〈**Development of New Products**〉

Power Regenerative Converter, THYFREC CV240S

Harmonic restraint, Power regeneration, 120˚ conduction, Power factor improvement, Common converter system, Environment compatibility

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Abstract

Recently, it has become necessary to use energy more effectively by adopting a regenerative converter. Further, there are increasing needs for harmonic restraint on the source side and for reduction of facility capacities through power factor improvements.

We developed and commercialized THYFREC CV240S. In addition to our existing features for harmonic current restraint and improvement of power factors, the new product features power regeneration function using a low-cost system configuration. This series can be used for a variety of applications such as harmonic restraint for fans and pumps, energy saving for elevators and cranes, and application on steel production lines.

1. Preface

The diode rectifier-based speed control equipment or power conversion equipment increased recently for energy efficiency. The wider use of such products caused problems for harmonic currents flowing in power systems. Harmonic currents flowing in a power system give rise to various problems such as heating of a transformer in a substation or noise from capacitors in power factor improvement. The other trend for energy efficiency is that there is a migration from hydraulic drives to electric motor driven systems and a further trend to add power via a regenerative system for better energy efficiency.

We have a long history of product development for harmonic restraint system using active filters and PWM converters. Our products reflect this quality in the market.

In this paper, we introduce specifications and features of THYFREC CV240S Series (CV240S hereafter) newly developed and released according to present needs. These are successor models to the conventional THYFREC CV210S Series.

2. Product Outlines of CV240S

2.1 Product Specifications

Table 1 shows the product specifications of CV240S Series classified by capacities, and Table 2 shows the common specifications for control. CV240S Series comes in 20 models, 200V series models with the rated output capacities of 14～107kW and 400V series models of 14～775kW. The overload current rating is a dual rating, normal-duty setting of 120% for one minute and heavy-duty setting of 150% for one minute. According to the application, either one can be selected by the user. The 400V series models of 475H, 550H and 660H are arranged into 2-parallel unit configuration so that the overall capacity can be expanded in parallel running.

2.2 Features

CV240S Series has been engineered to best work with THYFREC VT240S inverter series featuring general-purpose and high-performance functions (VT240S hereafter). As a result, features for higher performance, further energy saving, and easy operation are realized.

Major features are described below.

(1) Restraint of harmonic currents

Since sine wave approximation PWM current control is applied to produce a sine wave of input currents, it is possible to restrain harmonic currents that would flow in the power system. Its performance characteristics meet the requirements of the IEC Standard for harmonics regulation. Fig. 1 shows a comparison of percentage content of harmonics between two cases when stand-alone inverter (with or without reactors) is used and when CV240S is applied. In the former case (inverter alone), the percentage of low order harmonics, 5th and 7th, is predominant. When CV240S is applied, on the other hand, the percentage can be suppressed to almost zero from low to high orders.

(2) Power regeneration by 120˚ conduction

In addition to features of conventional PWM control systems, CV240S Series now makes it possible to incorporate power regeneration through 120˚ conduction. Therefore, regenerated energy from motors can be returned to the source side using CV240S and low-cost filters. Continuous 100% power regeneration is also possible. Fig. 2 shows the principle of 120˚ conduction. It also shows an example of voltage and

Table 1 Specifications of CV240S Series

Product features in terms of capacities are specified in a dual rating system of normal-duty overload and heavy duty overload.

(a) 200V series CV240S-011L～090L

Type: CV240S-□□□□		011L	018L	030L	045L	075L	090L
Equipment ratings	Normal-duty: Rated output capacity (kW)※1	14	22	37	55	89	107
	Normal-duty: Connected inverter capacity (kW)	7.5/11	15/18.5	22/30	37/45	55/75	90
	Normal-duty: Rated input current (A)	44	69	116	173	281	338
	Normal-duty: Overload current rating	120%-1min 140%-2.5s (both driving and regeneration)					
	Heavy-duty: Rated output capacity (kW)※1	9	18	27	45	66	89
	Heavy-duty: Connected inverter capacity (kW)	7.5	11/15	18.5/22	30/37	45/55	75
	Heavy-duty: Rated input current (A)	30	58	85	143	209	281
	Heavy-duty: Overload current rating	150%-1min 175%-2.5s (both driving and regeneration)					
	DC output voltage (V)	317.5～360V DC variable					
	Input power factor※2	0.95 or above					
Power source	Voltage / frequency (Hz)	3-phase 200～230V ±10% / 50Hz or 60Hz ±5%					
Construction	Installation system※3	Wall-mounted					
	Protective construction	IP00					
	Approx. mass (kg)※4	7.5	12	25	40	80	200
	Cooling method	Forced air cooling					
	Paint color	Munsell N4.0 (gray)					
Operating environment		Indoors: Ambient temperature −10～50℃, relative humidity 95% or below (no dew condensation) Altitude: 1000m or below, Vibration: 4.9m/s^2 Max. Free from corrosive or explosive gas, steam, dust, oil mist, cotton lint, etc.					

(b) 400V series CV240S-011H～660H

Type: CV240S-□□□□		011H	018H	037H	055H	075H	110H	132H	200H	250H	315H	400H	475H	550H	660H
Equipment ratings	Normal-duty: Rated output capacity (kW)※1	14	21	44	66	90	133	158	237	294	370	468	558	646	775
	Normal-duty: Connected inverter capacity (kW)	7.5/11	15/18.5	22/30/37	45/55	75	90/110	132	160/185/200	250	280/315	355/400	450/475	550	660
	Normal-duty: Rated input current (A)	22	34	69	104	142	211	250	375	466	586	741	912	1056	1267
	Normal-duty: Overload current rating	120%-1min 140%-2.5s (both driving and regeneration)													
	Heavy-duty: Rated output capacity (kW)※1	9	18	35	54	66	109	133	189	237	294	370	470	558	646
	Heavy-duty: Connected inverter capacity (kW)	7.5	11/15	18.5/22/30	37/45	55	75/90	110	132/160	185/200	220/250	280/315	355/400	450/475	550
	Heavy-duty: Rated input current (A)	15	29	56	85	104	172	211	300	375	466	586	768	912	1056
	Heavy-duty: Overload current rating	150%-1min 175%-2.5s (both driving and regeneration)													
	DC output voltage (V)	635～720V DC variable													
	Input power factor※2	0.95 or above													
Power source	Voltage / frequency (Hz)	3-phase 380～460V ±10% / 50Hz or 60Hz ±5%													
Construction	Installation system※3	Wall-mounted													
	Protective construction	IP00													
	Approx. mass (kg)※4	7.5	12	25	42	45	65	90	200	285	290	295	285 × 2	290 × 2	295 × 2
	Cooling method	Forced air cooled													
	Paint color	Munsell N4.0 (gray)													
Operating environment		Indoors: Ambient temperature −10～50℃, Relative humidity 95% or below (no dew condensation) Altitude: 1000m or below, Vibration: 4.9m/s^2 Max. Free from corrosive or explosive gas, steam, dust, oil mist, cotton lint, etc.													

Notes:

※1. When the source voltage is of 200V series, the indicated values are available at 220V, and 440V for 400V series. At values lower than these levels, reduced rating has to be applied.

※2. Applicable when the PWM control system is selected.

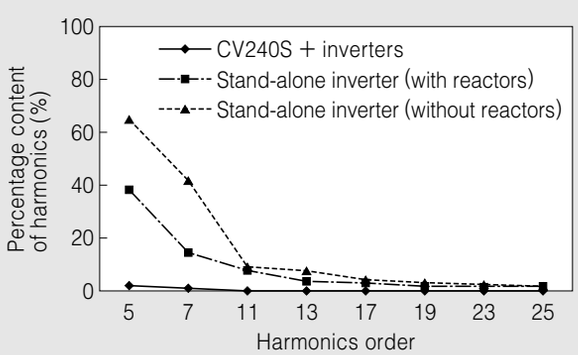
※3. External parts [AC reactors, capacitor box (capacitors and resistors for 045L and 055H or above)] are separately installed. Grounding capacitors and resistors (option) of other equipment for prevention of misoperation are also installed separately.

※4. Mass is only for the main unit.

Table 2 Common Control Specifications of CV240S

Features of the control specifications are that the 120˚ conduction control system is added to the conventional feature of the PWM control system. According to user's application, either one can be selected.

	PWM control	120˚ conduction control
Control system	All digital sine wave approximation PWM control	All digital 120˚ conduction control
Operation panel	V24-OP1: LCD panel or V24-OP2: LED panel	
Retry function	Arbitrary setting of 1 to 10 times	
Protective functions	AC input overcurrent (OC), overload (OL), DC overvoltage (OV), undervoltage (UVT), heatsink overheating (UOH), power module error (PM), plus self-diagnosis (CN/IO/CPU/DER) Ground fault detection (GRD): ON/OFF selection possible by parameters Line overvoltage (LOV), Line undervoltage (LUV): selection of major/ minor faults possible Fuse blown (EF): contact outputs only	
Fault hysteresis	4 past faults recorded. Contents of record: Primary and secondary factors, source frequency, current, DC voltage, H/W detection error, total electrification time, and total operation time shortly before tripping.	
Others	Cooling fan ON/OFF control, standard serial communication	



Note: Tentative values for an 11kW unit (at 100% load) of the 400V series. They can vary according to the capacity and load factor.

Fig. 1 Analysis of Harmonics for CV240S and a Stand-Alone Inverter

In the case of a stand-alone inverter (with or without reactors), percentage content of low-order harmonics (5th and 7th) is high. In the case of a combination of CV240S and inverters, percentage content of harmonics can be suppressed to almost zero from low to high orders.

current waveforms when the Insulated Gate Bipolar Transistor (IGBT) in Phase R is turned on and off for 120˚ conduction. In the 120˚ conduction control system, IGBTs are sequentially turned on for changeover 120˚ phase shift in the power source.

(3) Execution of high power factor control

Fig. 3 shows current waveforms on input side observed when the PWM control system of CV240S is applied and 120˚ conduction control is used. In the case of operation of inverter alone, input power factor

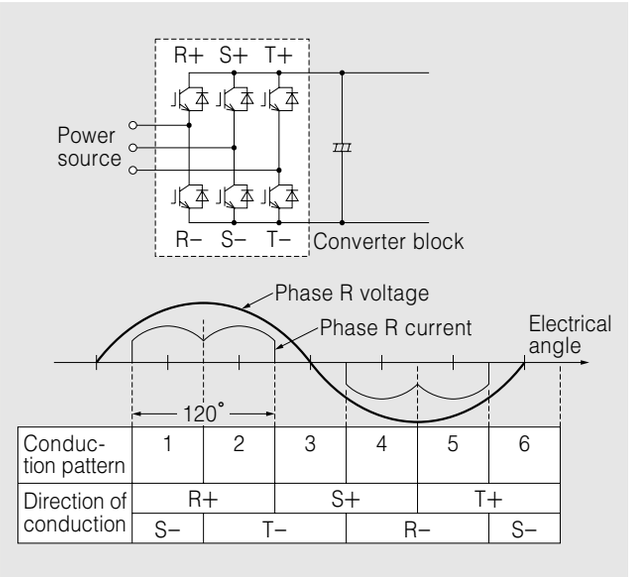
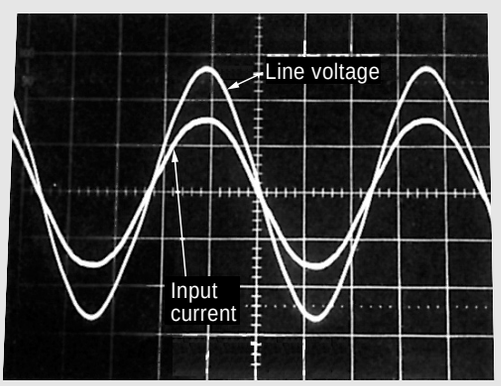
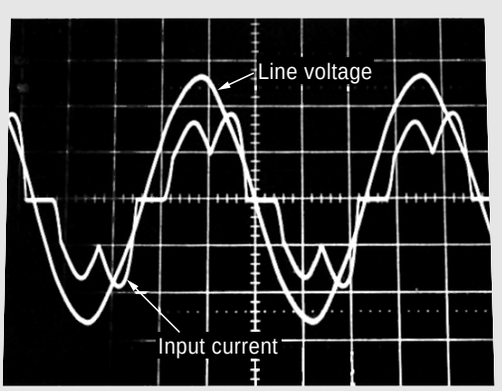


Fig. 2 Principle of 120˚ Conduction

This figure shows that upper and lower converter arms are sequentially changed over at every 120˚ phase difference.



(a) Input current waveforms of the PWM control system



(b) Input current waveforms of the 120˚ conduction control system

Fig. 3 Current Waveforms on Input Side for PWM Control System and 120˚ Conduction Control System

For the PWM control system, both line voltage and input current are sine wave and in phase. For the 120˚ conduction control system, the input current phase lags from the line voltage. However, an input power factor of 0.9 or above can be assured.

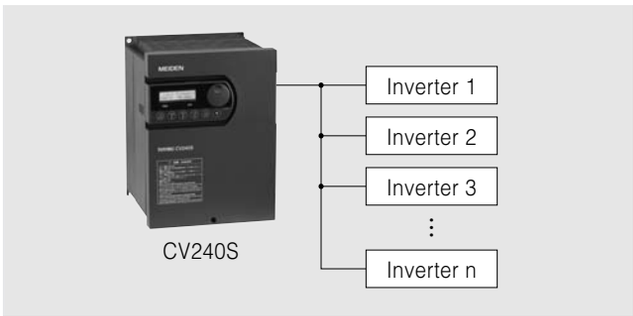


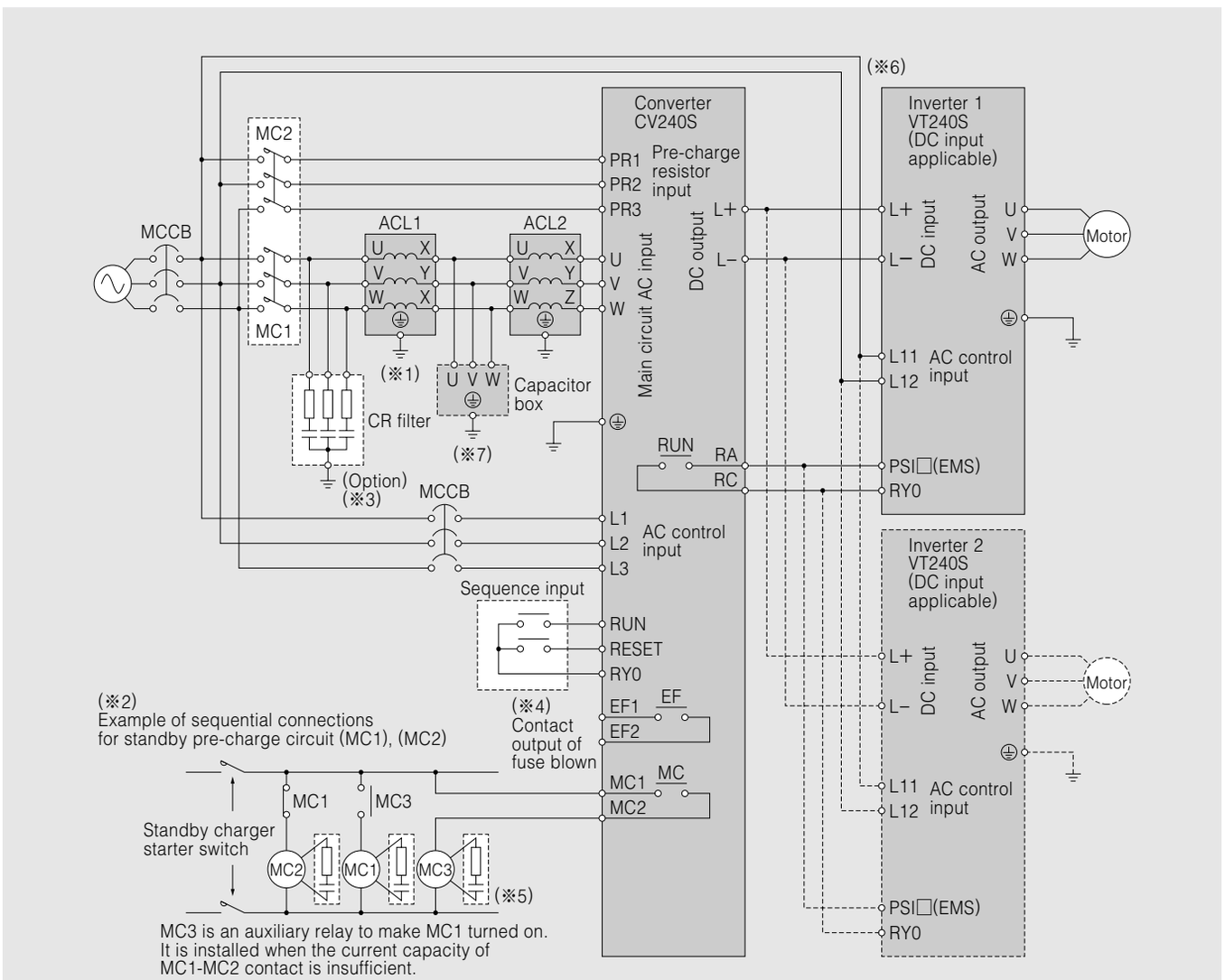
Fig. 4 Example of Connections where a Common Converter is Used

This example shows multiplex connections where a single CV240S is connected with multiple inverters.

is generally around 0.85 while AC reactors are connected. In the case of CV240S PWM control system, it is possible to reduce the capacity of power equipment because of high power factor control where the input power factor is almost uniformly maintained. Even in the case that the 120˚ conduction control system configured with the use of low-cost input filters described previously, the input power factor can be improved as high as 0.9 or above.

(4) Common converter system

A single CV240S unit can be connected with multiple inverters. In such a case, structuring of a multi-axis type system can be realized. Fig. 4 shows an example



Notes:
※1. An example of the connections is shown for the PWM control system. In the case of the 120˚ conduction control system, ACL2 and a capacitor box can be omitted.
※2. This is a circuit for actuating magnetic contactors MC1 and MC2. In the first place, MC2 on charger rheostat input side is turned on. MC1 on main-circuit input side is then turned on receiving a signal of "standby charge finished" from MC1-MC2 (contact).
※3. Installation of a CR filter is recommended for the prevention of misoperation in other devices.
※4. A switch is closed by fuse blowout.
※5. Magnetic contactors and relay coils installed near the converter have to be equipped with surge absorbers.
※6. For VT240S Series, wiring for AC control inputs is needed for capacities of 015L/075H or above.
※7. The capacitor box consists of resistors and capacitors for versions of 045L/055H or above.

Fig. 5 Main Circuit System Configuration Diagram of CV240S

The main circuit system configuration diagram is shown where the PWM control system has been adopted. In the case of the 120˚ conduction control system, ACL2 and a capacitor box can be omitted.

of connections where a common converter is used. When this common converter is used, the converter capacity should be chosen to be greater than the total capacity of multiple inverters.

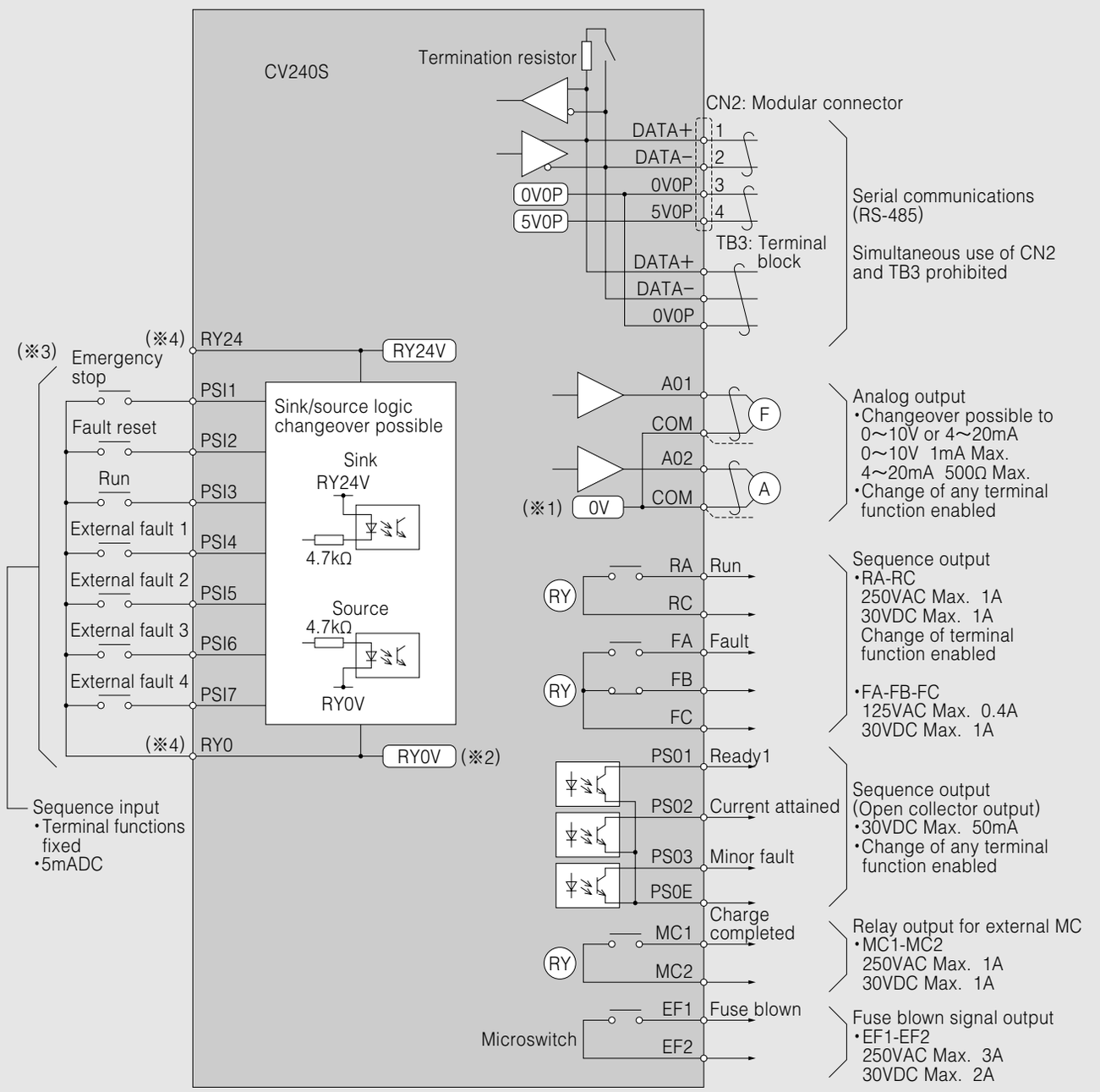
2.3 Chemical Regulation Compliance

(1) Restriction of Hazardous Substances (RoHS)

CV240S complies with the EU RoHS Directive. Our converters are environmentally sound products free from hazardous substances such as lead, hexavalent chromium, etc.

(2) Reduction of losses

Through an improved modulation system for PWM control, CV240S improves converter efficiency.



Notes:
※1. Two points of COM are internally connected.
※2. Since RY0, 0VOP, and COM are insulated, no connections are required.
※3. This figure shows an example of sink logic connections.
※4. RY24 and RY0 must not be short-circuited.

Fig. 6 Control Circuit of CV240S

This figure indicates that connections via serial communication are possible for the sequence I/O and analog outputs.

Table 3 Control Terminal Functions of CV240S

Features of control terminal functions include programmable sequence and analog outputs and free terminal assignment change.

Name	Functions
Sequence input	7 points fixed: Sink/Source changeover possible Operation command, fault reset, emergency stop, external errors 1～4
Analog output	Voltage output (0～10V) or current output (4～20mA): 2 points programmable Input current, input voltage, input power, DC output voltage, heatsink temperature, overload monitor, effective current, reactive current
Sequence output	Relay contact 1 point Programmable Relay contact 1 point Programmable Open collector 3 points Programmable Run, fault, minor fault, ready, current attained, charge completed, external fan control, operation delay answer
Communi-cations	Serial communication by RS485 Choose a terminal block or a modular jack

3. Circuit Configuration

3.1 Main Circuit Configuration

Fig. 5 shows the main circuit system configuration diagram of CV240S. It shows an example of 2-parallel connections of the PWM control system where two DC input type VT240S units are connected in parallel. In the case of the 120˚ conduction control system, the AC reactor (ACL1) is connected on only one incoming side and this configuration contributes to space saving.

3.2 Control Circuit Configuration

Fig. 6 shows the connection diagram of control circuit and Table 3 shows terminal functions. Formerly, the sequence input contact points have fixed functions: [RUN (operation command), EMS (emergency stop), and RST (error reset)]. For the CV240S, however, four trouble-signal external output are added, making 7 points in total. The analog outputs and sequence outputs adopt a more flexible method as a programmable type. It can be set to the function of an output terminal.

4. Postscript

This paper described CV240S Series products. Restraint of harmonic currents and effective use of energy by power regeneration are very important challenges to reduce the carbon footprint. With the various features of our products, we hope it will contribute to better environmental performance and energy conservation in many applications.