on Drawing 0302-T.	**DON'T:** Use circuit breakers instead of a fused switch to protect the converter. They do not withstand the repeated inrush current required to start the phase converter. The breaker will either trip during starting, thus preventing the converter from reaching full speed, or it will cause a shutdown of the converter that could result in damage to the connected load. Increasing the size of the breaker will result in poor protection that could damage the converter and wiring. It is okay to use a circuit breaker in the single-phase panel that feeds the converter and load if that breaker is sized according to the procedures described in this instruction book.
DO: Always be certain that power is off before removing any covers or connecting any wires.	**DON'T:** Draw any other single-phase load through the converter fuses. Refer to installation drawing 0302-T.
DO: Remove the converter from the skid	**DON'T:** Bolt the converter down.
DO: Use the ring terminals connected to the converter wires. Crimp only with an approved crimping tool of the correct size for the terminals.	**DON'T:** Use wire nuts or twist type connectors to connect the converter.
DO: Connect all single-phase loads, including controls, only to L1 and L2.	**DON'T:** Connect the manufactured leg T3 to any control circuits or to any single-phase loads.
DO: Insulate all connections with rubber and plastic tape or heat shrinkable tubing.	**DON'T:** Use plastic tape only. It does not have the required mechanical strength to protect the electrical connection.

<u>Failure to observe these basic precautions accounts for the majority of converter system failures.</u>

READ THIS SECTION CAREFULLY!
MORE THAN HALF OF ALL "CONVERTER" PROBLEMS RESULT FROM INADEQUATE SINGLE-PHASE SERVICE SIZE AND/OR UNDERSIZED BRANCH CIRCUIT BREAKERS

II. SIZING THE SINGLE-PHASE SERVICE - FUSE RATINGS AND WIRE SIZES

It is extremely important to verify that you have adequate single-phase service for the total planned load. The maximum 3-phase current that you can draw is about 50% of the single-phase service. That means a 200A single-phase service will give you approximately 100A of 3-phase through the converter. You must also select the proper size single-phase branch circuit to supply your converter and load.

The converter consumes very little energy when running under load. The service size and branch circuit rating are determined ***only*** by the amount of connected three-phase load.

To determine your total three-phase load demand:

- Add the total 3-phase full load currents for every load that will operate simultaneously. As a rule you can estimate that the load will draw 2.5 amps per kilowatt at 230 volts. For example, if you plan to run 20 KW simultaneously, your 3-phase full load current will be 50 amps. If you are operating at 208 or 460 volts you must adjust the current accordingly. Use 2.8 amps/KW for 208 volts and 1.25 amps/KW for 460 volts.

To determine the required single-phase branch circuit to feed the converter and load:

- Multiply the total 3-phase full load current by 1.73. This is the exact single-phase current which you will draw. It is also the ***absolute minimum single-phase service*** you will need to operate the load. However, the National Electric Code requires that you multiply the 3-phase current by 2.5 (instead of 1.73) to allow for an adequate overload and safety margin. This is a conservative way to select your wire and branch circuit size and will assure your compliance with code. **If you use a breaker of smaller rating than called for by this calculation, it may trip when the converter starts or may be too small to handle the entire planned load.**

To determine the single and 3-phase wire size required, disconnect switch and fuse ratings:

- Refer to the table and diagram on drawing 0302-T or 0302-TA

Check the nameplate and note the type of your converter for the proper connection drawing:

Type **T** converters (Model number format T-10000) require a separately mounted fused switch to turn the converter on and to provide short circuit protection for the converter. Refer to drawing 0302-T.

Type **T-A** converters (Model number format T-10000-A) contain fuses and magnetic controls and **do not** require a separate fused switch. Refer to drawing 0302-TA.

III. INSTALLATION

BEFORE YOU CONNECT ANY WIRES
Be sure all POWER IS OFF at the main panel.

SELECTING A CONVERTER LOCATION

Pick a location as close as practical to the incoming single-phase service panel or if preferred, near the 3-phase load. It must be a dry location with adequate ventilation free of dirt, filings, chips, sawdust and other debris that could enter the converter through the ventilation intakes. The converter warranty does not cover failure caused by water or foreign material ingress. Kay Industries also offers weatherproof enclosures for outdoor installation.

GENERAL WIRING INSTRUCTIONS

1. Remove the converter from the skid and set it in place on the mounting pads included in the package. **Do not bolt the converter to the floor or any other mounting surface.** Rigid mounting amplifies noise, increases internal vibrations that can loosen terminals and can distort the frame causing the rotor to lock. Kay Industries recommends making a temporary connection to verify the converter is adequate for the load before finalizing the installation. This can be done quickly and may save a great deal of time and labor if an exchange is necessary.

2. Type T and T-A converters are pre-wired to operate on 230 volts unless ordered otherwise. The 460-volt option is only available if indicated on the nameplate. The input operating voltage of these converters cannot be changed without additional modifications. Consult Kay Industries if this change is necessary. All phase converters produce three-wire delta output only. ***For four-wire wye output, consult the factory for an appropriate transformer.***

3. For Type T Converters, mount the fused disconnect switch as close as practical to the converter. Connect the disconnect switch to the single-phase branch circuit wire at the service with wire size not less than shown on Drawing 0302-T. If the location of the converter is more than 50 feet from the service panel or if using aluminum wire, then increase the wire size appropriately.

4. Connect the load side of your fused disconnect to the converter leads marked L1 and L2 in the junction box. Lead T3 is the manufactured phase. If you are using a three-pole fused disconnect, connect T3 to the third pole on the load side of the switch. If you are using a two-pole disconnect, run T3 directly to the line side of the load disconnect or other load switching device.

5. Connect the single-phase power supply from the line side of your fused disconnect to the L1 and L2 terminals of the load disconnect switch.

6. Ground the converter by attaching the system ground wire to the ground lug in the converter junction box. If you have not grounded your load, do so before proceeding.

Label all wires "L1", "L2" and "T3" uniformly throughout the entire system. This will avoid confusion in wire tracing should any troubleshooting become necessary later.

CONNECTING THE TYPE T-A AUTOMATIC PHASEMASTER CONVERTER

The Phasemaster Automatic rotary phase converter (Type T-A) is identical in operation and performance to the non-automatic converter (Type T) except that it is equipped with built-in time delay fuses to protect the converter and controls which allow the converter

- To be remotely started before starting the load
- To shut down when the load is off
- To prevent the load from starting unless the converter is running.

Before proceeding with the installation we suggest you review drawing 0302-TA to become familiar with how the converter is connected and electrically interlocked with the load equipment. The Type T-A converter is designed to turn on and off as required by the load. This control arrangement is accomplished using an adjustable time-delay relay and magnetic contactor that are built into a side mounted pre-wired enclosure.

Type **T-A** converter connections are divided into three groups. **Group 1** supplies single-phase power to the converter. **Group 2** connections supply 3-phase power to the load. **Group 3** wiring coordinates the starting and stopping of the converter with the load.

Group 1: Single-phase power connections to the converter
Determine the proper size single-phase branch circuit for the load. This calculation is described in detail in Section II. Route the single-phase input power cables and ground conductor in properly sized conduit from your branch circuit and/or disconnect to the phase converter control enclosure. Use the existing knock-out provided or make a new penetration in the enclosure appropriate to conduit size and secure the conduit at both ends.

Group 2: Three-phase power connections from the converter to the load
Route the three-phase output power cables and ground conductor in properly sized conduit from the phase converter control enclosure to the load. If required, make a new penetration in the enclosure appropriate to your installation and secure the conduit at both ends.

Group 3: Control power connections between the converter and the load
Wire these circuits with an appropriate length of 4 or 5 conductor cable or individual conductors within a conduit. (Four conductors are actually required, but it doesn’t hurt to have a spare when dealing with control wiring.) Wire size AWG 14 is adequate for all control wiring. Route this wire between the load and the phase converter control enclosure.

Group 1 & 2 Wiring:
With conduits and cables in place, you are ready to make the power connections.

1. Connect the Group 1 input power leads to L1 and L2 on the input terminal block in the converter enclosure. Connect the ground (NOT NEUTRAL) wire to the terminal marked “Ground”. Make the corresponding connections in your branch circuit panel.

2. Connect the ground cable from your load to the terminal marked “Ground”.

3. Connect the Group 2 load cables to the output terminal block to the output terminals designated T1, T2, and T3 in the starter panel enclosure. Tighten the terminal blocks and label the cables at both ends T1, T2, and T3 to correspond with the connections within the converter enclosure. Later, you may change these connections at the load to change rotation of fan motors, but keep the labels on the cables so that they are marked consistently throughout the system.

4. Be sure that T3 is not supplying power to any relays or other control components inside the transmitter.

Group 3 Wiring: Connecting the type T-A converter with the load controller

The phase converter must be operating before the transmitter high voltage supply or any other 3-phase load can be turned on. To accomplish this, an actuator contact from the transmitter controller must be connected to the converter. The converter contains a timing relay that will start counting when the converter starts. It then closes a dry output control contact after a short time delay. This contact closure can be used as an electrical interlock or to announce that the converter is running and that 3-phase power is available at the load terminals. The converter is shipped with a factory installed jumper wire across the actuator terminal block.

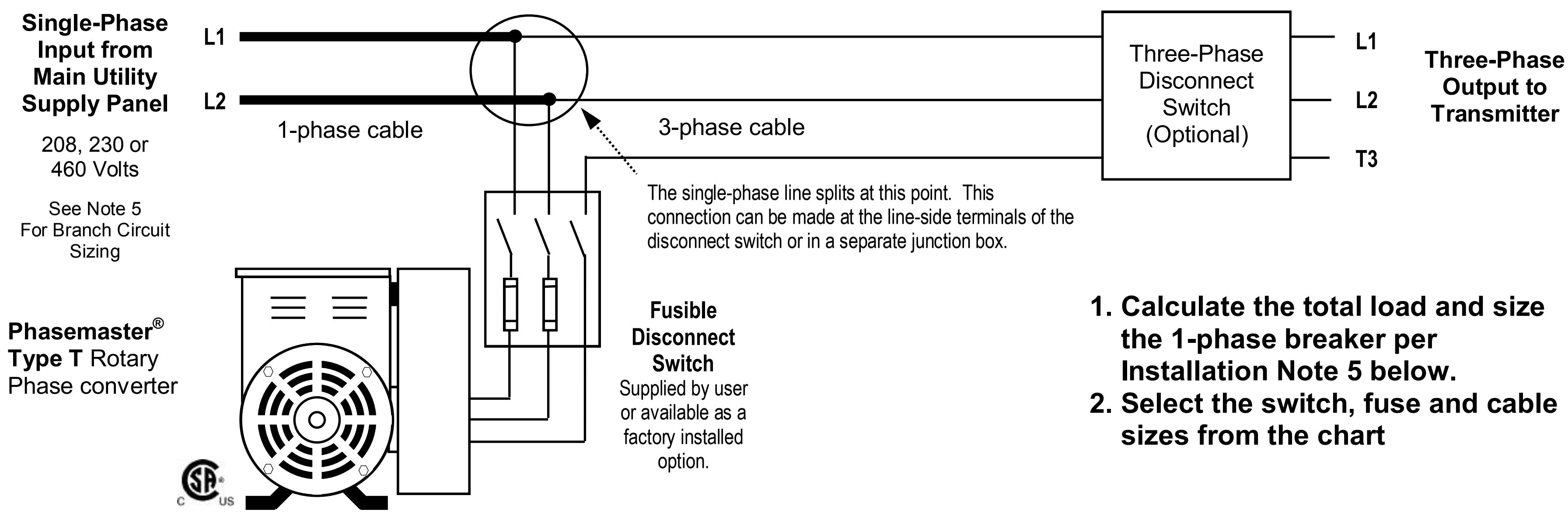
The Type T-A converter control is designed to be interlocked with the transmitter or with a transfer switch if used with a back-up generator. This control arrangement prevents the converter from starting into a load and enables it to be coordinated with other equipment. Since these starting arrangements differ widely among equipment types and manufacturers, there is no single method of connecting them all. However the following information will aid you in connecting the control circuits.

1. Using two (2) of the Group 3 control wires installed, connect the load's start-stop switch or normally open starting contact across the terminals marked "Actuator Contacts From Load Controller" in the converter enclosure. The factory installed jumper should be removed at this time.

   Note:
   Unless you have specified a low voltage control for the converter, there will be 230 volts present across these contacts. The actuator contacts from your controller (PLC, timer, transfer switch, etc.) that turn the converter on and off must be rated for 230 volts.

2. The remaining two (2) Group 3 control wires will be connected inside the converter control enclosure to the terminals marked "Output to Load Controller." This is a timed contact which will close when the converter is up to speed. Connect the opposite end of these wires in series with the load contactor circuit between the contactor coil and the control voltage source. Consult the load controller wiring diagram if necessary to determine the best point to break into the control circuit. The "dry contact" from the time-delay relay of the converter will now make and break the load contactor voltage as the converter is turned on and off whenever the load is called for by the load actuator switch.

After tightening all terminals and checking wiring, adjust the time-delay relay to approximately 10 seconds, start the converter and observe that the load does not become energized until after the converter has reached full speed. If the converter does not reach full speed within ten seconds, there may be problem of excessive utility line voltage drop or inadequate transformer capacity. Refer to the section of the main manual titled **In Case of Trouble**. If the load starts before the converter reaches full speed, increase the time on the time-delay relay. Once the time delay relay is set up, turn off all power and replace all covers.



1. Calculate the total load and size the 1-phase breaker per Installation Note 5 below.
2. Select the switch, fuse and cable sizes from the chart

DISCONNECT SWITCH AND WIRE SIZE SELECTION CHART								
Model	230 Volts				460 Volts			
No.	Switch	Fuse	1-Ph Cable	3-Ph Cable	Switch	Fuse	1-Ph Cable	3-Ph Cable
T-1300	30	30	8	10	30	15	10	12
T-2000	60	35	6	8	30	15	8	12
T-2500	60	40	4	8	30	20	8	10
T-4000	60	60	1	6	30	30	6	10
T-5000	100	80	1/0	4	60	40	4	8
T-7500	100	100	3/0	4	60	50	2	6
T-8000	200	125	4/0	2	60	60	1/0	6
T-10000	200	150	2-1/0	1/0	100	75	2/0	4
T-12000	200	175	2-2/0	2/0	100	80	2/0	4
T-14000	200	200	2-3/0	3/0	100	100	3/0	2

Wiring Notes:
- Conductor sizes are based on type THHN, 90° C, copper conductors in 30° C max. ambient.
- These are minimum recommended sizes for the load motor HP rating indicated.
- For larger loads refer to installation note 5 and increase conductor size accordingly.
- Increase wire size for Aluminum conductors or runs in excess of 50 feet.
- Consult National Electric Code for runs in excess of 50 feet or for aluminum conductors.
- Do not use circuit breakers. See Installation Note 2.

INSTALLATION NOTES

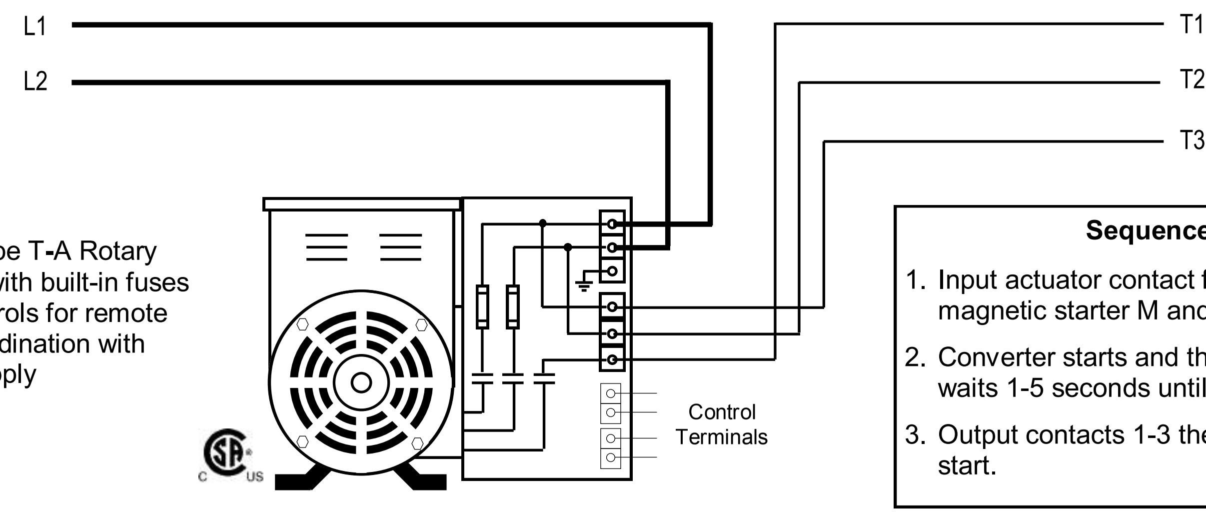
1. This diagram does not replace or supersede any requirements of local, state or national electric codes.
2. Use only dual element time delay fuses to protect the phase converter.
3. Do not bolt converter to floor. Use vibration pads supplied with unit.
4. Do not connect control circuits to manufactured phase, T3.
5. National Electric Code (NEC) requires single-phase cable and branch circuit to be rated for 250% of three-phase load current.
6. The 3-pole converter switch is used to provide electrical isolation when the converter is off. But it is only necessary to fuse converter input lines L1 & L2. T3 is not fused. A 2-pole fusible switch may be substituted if the optional 3-pole load disconnect is used.
7. No-load output voltage L2-T3 will exceed L1-L2 by 12-15%. Voltages will balance when load is connected.

Connection Diagram for **Phasemaster Type T** Rotary Phase Converter with Field Mounted Manual Controls

0302-T

Single-Phase Input from Main Utility Supply Panel

Three-Phase Output to Transmitter

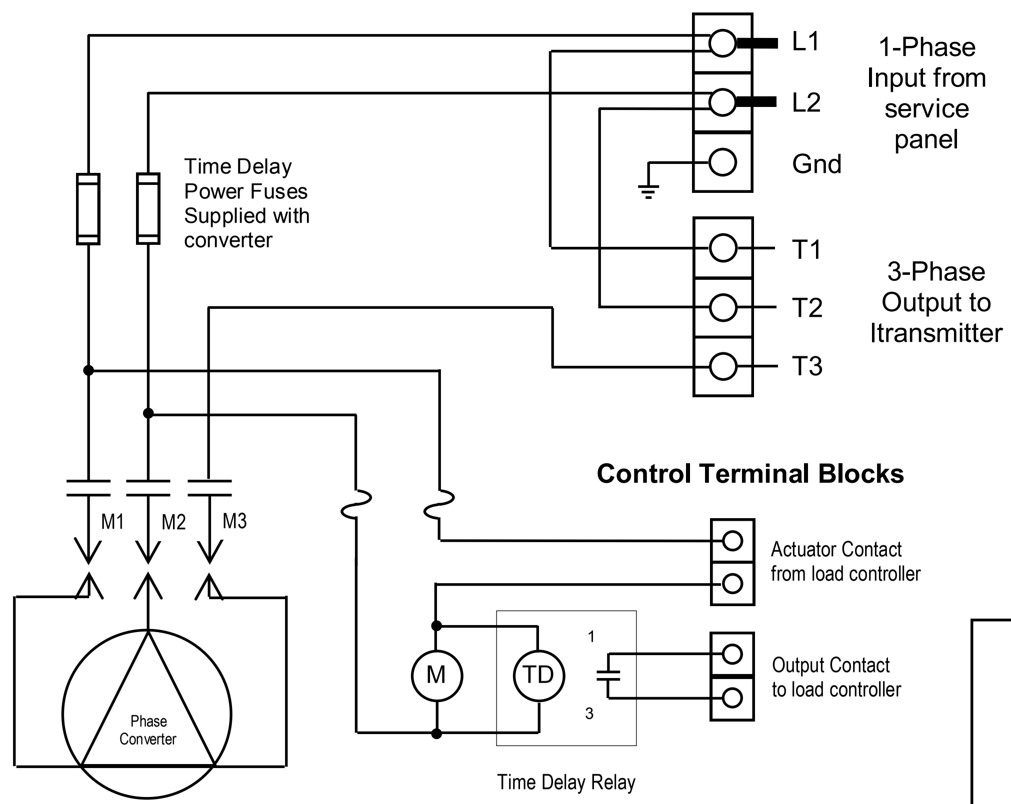


Phasemaster® Type T-A Rotary Phase Converter with built-in fuses and magnetic controls for remote actuation and coordination with back-up power supply

Sequence of Operation

1. Input actuator contact from load controller closes magnetic starter M and energizes timing relay TD.
2. Converter starts and the adjustable timing relay waits 1-5 seconds until converter reaches full speed.
3. Output contacts 1-3 then close allowing the load to start.

Control Panel Connection Detail



WIRE SIZE SELECTION CHART							
Model No.	Max KW	230 Volts			460 Volts		
		Fuse*	1-Ph Cable	3-Ph Cable	Fuse*	1-Ph Cable	3-Ph Cable
T-1300-A	6	30	#8	#10	15	#10	#12
T-2000-A	8	35	6	8	15	8	12
T-2500-A	10	40	4	8	20	8	10
T-4000-A	16	60	1	6	30	6	10
T-5000-A	20	80	1/0	4	40	4	8
T-7500-A	25	100	3/0	4	50	2	6
T-8000-A	30	125	4/0	2	60	1/0	6
T-10000-A	38	150	2-1/0	1/0	75	2/0	4
T-12000-A	45	175	2-2/0	2/0	80	2/0	4
T-14000-A	55	200	2-2/0	3/0	100	3/0	2

* Supplied with converter

Connection Diagram for Type T-A
Phasemaster Rotary Phase Converter
with automatic controls

0302-TA

IV. OPERATION

The PHASEMASTER converter may operate continuously with or without a connected load. However, the converter operating temperature and noise level will be higher at no-load than under loaded conditions. The converter will not be damaged nor will it overheat if operated unloaded.

1. **Never start the converter under load.**
2. Wait until the converter reaches full speed before turning on any load.
3. Whenever possible, avoid applying more than one load at the same time.

HIGH-LOW LOAD RANGE SWITCH

All Type T **Phasemaster**® converters contain a High-Low Load Range switch that enables the converter to maintain balanced output voltage over its entire output range from minimum to maximum converter output. Its purpose is to compensate for a load that is insufficient to bring the converter output voltage into balance with the utility supplied voltage.

In a rotary phase converter, the voltage of the manufactured leg varies according to the amount of connected load. Under no-load conditions this voltage will be about 15% above the utility voltage. As load is applied, the manufactured phase drops rapidly into balance with the other two lines as the load increases to about 25% of converter capacity and remains there over the remainder of the range. Under most load conditions all three phases will balance to within 2-5%,

In applications involving varying load, the converter must be sized for the maximum load, but there are times when only a small portion of the load is connected. Under this condition the manufactured phase voltage is too high and could cause nuisance tripping due to current imbalance. When the load current returns to a higher value, the voltage is balanced and the problem goes away.

The High-Low Load Range Switch can be operated manually or by an external relay, auxiliary switch or by other means to operate a relay when the load is changed. This relay switches a block of capacitors and brings the output voltage to an acceptable level within just a few cycles to balance the voltage before the load is affected.

APPLICATION:

In the LOW position, the output voltage of the converter is reduced by 5-10%. In general, the LOW position should be used whenever the load is less than 30% of the converter rating or the voltage is in excess of 240 volts (480 V in a 460 V. system). The LOW position should also be used for loads which have low idle currents but require very large instantaneous currents. Such applications include Radio/TV transmitters, Lasers, X-ray machines, CNC machine tools, etc. The LOW setting prevents excessive voltage from being applied to the load power supply during periods of low power requirements.

The HIGH setting should be used for all applications where the converter is continuously loaded to 30% or more of its rated capacity or when the incoming line voltage is less than 220 volts (440 volts in a 460 V. system). The HIGH position should not be used when the incoming voltage is greater than 240 volts.

MANUAL OPERATION:

The HIGH-LOW range switch is set to the LOW position at the factory. If the HIGH-LOW switch has been specifically recommended for the load, it should be left in the low range. To operate in the HIGH range, set the switch to HIGH. It is not necessary to shut-down the converter to operate the switch.

AUTOMATIC OPERATION:

The HIGH-LOW range relay may be operated automatically by use of an auxiliary contact on the starter of the load. A normally open auxiliary contact should be added to the starter of any load greater than 30% of the converter capacity. That contact is then connected to the two-terminal block in the converter control box marked “HIGH/LOW”.

V. CONVERTER CHECKOUT

1. Start the converter. Small converters (T-2500 and below) should reach full speed in about two seconds. Larger units may require up to seven seconds. Every converter is factory tested prior to shipment and is well within these time limits. If the converter takes longer to reach full speed, your line voltage is dropping which means your service may be inadequate.

2. Check the single-phase utility input supply voltage between L1 and L2. It should be 220 to 240 volts. In general the input voltage should not exceed 240 volts on a 230 volt system or 480 volts on a 460 volt system. If the input voltage is too high, the result could be excessive manufactured phase voltage accompanied by load current imbalance.

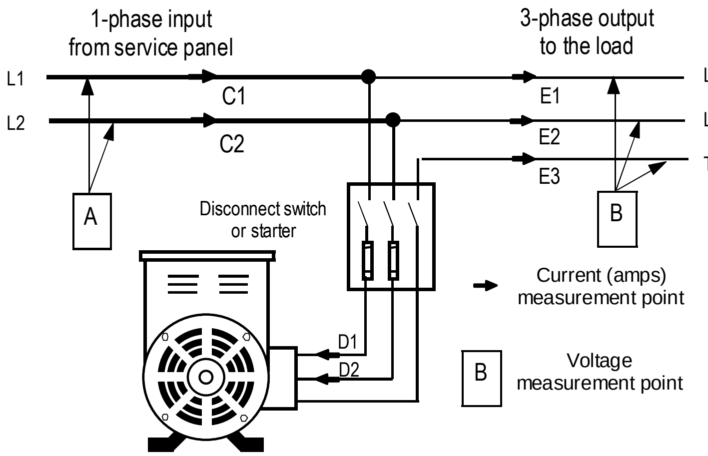
3. IF YOUR **INCOMING** LINE VOLTAGE EXCEEDS 240 VOLTS, you may need to have the utility company reduce the incoming voltage or install a buck-boost transformer to drop the voltage to an acceptable level. Consult Kay Industries on this subject if you have questions about how to proceed.

4. Refer to the diagram below and measure the voltages between L1-L2, L1-T3, and L2-T3 at points A and B with the converter running but with the load equipment turned off. These are the no load idle voltages. The L2-T3 voltage is the manufactured phase voltage. It will be higher than the other voltages**.** All voltage measurements should be taken line-to-line. Line-to-ground voltages **are not** significant measurements of converter performance.

5. The normal output voltage measured between L2 and T3 will range from 260 to 290 volts on a 230 volt system and 490 to 525 volts on a 460 volt system depending upon the input voltage between L1 and L2. This is a **normal** idle condition. There is no danger to the load from the L2-T3 voltage. Although it is somewhat high when there is no load, this voltage will drop when the converter begins to supply power to a load and will balance within 2-5% of the other phase voltages as the converter approaches full load.

6. With the load applied, place the High-Low switch in the "Low" position and measure the three phase to phase voltages. Then switch to the "High" position and take the same voltage measurements. Calculate the average of the three voltages. Leave the switch in the position that produces the best voltage balance at the planned operating power. Normally all voltages will be within 2-5% of the average.

7. If fan motors rotate backwards, reverse the L-1, L-2 connections at the transmitter.



Voltage Measurements			
Meter Point	Lines measured	Converter on Load off	Converter on Load running
A	L1-L2		
B	L1-L2		
B	L1-T3		
B	L2-T3		
Current (Amperage) Measurements			
	Amps Measured	No Load	Load Running
C1	Total		
C2	Total		
D1	Converter		
D2	Converter		
E1	Load	0	
E2	Load	0	
E3	Load	0	

8. Make a record of all voltages at each measurement point and retain these readings in a log for future reference. Large deviations could indicate problems with either the utility supply voltage or the load conditions.

VI. MAINTENANCE

The PHASEMASTER converter requires very little ongoing maintenance other than periodic lubrication, cleaning and inspection.

LUBRICATION

The only parts subject to wear are the bearings. PHASEMASTER converter bearings contain a heat, moisture, and rust resisting polyurea based lubricant rated to operate in the temperature range of -35 to +350 degrees Fahrenheit. Lithium based lubricants are incompatible and will cause bearing failure.

The converter bearings are pre-packed with grease and sealed by the bearing manufacturer. This initial charge plus a generous additional amount placed in the bearing housing during manufacturing is normally enough to last the lifetime of the bearing. Converters exposed to severe operating conditions including high heat, moisture, overloads, dirt or limited ventilation require periodic lubrication. To grease the bearings in a smaller converter not having grease fittings, remove the end-bells and remove the excess grease. Replace it with a generous supply of a compatible lubricant such as Chevron SRI. To lubricate a larger converter, inject a small amount of grease slowly into the grease fittings. Do not use high-pressure equipment. Take care not to saturate the windings with grease over an extended time. Remember, this grease goes somewhere when it leaves the bearing.

INSPECTION

Inspect the converter periodically to ensure the ventilation slots are clear. If operating in a dusty or dirty environment, remove the end-bells and clean the windings of excess grease, dust and debris. On Type T-A converters, inspect all power and control components for loose connections and damaged, pitted or carbonized contacts. Clean, tighten or replace as necessary.

MAINTENANCE SCHEDULE

Action	Monthly	Semi-Annual	Annual	Bi-Annual
Grease Bearings with Chevron SRI or an equivalent lubricant.			**X**	
Check voltage L2-T3 and record in log.	**X**			
Listen for abnormal noise or excessive vibration. Tighten rods and bolts if needed.	**X**			
Shut down converter and blow out dust and debris from stator.		**X**		
Open control compartment and inspect power and control connections and contacts. Clean and tighten terminals.			**X**	
Remove end bells and rotor. Clean Stator. Check bearings for wear. Reassemble using 40 Ft-Lb. torque on all bolts and nuts.				**X**

This is a suggested maintenance schedule. Your particular application may require more or less frequent attention. We suggest that you begin with this schedule and modify it as needed over time.

The **Phasemaster**® rotary converter is a highly reliable machine. With this equipment, as with all electromechanical devices, problems do occur. If you experience difficulty, our factory engineers will be happy to assist you by telephone.

VII. IN CASE OF TROUBLE

Condition	What to look for	Corrective action
Converter does not start. No sound.	Check power source with a voltmeter. L-1 to L-2 should read 230 volts (or 460 volts in a 460 volt system.	Restore power. Reset main breaker and replace with correct size if too small.
	Check the fuses by removing them and testing with a continuity checker or ohmmeter.	Replace fuses if needed.
	Check for loose terminals. Be sure lugs are not crimped on cable insulation.	Tighten or re-terminate as required.
Converter hums but does not start.	Be sure that no load device is starting with the Phasemaster. The converter should be running before any load is placed on it	Turn off all loads and re-start the Phasemaster.
	Be sure that the incoming single-phase lines (L-1 and L-2) are properly connected to L-1 and L-2 in the converter junction box. Do not connect either incoming line to T-3 of the converter.	Connect the power source to L-1 and L-2 in the converter. Connect T-3 to the load only.
	Make sure the rotor moves freely by moving it with a screwdriver or other tool with power off.	Loosen bolts and re-tighten to free rotor. If rotor does not turn freely after doing this, call factory.
Converter starts and breakers trip	Check to be certain of the time-delay characteristics of the breakers. They should have similar characteristics to time delay fuses. Ordinary household type breakers are not suitable.	Replace with delay type breakers or time delay fuses. Do not oversize the breakers.
Load(s) always trip overloads during or shortly after startup	Check the line voltage (L-1 to L-2) with an analog voltmeter during start and determine the amount of line voltage drop. Check transformer capacity. If the line voltage drops more than 10% of no load line voltage, take corrective action.	Increase supply line cable size and transformer size if required. Your power company can usually help with transformer problems.
A loud humming noise or chatter comes from the load starting relay.	Check voltage between L-2 and T-3. If voltage remains below 200 volts (for a 230 volt system) or 185 volts (for a 208 volt system)after the motor starts, the converter is too small for the application.	Contact factory for further assistance or possible exchange.
	The manufactured phase T-3 could be connected to the motor starting relay. Check to ensure correct voltage on this relay coil.	Rewire the control coil circuit so that T-3 does not energize the starter coil.
The voltage measured between L-2 and T-3 is about 30-40 volts higher than the line voltage (L-1 to L-2) with no load applied to the Phasemaster.	This is a normal condition and verifies correct operation of the Phasemaster. When the load is applied, this voltage will be reduced as the load increases. No damage will occur to properly connected equipment.	This condition requires no action.
Load does not start or run properly.	Check the converter output voltages under load conditions. L1 to L2 should remain within a few volts of 230 or 460. L2 to T3 may drop momentarily below 180 (or 400) but recover to 220 (440) or above.	If the L2 to T3 voltage remains below 210 (420) volts, the converter may be too small for the application. Contact factory for recommendations or possible exchange.
Excessive noise or vibration.	Noise and vibration are usually the result of a resonance caused by a mounting surface that does not support the converter well. These problems also occur when the converter is bolted tightly to any surface.	Be sure to remove the converter from the shipping skid and place it on a substantial floor using the shock absorbing pads supplied with the converter. Do not bolt the converter to any surface.
The three-phase currents are not equal.	If the load comes up to its rated load and none of its three legs exceeds its nameplate F.L.A. rating, there is no problem. If the L1 and L2 legs are significantly higher than the T3 leg (measured at the load input, not the converter input) then a larger converter or correction capacitors may be required.	Consult with factory to review application.

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APPLICATION AND PERFORMANCE OF ROTARY PHASE CONVERTERS AS AN ALTERNATIVE TO UTILITY SUPPLIED THREE-PHASE POWER

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SUMMARY

A very common problem facing broadcast station owners is obtaining three-phase (3-phase) power service at prospective transmitter sites. Utility companies often charge exorbitant fees to extend service to remote areas. This often forces owners to select sites purely on the basis of affordable three-phase availability while compromising other desirable features of site selection.

The advent of the rotary phase converter in the early 1960's has contributed significantly to the broadcasting industry by providing the capability to produce three-phase power on site from any single-phase (1-phase) source. A rotary phase converter is an induction machine which operates on a single-phase supply and produces a true three-phase output. It is capable of supplying the full rated input requirement of any three-phase induction, resistance or rectifier load.

The cost savings to be realized by use of a phase converter can be breathtaking compared to the alternative utility costs. Documented savings of $100,000 or more are commonplace. However, the use of phase converters remains something of a mystery to many who could benefit from them most. Chief among the reasons for this are widespread anecdotal accounts of field problems and other misunderstandings of their application. Nonetheless, well over 1500 radio and TV stations worldwide including in 1000 in the U. S. are successfully operating on phase converters with a service record exceeding 45 years.

The purpose of this paper is to explain the construction and performance of phase converters and characterize their application on broadcast transmitters. It is anticipated that a broader knowledge of converter capability and performance among owners and engineers would enable them to approach transmitter siting with a broader range of options.

TRANSMITTER SITE SELECTION FACTORS

A natural result of growth in the broadcasting industry is that the number of ideal transmitter sites is reduced while their costs continue to increase. Finding a good site where 3-phase power is available can pose a real problem in some areas.

Transmitter site selection often becomes an economic compromise of many factors, some of which are beyond the scope of this paper. However, judging from hundreds of interviews and conversations with station owners and engineers, a consensus view is that most siting issues fall in the following list:

- Availability of three-phase power
- Land lease or purchase cost
- Site Accessibility
- Potential Interference

Availability of Three-Phase

Virtually all radio transmitters of 5 KW and larger and TV transmitters over 1KW require 3-phase power input. Equipment designers prefer 3-phase because its rectified output has much less ripple than 1-phase and requires less filtering to produce a clean DC output. However, in the real world, three-phase just does not exist everywhere and utility companies may not be willing to supply it within a reasonable cost or time frame.

Land cost

Antenna farms or other developed sites where power is already available can be very expensive. By contrast there may be attractive undeveloped areas or inexpensive BLM leases which would be ideal sites if 3-phase were available.

Interference

This becomes a critical issue whenever locating near existing stations. The availability of 3-phase power must be weighed against the added cost of circulators, traps, grounding systems, special antennas and other costs incurred to eliminate interference.

Site Accessibility

Even low cost sites which have 3-phase and are interference free may be unreliable locations if land owners are reluctant or unwilling to grant unlimited passage on private lands and roads. The availability or cost of access rights can drive up the price of an otherwise attractive site.

Final site selection may require a compromise on one or more of the above points. But it is unlikely that a site without 3-phase could be seriously considered even if that choice were highly ranked in every other category. There are three alternatives which the owner can consider where 3-phase power is not available. They are: 1) Request a utility line extension. 2) Install on-site power generation equipment. 3) Use a phase converter.

UTILITY POWER EXTENSION POLICIES

Every utility has its own policy on new service requests. However, it is useful to understand the general issues which impact the utility decision and the alternatives which they may offer.

The factor weighed most heavily is the proximity of the proposed site to the nearest sub-station or 3-phase power line with adequate capacity. A 3-phase line near the desired site does not guarantee the station a service drop if the line is loaded to its limit by other users. In such cases, the utility may choose to increase the capacity of the service transformer, install a new 3-phase line, upgrade an existing line to 3-phase, deny the request for 3-phase, or offer a 1 -phase service.

To convert an existing 1-phase line to 3-phase, the power company must string at least one additional cable and replace the 1-phase transformer with a 3-phase unit. In some cases, the utility may cut corners and simply add one more 1-phase transformer and thus supply open-delta three-phase. Open-delta is a very common practice in rural areas because it saves money on transformers. However, it has very poor voltage stability and often undergoes wide voltage swings.

Three-phase line extensions are ideal but are very costly because they entail a complete new installation of poles, lines, insulators, supports and other hardware. The costs are further affected by terrain and accessibility to the new site.

As utilities come under increasing pressure from public regulatory agencies to justify capital investments (which include new distribution lines) when seeking rate increases, they have become very particular about where they extend new services. If the investment of extending a line is not paid back fast enough through energy revenues, the utility will charge the customer for the new service. There are no absolute rules governing the calculation of these charges, however, it is widely accepted that line extension costs range from $30,000 to $90,000 per mile with $50,000 being a common average.

Engine Generators

The diesel or engine driven generator is a commonly considered alternative to a converter. However, generators are expensive and are usually not justifiable as the primary 3-phase source when compared to a phase converter (assuming an adequate single-phase service is already available). In addition to high initial cost, the logistics of fuel supply can pose a serious problem in some geographical areas.

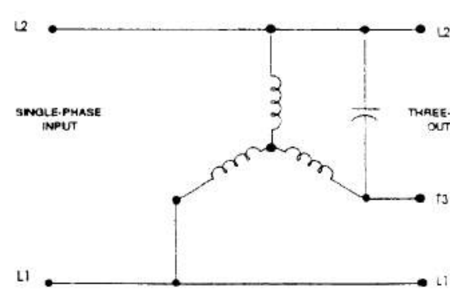
It is not uncommon that the energy cost alone of operating a transmitter on utility power will be 50-60% less than the cost of diesel fuel for the same transmitter power output. Those savings will often pay for a phase converter in a matter of months.

Further, the maintenance costs of engine generators tends to be quite high and downtime is longer than phase converters when outages occur.

PHASE CONVERTER FUNDAMENTALS

Types of Converters

A phase converter is simply a device which permits a 3-phase machine to be operated from a 1-phase source. It does so by producing a manufactured phase which becomes the third wire connection to the load. There are two types of converters, rotary and static. Static converters are less expensive than rotaries and are useful on light duty motor loads. They are not suitable for rectifier loads as found in transmitter applications. Therefore only rotary converters will be discussed here.



ROTARY PHASE CONVERTER SIMPLIFIED EQUIVALENT CIRCUIT

Converter Construction and Operation

A common misconception is that a rotary phase converter is similar to a mechanically coupled motor-generator set. In reality, the converter is a single armature device constructed much like a three-phase induction motor. It consists of a stator frame with a symmetrical three-phase winding and a specifically modified squirrel cage rotor. A large capacitor bank is placed across a set of windings between one of the input lines and the manufacture phase. A simplified equivalent circuit is shown in figure 1.

When the converter is energized, single-phase power is applied to one of the winding groups. This produces an internal magnetic field proportional to the applied single-phase line. The capacitor bank provides a phase shifted voltage to another coil group which creates a starting torque on the rotor. As the rotor spins, it picks up a replica of the utility supply through induction. As the rotor passes each stator coil group (each separated by 120 mechanical degrees) the single-phase field is replicated in the other two coil groups. The result is a three-phase sinusoidal output with each phase shifted by 120 degrees.

In this context, it becomes clear that a rotary phase converter is actually a rotating transformer where the rotor acts as a secondary winding on bearings.

Output Characteristics

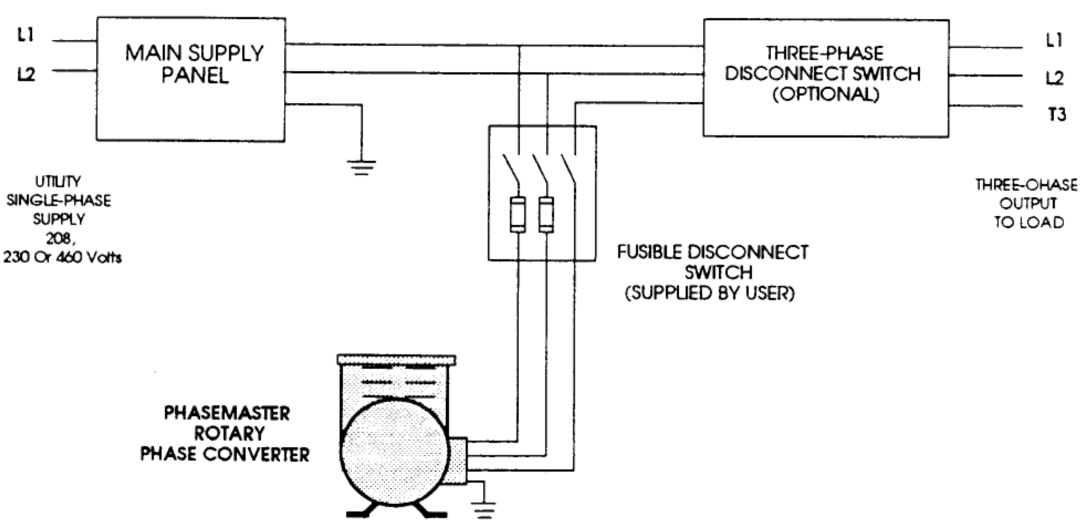
Two of the three lines in a converter system come right from the utility (figure 2). Therefore, the important output characteristic is the behavior of the manufactured phase in relationship to the two utility lines.

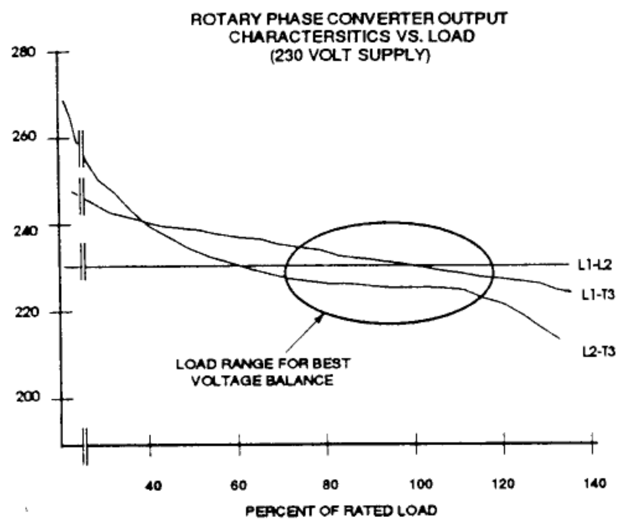
The energy which flows into the manufactured phase passes across the internal air gap between rotor and stator. The greater the load, the more energy has to cross the air gap. And since magnetic fields do not travel through air as well as iron the greater the effect on output voltage. The output diagram in figure 3 shows the behavior of the output voltages in relation to load. Note that at under no-load conditions, the manufactured phase voltage (L1 -T3) is substantially higher than the incoming line voltage. As load increases, the voltage drops so that under full load conditions, the three voltages are quite closely balanced. The significance of this load dependent voltage will be discussed in further detail.

Ratings

Standard single unit converter output ratings are available up to 100 KW. But there is no theoretical limit to the total load size a converter can service. They may be paralleled indefinitely for any load. The only restriction is the maximum 1-phase load allowed by the utility. In practice the only time converters have to be paralleled is on large TV transmitters.

ROTARY PHASE CONVERTER TYPICAL CONNECTION DIAGRAM





ROTARY PHASE CONVERTER OUTPUT CHARACTERISTICS VS. LOAD (230 VOLT SUPPLY)

Except for the largest sizes, converters are usually dual voltage rated at 230/460 volts. Output is three wire closed delta.

Physical Size

Phase converters are dense and compact. The footprint of a converter for a typical 20 KW FM transmitter is about 24"X24". It stands 30" high and weighs 800 lbs.

Design Operating Duty

Rotary converters designed for broadcast service are capable of continuous operation, 24 hours per day, every day. They need not be shutdown except for periodic scheduled inspection and maintenance. They can operate unloaded or at full load indefinitely without effect. However, losses are higher under no-load conditions.

Equipment Standards

Unfortunately because of the highly specialized nature of phase converter broadcast applications, there are no published industry standards governing their performance or ratings. The three best known approval agencies in North America, CSA, UL, and ETL do have approval procedures for converters. However, these approvals are little more than equipment material and safety audits. They verify none of the manufacturer's specifications or performance claims. In the absence of strict industry standards, the most reliable yardstick of relative performance is a comparison of the physical frame size and weight of the converter.

The severity of transmitter applications requires a physically larger frame and rotor than would be necessary to operate an induction motor load. If a motor is difficult to start, capacitors may be added to boost starting torque. Boosters are not effective on transmitters and are never a substitute for a larger converter frame size. It is recommended that users stick to converters which have been specifically designed for use on transmitters and have a demonstrable service record.

BROADCAST APPLICATIONS OF PHASE CONVERTERS

Operating Benefits

The most obvious benefit of phase conversion is the ability to operate 3-phase equipment while avoiding utility installation charges. But there are several other economic and technical advantages to converters which can be beneficial to owners and engineers.

1. Immediate Power Availability
A very important factor in the decision of whether to go with utility or a converter is the time required to extend the new lines. Depending on the distance or the utility work load, new services may take from weeks to months before the user can energize. The converter is a simple solution to this dilemma. It can be installed very quickly to allow start-up with minimal delay. Even if utility 3-phase is brought in later, the relatively small converter investment may save much greater revenues which would be lost in delays.

2. Elimination of Utility Demand Charges
The rate structure of 3-phase electric power often includes a component known as a demand charge. This charge seldom applies to 1-phase services. Over the years, many station owners have discovered that their power supplier serviced them with a 1-phase which did not include demand charges. The use of the converter was not only a satisfactory alternative to utility 3-phase, but the rate structure was more favorable when purchasing as a 1-phase customer.

3. Reduction of Utility Line Transients
Almost everyone who has operated a transmitter is familiar with the phenomenon of utility line noise. Such transients result from system switching disturbances and load changes, and can damage equipment or take a station off the air. Since a converter is capable of storing a large amount of energy in its rotating magnetic field, it can ride through momentary voltage sags by generating energy back into the systems during the voltage drop. This type of event accounts for nearly 80% of all line disturbances and the effects are greatly reduced or eliminated by the converter. The converter also buffers voltage spikes.

4. Stabilization of Open-Delta Service

Open-delta service as previously discussed is a common form of three-phase which has very poor voltage regulation on one leg. By contrast transmitters require stable power supply voltage. Voltage swings are a very common nuisance to stations unlucky enough to have open-delta service. Phase converters are an effective method of closing the delta and stabilizing the wild leg and eliminating the unplanned downtime caused by open-delta service.

Converter Selection Criteria

When properly selected and installed, converters are capable of output and performance which is nearly indistinguishable from utility three-phase. The typical data required to insure a successful application includes the following:

- Type of transmitter, AM, FM, TV
- Manufacturer
- Input Power consumption in KW at operating ERP
- Day-Night output, if different

Once this data is known, selecting the proper converter is a straightforward procedure. The key to successful sizing is to match the converter output as closely as possible to the load. This requires knowing the true input power consumption at the actual operating output of the transmitter. On AM transmitters this is usually expressed at 100% modulation.

This sizing technique produces the best possible voltage balance. A properly sized rotary converter will provide operating load voltage balance (% regulation) ranging from a maximum of 5% and most commonly 2-3% or better.

Load matching is important to sizing because as discussed earlier, the output characteristics of converters vary with load. The phenomenon is only significant when attempting to operate a transmitter which draws considerably more than OR less than the rated output of the converter. The resulting voltage imbalance can cause an increase in AM noise level. This condition is easily avoided by proper selection. Field remedies are also available.

Load matching and voltage balance issues also affect AM stations which operate at reduced nighttime power. This situation is easily handled one of two ways. The first is by employing an output voltage control switching arrangement that reduces the converter output voltage characteristics by dropping a portion of the capacitor bank. The second method is by splitting the load between two parallel converters (figure 4). One converter is .

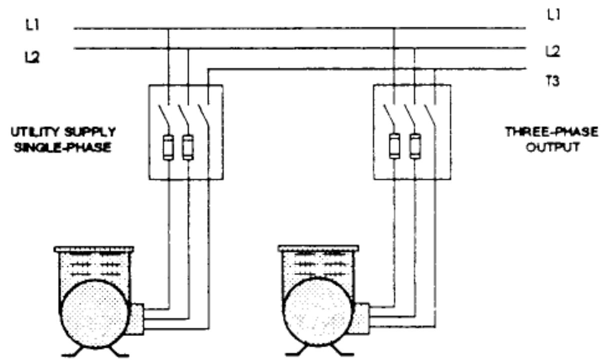


FIGURE 4

ROTARY PHASE CONVERTER CONNECTION
FOR PARALLEL OPERATION

sized for the night load only. During the day they run together. At night one converter is switched off and the other unit carries the entire reduced load

SITE ENGINEERING CONSIDERATIONS

Phase converters have clearly demonstrated the ability to handle high power installations on all types of transmitters. Nonetheless, the potential for misapplication is always present unless all system operating requirements are reviewed. When these issues are addressed, engineers and owners can approach the use of phase converters with total confidence.

Size of Utility Service

Undersized utility service transformers are a very common field problem. Engineers should work with the utility to insure the incoming service is adequate to supply the entire site load without excessive voltage drop. An FM transmitter with a rating of 20 KW will actually draw more like 35 KW at full operating load. If the site also has an air conditioning load, tower lights, etc. totaling an additional 10 KW, then 45 KW becomes the total 1-phase demand which the utility must be able to supply. However, the converter is sized only for the amount of connected 3-phase load.

Planned Operating Load Levels

A phase converter should always be sized for the maximum power which the transmitter consumes at normal operating levels. If a different output power is anticipated at a future date, consultation with the converter manufacturer is recommended to assure that converter design takes future needs into account.

Converter Control Systems

The most common and least expensive control scheme uses a fusible disconnect switch for isolation and short circuit protection. The converter is manually switched on and runs continuously until manually shut down. However, there are operating conditions which call for a greater degree of control. For this reason, engineers may want to consider specifying automatic controls to start and stop the unit remotely.

Automatic controls use a magnetic contactor to start and stop the converter from a remote control station. A timing relay locks out the load until the converter reaches full speed and is producing three-phase (about three seconds). Automatic controls should be considered for sites which are unattended at any time or stations which sign-off at night. The convenience of this feature is widely appreciated by existing users.

Another key advantage of automatic controls is improved system reliability. Utility service in remote areas is notorious for frequent outages. Stations which use emergency back-up generators must have a way of isolating the converter when the transfer switch changes over to the emergency source. The automatic control provides this function as well as the ability to restart the converter in advance of switching back to the primary supply. It also prevents the converter from attempting to restart into a load when power returns after an outage.

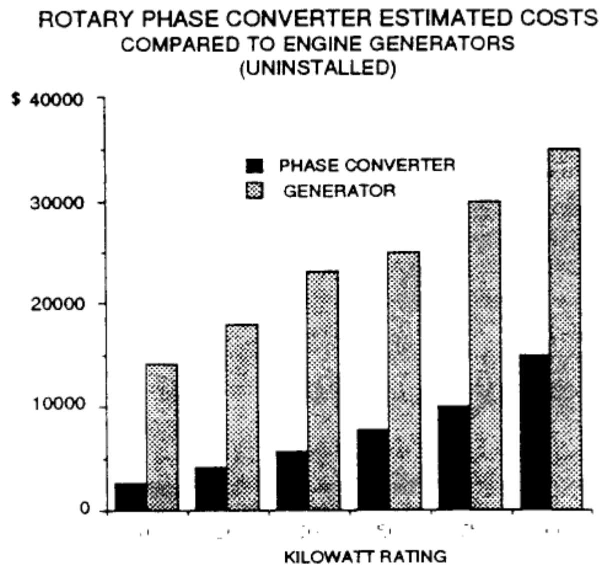
ANALYSIS OF CONVERTER FEASIBILITY

The question of whether to consider a phase converter as an alternative to utility 3-phase reduces to an evaluation of economics and relative risk factors. A complete economic analysis of the converter should include 1) Installed equipment cost, 2) Utility charges to bring in the three-phase line, 3) The difference in rate structure between single and three-phase service, 4) The operating cost of maintenance and losses, and 5) An analysis of the reliability record of converters.

Converter Costs

Approximate converter costs through 100 KW are shown on the graph in figure 5. Large rating units can be priced as parallel combinations. Estimating prices of generators are shown for comparison. (Generator costs do not include fuel storage tanks).

A review of utility rate structures is strongly encouraged. The analysis of rates will reveal if they favor a customer metered at 1-phase or 3-phase.



Efficiency

A common engineering concern is phase converter efficiency. The response to this question lies in understanding the difference between the converter efficiency taken alone and the overall *system* efficiency. The phase converter only sees one third of the system energy, so its efficiency taken out of context is not significant. Two of the three load connections come right from the utility supply without passing through the converter. Converters like most rotating machines are nominally 90% efficient at the upper end of their load range. Thus the full load system losses are approximately equal to 10% times 33% or 3.3% of the rated load.

Operating Costs

No-load operation is the most inefficient running mode of a converter (or for that matter, any machine). As discussed above, the actual losses incurred by operating a converter system are quite small at full load. In fact, the large power factor correction capacitors in the converter will commonly improve the overall system efficiency enough to compensate for converter losses. Even without regard to these possible savings, the estimated cost of losses for a converter running a 20 KW FM transmitter operating at 70% efficiency running 24 hours per day would be less than $100 per month based on energy costs of fifteen cents per kilowatt-hour. Maintenance costs alone on a generator of this size would average 1.5 cents per kilowatt-hour or $300 per month.

INSTALLATION AND MAINTENANCE

Converter installation is neither costly nor complicated. Careful attention should be given to the manufacturer's instructions. Most start-up problems are traceable to installer deviations from recommended practices.

The converter is usually installed near the main power service entrance. An inexpensive fusible switch isolates the converter and provides its primary short circuit protection. A converter does not have to be bolted down since it does not have to be braced against starting loads. A typical converter installation can be made in four hours or less.

Rotary converters require very little ongoing maintenance. The most effective maintenance program starts with strict adherence to recommended installation procedures. Once in service, the units should be inspected periodically. The ventilation slots must remain open and bearings lightly lubricated at intervals of 12-18 months. No further formal maintenance is required or recommended.

RELIABILITY RECORD

Many station engineers have observed the converter has far fewer outage occurrences than the utility supply. Of course this is not unexpected in many areas where weather conditions play havoc with rural distribution systems.

One make of converter has been used successfully in service on transmitters for more than 45 years. There are presently more than 1200 stations known to be operating on these rotary converters. Many have been operating around the clock for 10 years or more without being shut down for maintenance.

The field failure rate averages well under one percent per year. This includes all types of failures regardless of cause or severity. Direct lightning strikes remain the most common cause of catastrophic converter failure. The addition of lightning arrestors as a standard phase converter accessory on transmitter applications has greatly reduced but not totally eliminated this failure mode.

By nature, phase converters are not service prone. Except for add-on controls they contain no contacts or switches. Apart from the rotor and bearings all other components are static devices. The most . common cause for service of rotary converters are failed capacitors usually resulting from external utility system transients or lightning. Less common service issues are wiring and connector related. The connector and wiring problems usually stem from abrasion of taped joints or connections which are not sufficiently tightened during installation.

Film type capacitors, if defective generally fail open. Capacitors rarely fail to a short circuit condition. Usually the only sign of defective capacitors is poor starting performance or sagging voltage on the manufactured phase. Both problems are easily corrected.

Bearings are the most commonly expressed concern of converter owners. In service, however, bearing failures are uncommon. The principal reason for that is that the bearings carry only the load of the spinning rotor. There is no external shaft extension on a phase converter and consequently no outside mechanical load on the bearings. Bearing life of 15 to 20 years is not uncommon with five year life a minimum expectation for installations operated continuously without shutdown.

A note of caution is in order here. Most rotary converters on the market have been designed for motor loads and are not well suited for transmitter service. Even subtle design differences in rotor construction and accessories can make a significant difference in transmitter performance. Owners and engineers will naturally want to examine and verify the service record of a manufacturer's experience on broadcast transmitter applications.

CONCLUSION

Specialized designs of rotary phase converters have been field tested for 45 years on virtually all makes of broadcast transmitters. The experience with these machines has clearly demonstrated them to be suitable replacements for utility supplied three-phase power without sacrifice of transmitter performance or reliability.

In view of their accumulated performance record and significant economic advantage, phase converters must be considered an important alternative power source which owners and engineers should not overlook when selecting transmitter sites.

This is a reprint of the paper which originally appeared in the 1988 NAB Engineering Conference proceedings. For more information about rotary phase converters for broadcast transmitter applications contact:

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About Kay Industries

Kay Industries, Inc., is the worldwide industry leader in designing, manufacturing, and marketing single-phase to three-phase electrical power converters. A privately held corporation since 1946, Kay Industries sells phase converters nationwide through a select network of electrical wholesalers, equipment dealers and manufacturers. It also exports to Central and South America, Europe and the Pacific Rim. Kay Industries, Inc., markets under the registered trademark Phasemaster® and is headquartered in South Bend, Indiana, with offices in Fremont, California.

Kay Industries, Inc., was the first converter manufacturer to commercially offer:

- Rotary converters (1960)
- Automatic controls (1972)
- Money-back performance guarantee (1975)
- Independent agency approval (CSA/NRTL) (1979)
- National toll-free lines (1980)
- Extended warrantees (1986)

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