YASKAWA

# Regenerative Solutions

## Make the right choice to drive electrical efficiency


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# Regenerative Methods

Maintaining highly efficient operation is important in today's industrial market. Moreover, users are searching for ways to not only make their systems operate efficiently, but also provide a financial benefit. The financial benefit is materialized in saving regenerative energy.

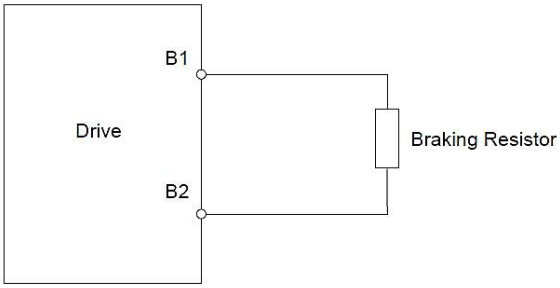
Most systems use dynamic braking resistors to mitigate regenerative energy. However, a resistor's method of regenerative energy mitigation is to burn of the energy as heat. In essence, this energy is wasted. Instead of wasting this energy many users are implementing regenerative solutions.

Regenerative solutions are safe method of directing energy back onto the line. These systems can pay back the cost of the regenerative device and the variable frequency drive (VFD) operating the motor. Common regenerative solutions include fundamental front ends, active front ends, and matrix drive technology. Each of these systems is differentiated by the benefits they provide in addition to redirecting regeneration. These additional benefits include harmonic mitigation, improved power factor, increased efficiency, simplified installation, integrated motor control, and compact size.

# Dynamic Braking Solutions

The most common method of dissipating regenerative energy is to burn it off using braking resistors. The advantage of this method is cost and possibly simplicity. Smaller drives have an extra built-in switch (IGBT) to divert the extra power to a resistor. Therefore, all you need is an external resistor to burn off the extra energy. A very simple concept, however, if you have large amounts of regenerative energy or the VFD doesn't have a built-in braking switch, then you need one or more external switches and resistors. Therefore, dynamic braking solutions can become quite complicated and expensive.

In addition to burning off the extra energy as heat, like a toaster, the heating elements presents a safety risk. If combustible materials, like wood dust, were to fall onto the hot resistor elements it could cause a fire. Also, a drive's internal brake switch used to divert the regenerative energy onto a resistor is limited in its capability. These internal brake switches are typically rated for 10% duty cycle, which means these packages can get quite large and complicated if regeneration needs to be dissipated for long durations of time.



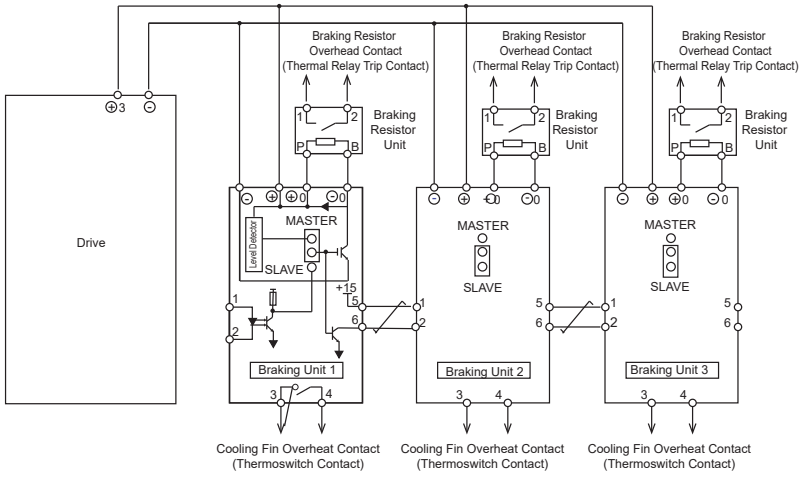

Drive with Internal Braking Switches

**Advantages**

- Cost
- Simplicity (internal only)

**Disdvantages**

- No energy savings (energy wasted as heat)
- Fire hazard
- Limited duty cycle (internal type)
- Large footprint
- Mounting location



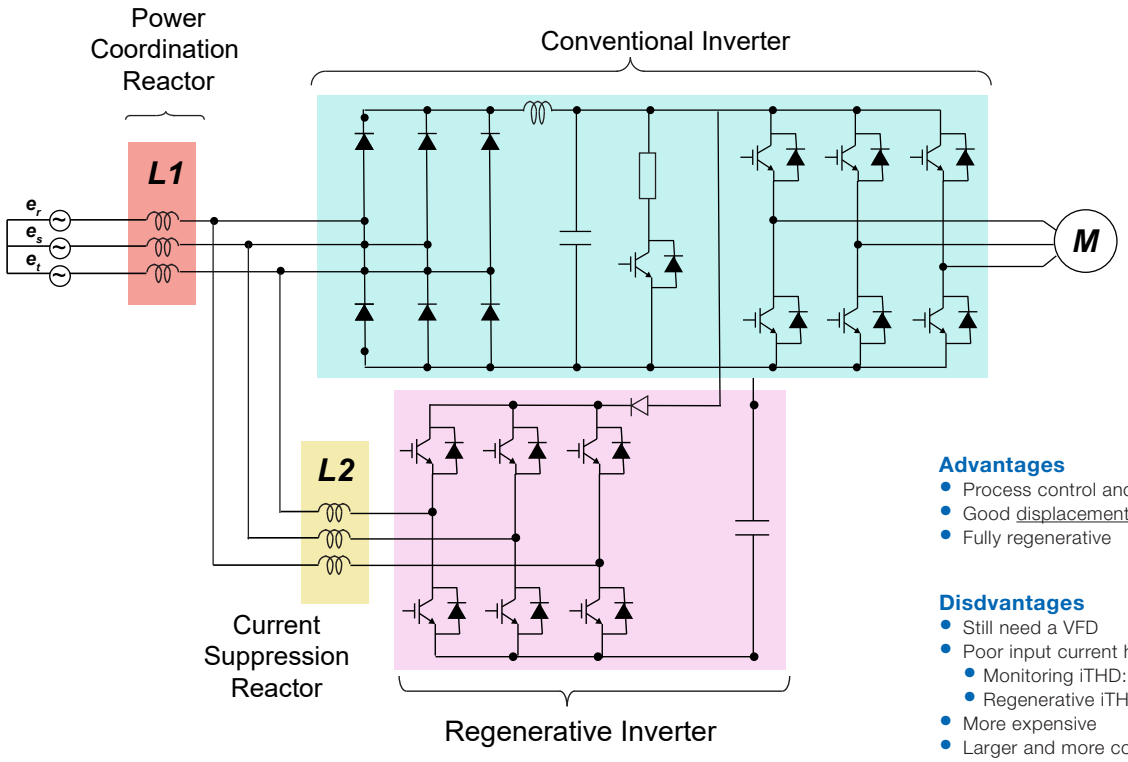

Drive with Internal Braking Switches

# Regenerative Solutions: Fundamental Front End

Fundamental Front Ends (FFE) are the first option available for saving regenerative energy. A FFEs connects to the DC bus of a VFD allowing it to redirect the extra energy back onto the line using a 6-step voltage waveform. These systems usually need a few more components than a simple dynamic braking package.

FFEs need an extra regenerative module, device protection (fusing), and input filtering (reactors). The simple 6-step regenerative waveform along with limited reactor filtering means these devices regenerate with input current harmonics of about 40% iTHD.

Also, FFEs still require a VFD to run the motor. Depending on the regenerative duty cycle, FFEs could be more expensive than a 10% duty dynamic braking package. However, FFEs quickly become a more economical solution when regenerative energy occurs for more than 20% of the application's duty cycle




**Advantages**

- Process control and energy savings
- Good displacement power factor
- Fully regenerative

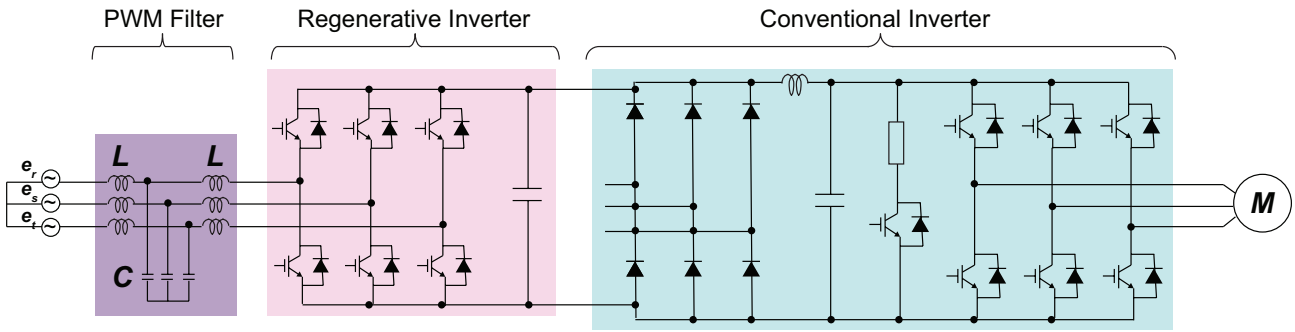
**Disdvantages**

- Still need a VFD
- Poor input current harmonics
  - Monitoring iTHD: 30-40%
  - Regenerative iTHD: 40-50%
- More expensive
- Larger and more complex
  - Reactors - Regenerative drive - Fusing
  - Wiring - Larger/additional enclosrues

# Regenerative Solutions: Active Front End

A more advanced regenerative solution is an active front end (AFE). AFEs are comprised of a regenerative converter and an input filter circuit. Unlike a FFE, an AFE is in-line with the VFD's input power.

The regenerative converter provides a DC output for the drive running the motor. This means the AFE has to regulate both motoring power and regenerative power




**Advantages**

- Process control and energy savings
- High power factor
- Low harmonics (< 5% iTHD at input)
- Fully regenerative
- Common busing

**Disdvantages**

- Still need a VFD
- More expensive
- Larger and more complex
  - Reactors - Regenerative drive - Fusing
  - Wiring - Larger/additional enclosrues

An AFE saves energy by putting the regenerative energy back onto the line. However, unlike an FFE, an AFE uses a PWM waveform to regenerate back onto the line.

The PWM waveform is then filtered using an input sine-wave filter. The higher level waveform and filtering provides a waveform with minimal input current harmonics. An AFE will keep input current harmonics to less than 5% at the input of the drive at rated power conditions.

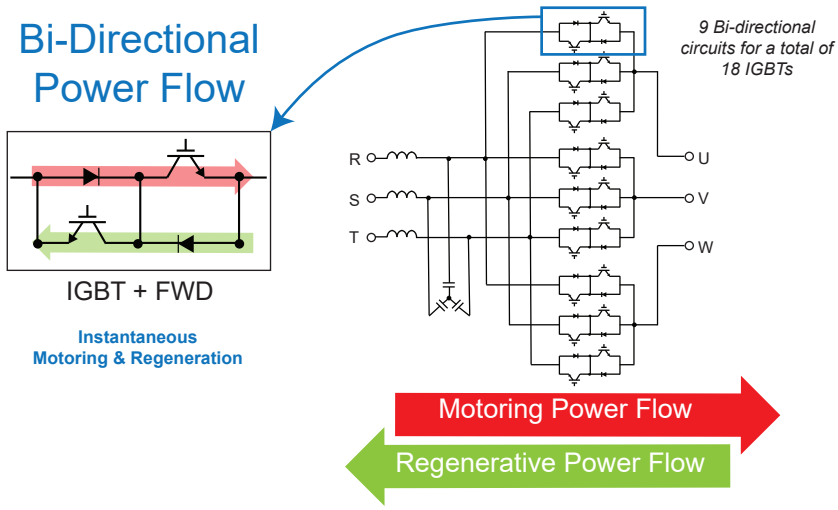
Along with the lower harmonic currents is a higher power factor. An AFE can operate near unity power factor at rated load, boosting operational efficiency. Similar to a FFE, an AFE still needs a drive to run the motor.

The adding components and wiring makes the AFE package larger and more expensive than the FFE.  The ideal use for AFE configuration is providing a common DC bus to multiple drive loads. In a common bus configuration, the AFE minimizes input current harmonics at rated load and handles the regenerative needs for all devices connected onto its DC bus.

# Regenerative Solution: Matrix Drive Technology

The final and most advanced regenerative solution uses matrix drive technology. Unlike conventional drives, matrix drive technology employs a system of nine bi-directional switches arranged in a matrix to convert a three-phase AC input voltage directly into a three-phase AC output voltage. The matrix drive's unique power conversion topology eliminates the need for a rectifying circuit (diode bridge) and DC smoothing circuit (DC bus capacitors) found in conventional AC drive inverters.

Matrix Drives inherently handle regeneration using their bi-direction IGBTs. These bi-direction switches allow for instantaneous and automatic regeneration. Matrix drive technology allows for continuous regeneration at the VFD's rated current with an additional 150% regenerative overload for 60 seconds. Wiring and installation is simplified using matrix drives due to their simple three wires in and three wires out power wiring requirements.




**Advantages**

- Continuous power regeneration
- Low input current harmonics
- Near unity power factor
- Higher system efficiency
- Compact design
- Across-the-line operation (eco mode)

An AFE adds components to reduce input current harmonics. However, matrix drives draw low harmonic current naturally as they operate the motor. That's right, matrix drives operate the motor. No need for an additional device to operate the motor. The capability to run the motor and handle regeneration is already built into matrix drives. Not only do matrix drives have low harmonics at rated load to facilitate IEEE 519 compliance, they continue to draw current with low harmonics throughout the load profile. Lower harmonics means higher power factor throughout operation and near unity power factor at rated load. Higher power factor and lower input current harmonics allows the matrix drive to operate more efficiently than a combined AFE and VFD solution.

## Conclusion

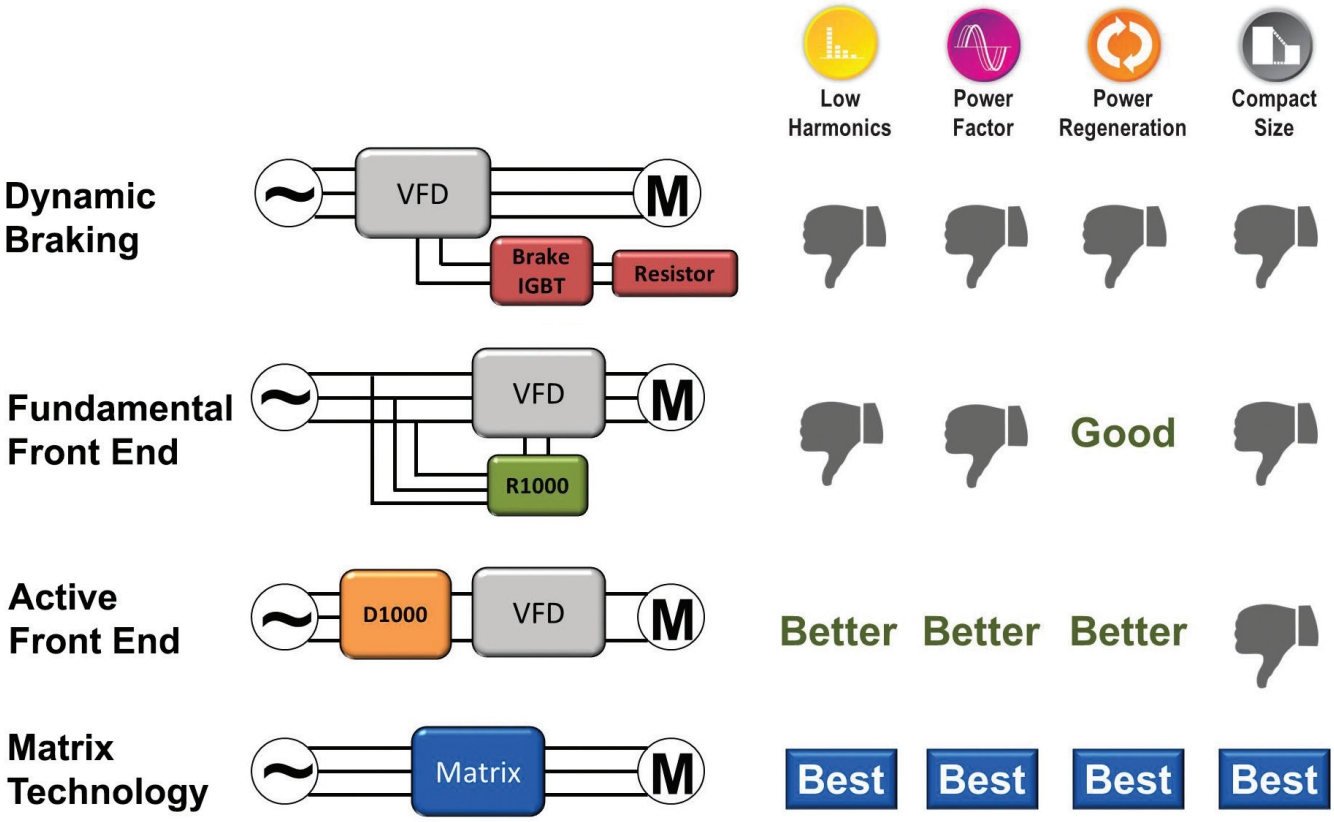
There are many solutions available to handle regenerative energy. So, which solution is best? It all depends on the additional needs of the application.

Braking resistors, FFEs, AFEs, and matrix drive technology all handle regenerative energy. Braking resistors are ideal for light regenerative applications such as a forced deceleration that only occurs during an emergency conditions (E-Stop). In these cases, energy savings will never be present in sufficient quantities to pay-back the cost of more advanced regenerative solutions.

However, if regeneration occurs more often, then the braking resistor packages can be quite large. These packages will always burn off the extra energy (nothing is saved) and they do not provide improved power factor or lower harmonics. FFE packages regenerates the energy back onto the line and save energy. They are the next best solution for regeneration. However, they can be larger than braking packages and they do nothing for improving power factor and lowering current harmonics.

AFE's offer the next best regenerative solution by providing low input current harmonics and a high power factor. However, they are more expensive, larger, and more complicated than FFEs. AFEs are ideally suited for common bus configurations.

Matrix drive technology provides the all-around best solution. Matrix drives provide a low harmonic, high power factor, highly efficient regenerative solution in a simple, easy to install, and compact configuration.

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