YASKAWA
Mechatronics Solutions

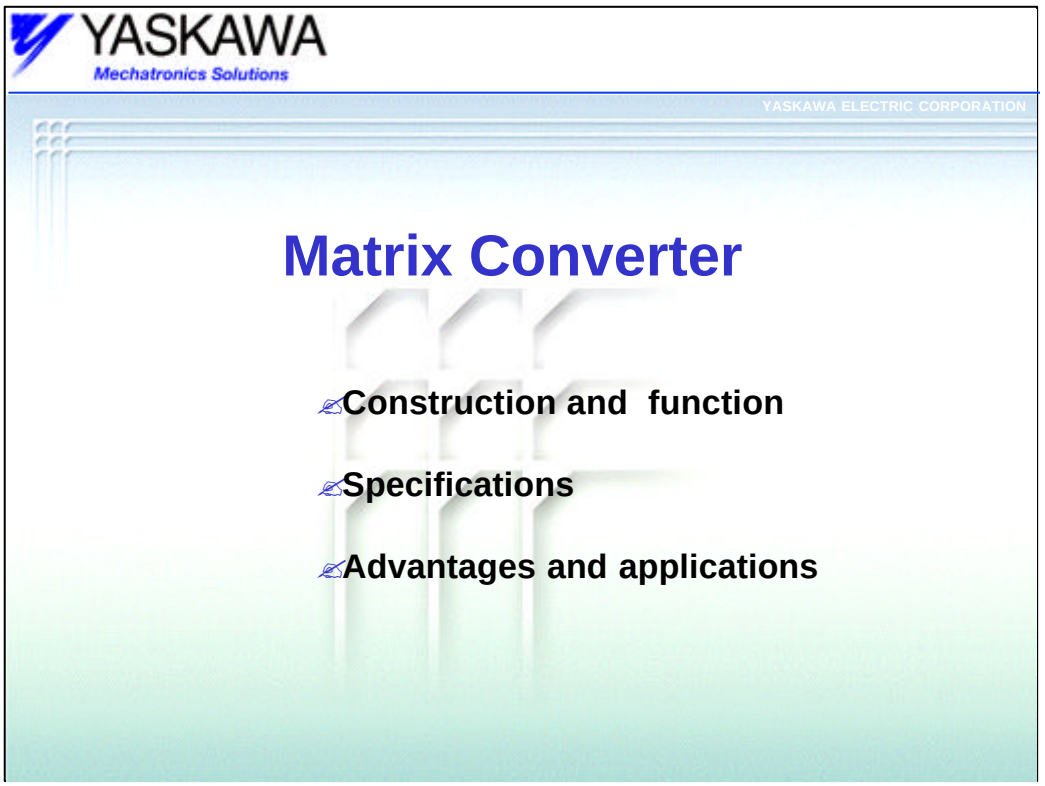
YASKAWA ELECTRIC CORPORATION

Matrix Converter

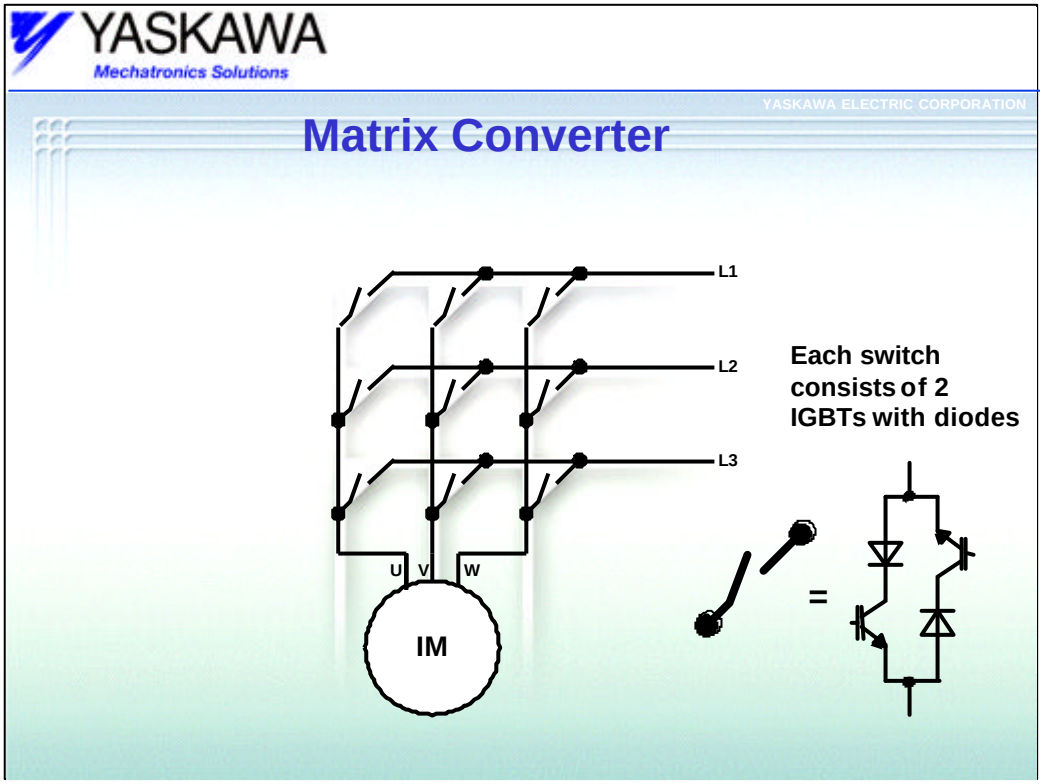
(22 kW, 400V)

The future has arrived

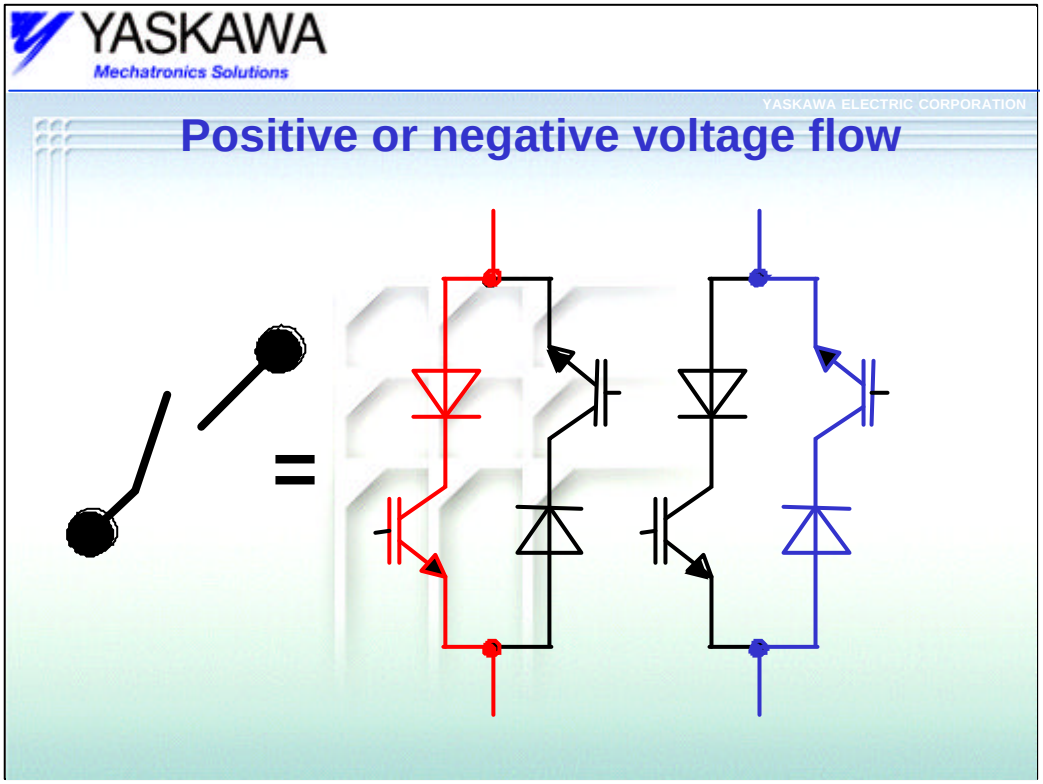
The working principle of matrix converters has already been known for many years. Now, with the help of the advancement of the IGBTs and the help of the fast digital processing, it was possible for Yaskawa to develop a matrix converter for mass production. Here a 400V unit for 22kW motor power is shown. The Matrix converter will be available in 400V-class unit with a power range from 5,5kW to 75kW and as 200V-class unit with a power range from 5,5 to 45kW.



At first the construction and function principles of the Matrix Converter are explained. Than we will see some of the most important specifications. The resulting advantages and application benefits will be explained thereafter.



The Matrix Converter belongs to the group of direct inverters. The 3 line phases will be connected directly via the switching matrix to the motor. Each of the switches consists of two IGBTs. There are nine switches. So we have 18 IGBTs in summery. In 22kW unit all IGBTs are in one module. The name Matrix Converter originates in the diagram of the power circuit, which remind you of a matrix system.

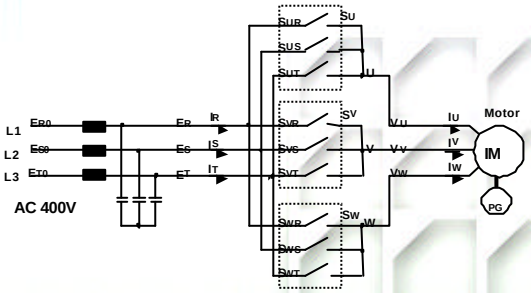


The IGBTs can connect either the positive or the negative voltage to the motor. The current flow is marked in red for positive and blue for negative current.

YASKAWA
Mechatronics Solutions

YASKAWA ELECTRIC CORPORATION

Matrix Equation



Equation of phase voltage

$$\begin{bmatrix} V_U \\ V_V \\ V_W \end{bmatrix} = \begin{bmatrix} S_U \\ S_V \\ S_W \end{bmatrix} \begin{bmatrix} E_R \\ E_S \\ E_T \end{bmatrix} \cdot \begin{bmatrix} S_{UR} & S_{US} & S_{UT} \\ S_{VR} & S_{VS} & S_{VT} \\ S_{WR} & S_{WS} & S_{WT} \end{bmatrix} \begin{bmatrix} E_R \\ E_S \\ E_T \end{bmatrix}$$

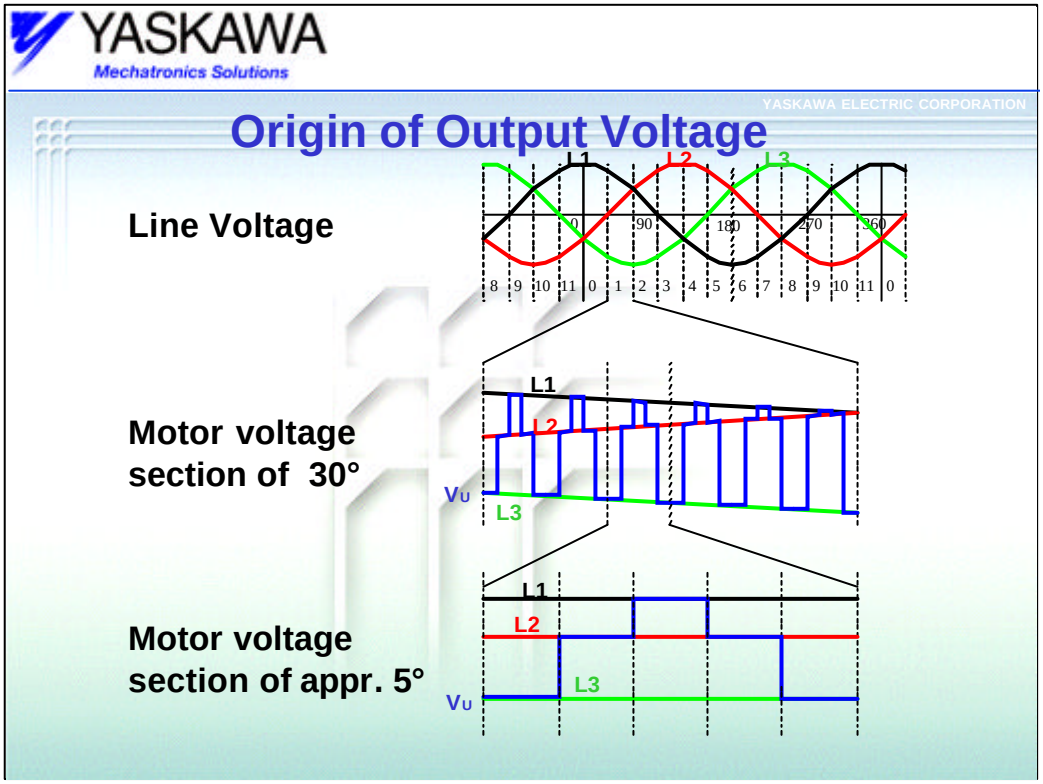
Equation of phase to phase voltage

$$\begin{bmatrix} V_{UV} \\ V_{VW} \\ V_{WU} \end{bmatrix} = \begin{bmatrix} S_{UR} - S_{VR} & S_{US} - S_{VS} & S_{UT} - S_{VT} \\ S_{VR} - S_{WR} & S_{VS} - S_{WS} & S_{VT} - S_{WT} \\ S_{WR} - S_{UR} & S_{WS} - S_{US} & S_{WT} - S_{UT} \end{bmatrix} \begin{bmatrix} E_R \\ E_S \\ E_T \end{bmatrix}$$

Switching rule

$$\begin{bmatrix} S_{UR} - S_{US} - S_{UT} \\ S_{VR} - S_{VS} - S_{VT} \\ S_{WR} - S_{WS} - S_{WT} \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

The shown matrix equations are the mathematical basis of the Matrix converter´s switching pattern. Also here you can recognize from where the name "matrix converter“ originate.

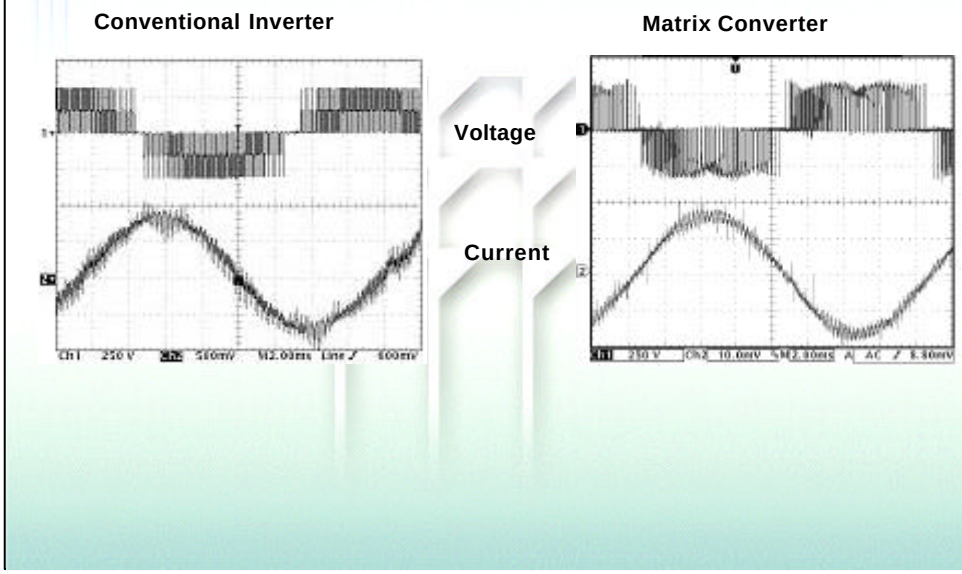


The Matrix converter controls the output voltage by using all 3 phases of the input voltage. This absorbs not only the current disturbances but brings also a clean output voltage. The 30° cut out shows the motor voltage in blue colour. The other colours show the level of the respective mains voltages. The last section zoom in to a 5° part of the motor voltages which clarifies even more the switching pattern.

YASKAWA
Mechatronics Solutions

YASKAWA ELECTRIC CORPORATION

Motor voltage and motor current



This is a comparison between the motor voltage of a conventional inverter and a matrix converter. The typical voltage of the Matrix converter consisting of the power supply voltage levels can be recognized clearly. The current of the matrix converter is substantially smoother, than the current of the conventional inverter.

YASKAWA
Mechatronics Solutions

YASKAWA ELECTRIC CORPORATION

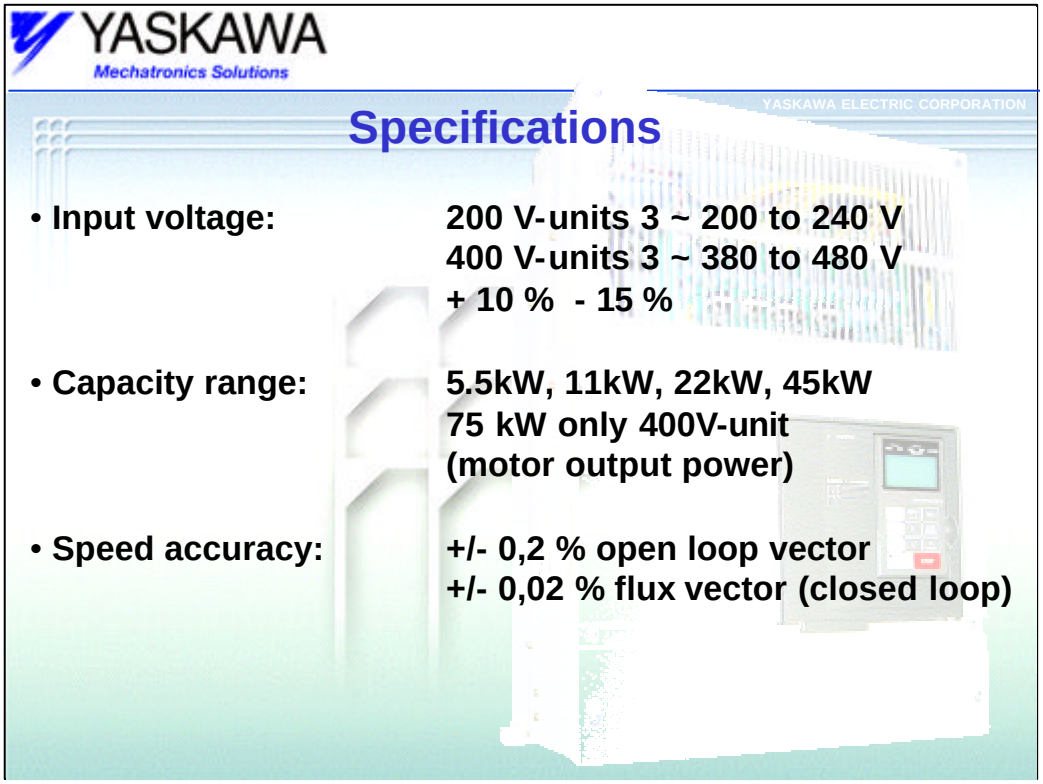
Specifications

- **Motor type: Standard asynchronous motor**
- **Control method: Sinus wave PWM**

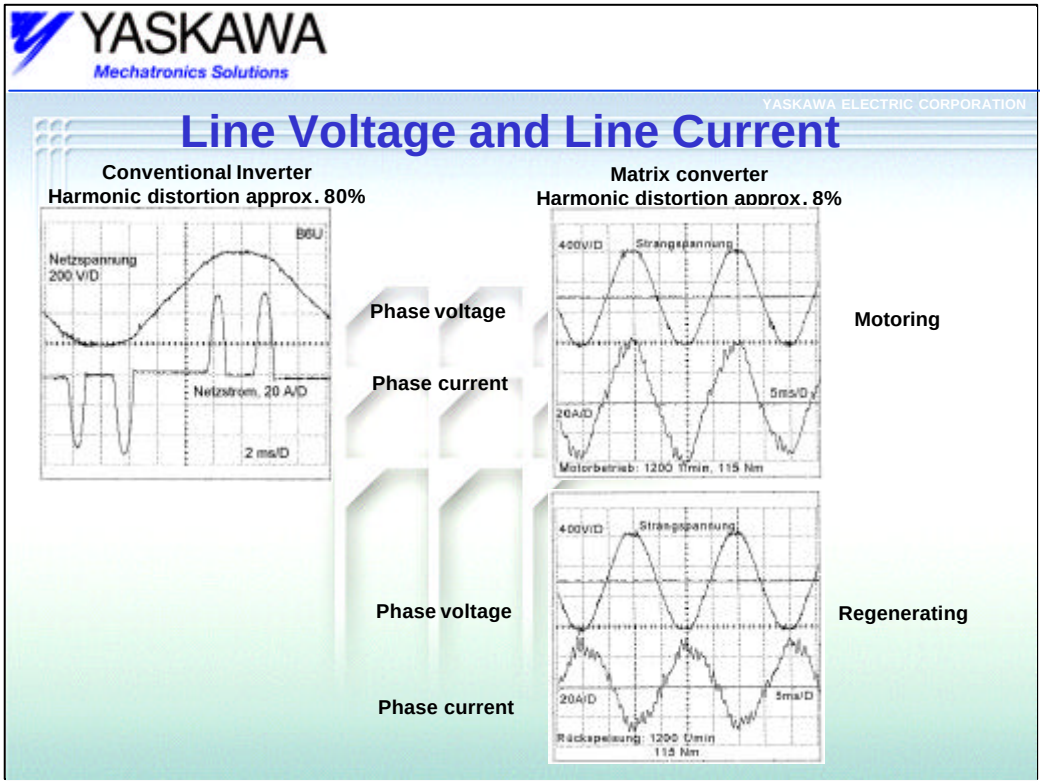
	speed control range / carrier frequency
V/f	1 : 10 / 4 kHz
Open loop vector control	1 : 10 / 4 kHz
Flux vector (closed loop)	1 : 1000 / 4, 8, (12) kHz

- **Frequencycy control range: 0 Hz to 120 Hz**
- **Overload capacity: 150% for 1 minute**

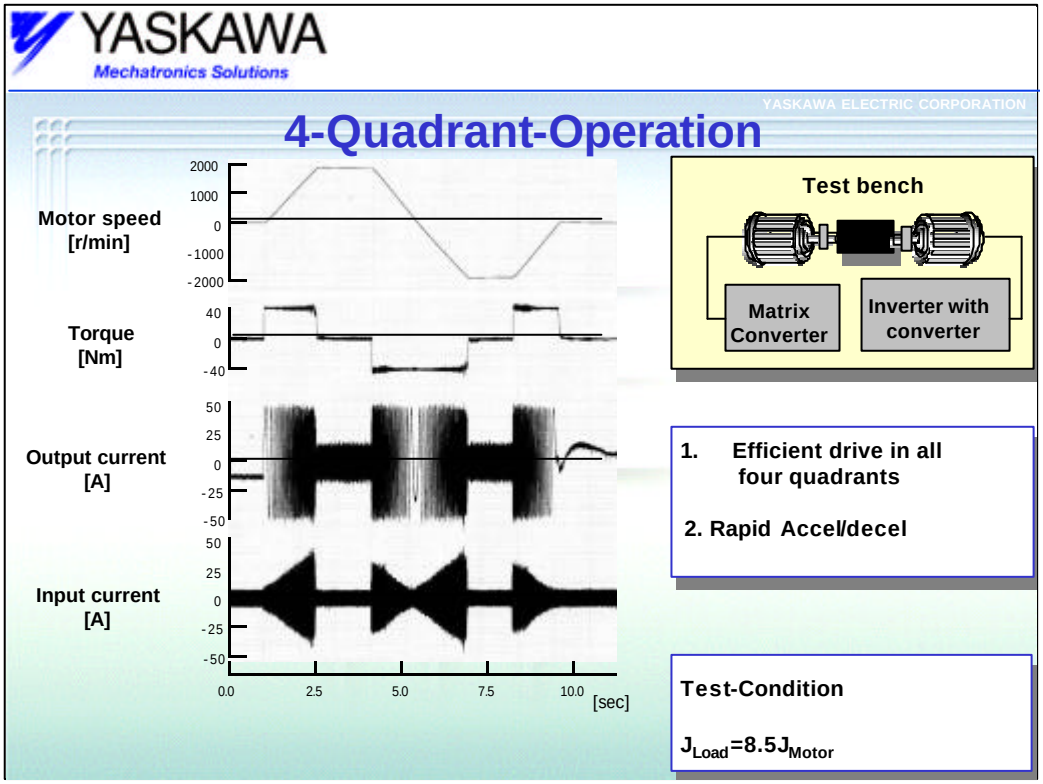
Some of the most important Specifications, which are not very different to conventional inverters. The matrix converter is build to use with asynchronous motors. The control methods are selectable. You can choose for V/f, open loop vector control or flux vector control with pulse generator. The speed control range depends from control method. The frequency control range is from 0 to 120Hz. The overload capability is 150% for one minute.



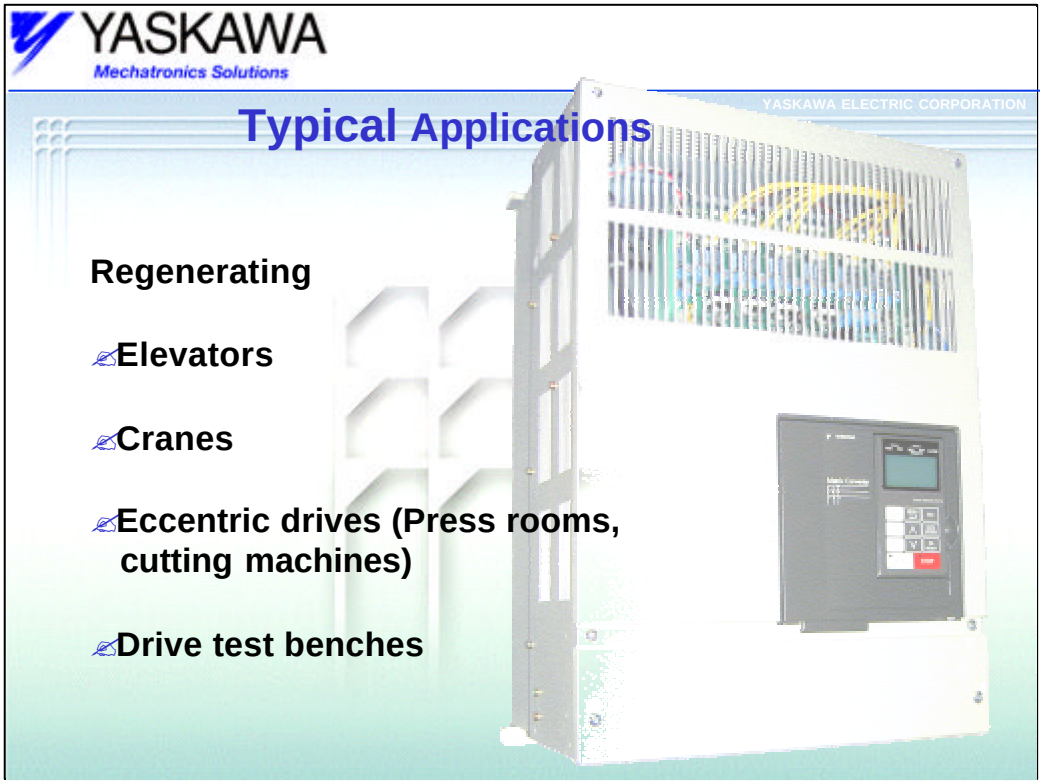
The input voltage range is the same than at conventional inverters. The capacity range is for 200 V units from 5.5 kW up to 45 kW and for 400 V units from 5.5 kW to 75 kW. The speed accuracy is the same than for conventional inverters.



Advantages of the matrix converter: Drastically decrease of the input current harmonic distortion. The typical line currents of a conventional inverter with the two current peaks, resulting from the B6 diode bridge for loading of the DC-Bus capacitors. These current peaks lead to an input current harmonic distortion of approx. 80%. The current of the matrix converter is almost sinusoidal and during load also almost in phase with the voltage. During regeneration the current is up to 180° shifted but still sinusoidal. This leads to a harmonic distortion of approx.. 8%.



A further large advantage is the regenerative operation without the need of a braking transistor or without special converter. The matrix converter is a direct inverter and feeds the regenerative energy back to the supply network without any additional equipment. Thus an efficient operation is possible in all four quadrants.



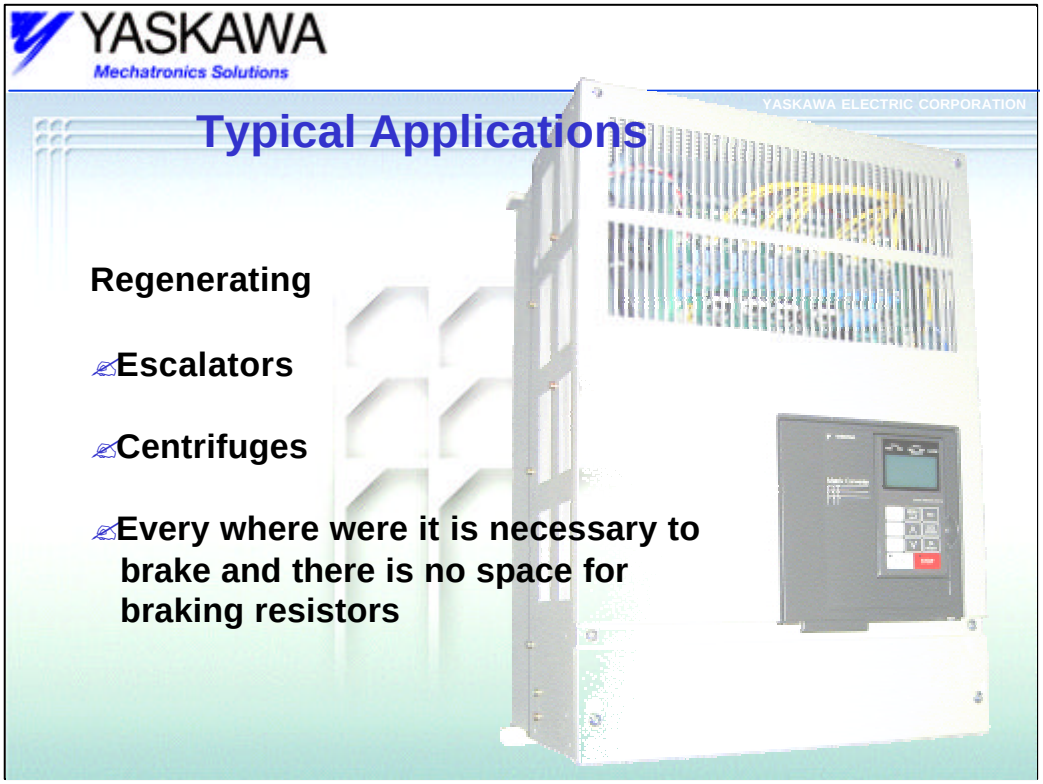
As a result of the advantages explained before the Matrix converter suits many applications such as:

•Elevators

•Cranes: while lowering the load

•Eccentric machines: presses and cutters are running in a continues cycle of motoring and regenerating.

•Test benches for engines and gear boxes: the test object running in motoring mode driving an asynchronous motor that feeds the energy back in to mains via the Matrix converter

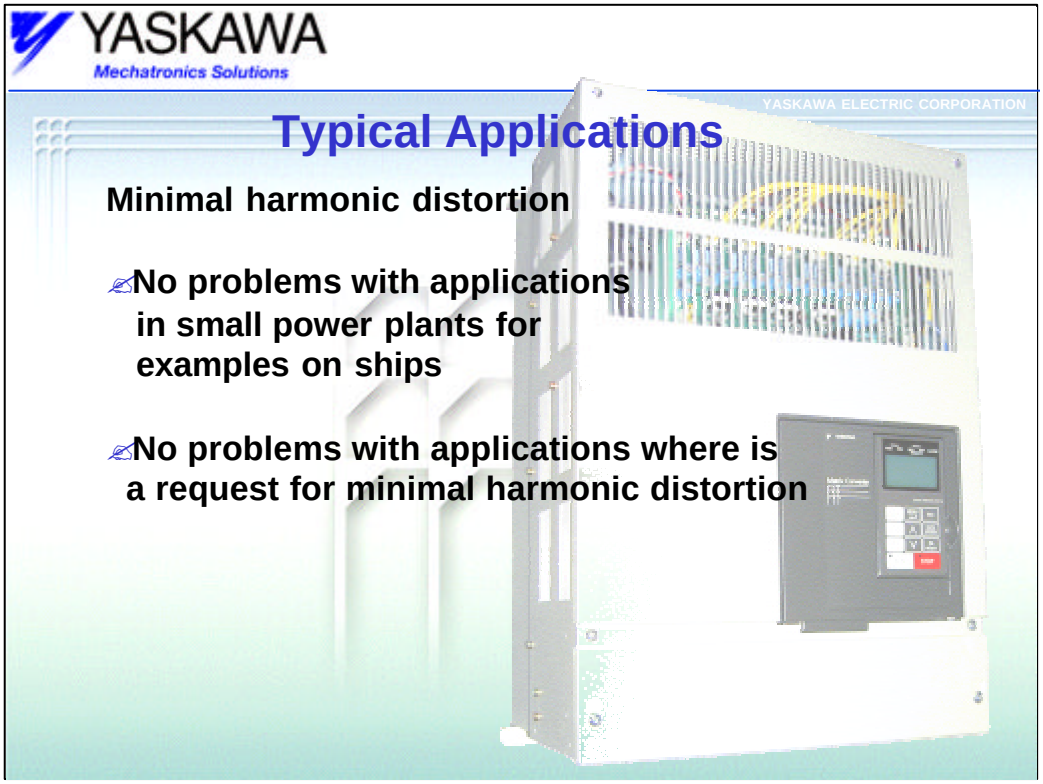


Further applications are:

•Escalators: for driving the same escalator upwards and downwards

•Centrifuges: the high inertia of centrifuge drives leads to very long deceleration times. The rational energy is feed back into the mains with full rated current of the drive which leads to a very quick and efficient stopping of the centrifuge.

•Every application, in which a heated up braking resistor will be dangerous such as textile industry e.g.



The very low harmonic distortion will increase the power quality enormously as low harmonics become more and more important.

With the Matrix converter an extremely over sizing of the equipment in isolated systems (IT) becomes obsolete as well as 12 pulse input systems with the need of costly additional transformers.

The matrix converter with the low distortion and the regenerative operation without additional braking transistor and braking resistor is where the future of drive technology goes.