PowerFlex 7000

Allen-Bradley

Technical Data

Medium Voltage Variable Frequency Drive
with Active Front End (AFE)

Rockwell Automation has advanced power conversion technology with Current Source topology using an active front-end, called a PWM (Pulse Width Modulated) Rectifier. This is a particularly attractive option for applications with new motors since it does not require an isolation transformer to meet IEEE-519 and EN61000-2-4 harmonic standards. Most available technologies in today's MV drive market require a multi-winding transformer to mitigate the unwanted harmonics through cancellation by phase shifting the transformer secondary windings.

The PWM rectifier requires a simple three phase input from the customer power supply. While an isolation transformer is not normally required, it can be configured to reduce the higher system voltage to operating voltage level based on the inverter and motor operation voltage. A simplified electrical diagram shows this type of configuration for a 4160 volt drive with Active Front End rectifier. Line reactors are normally used if the supply voltage meets the operational drive voltage and if new motors are supplied.

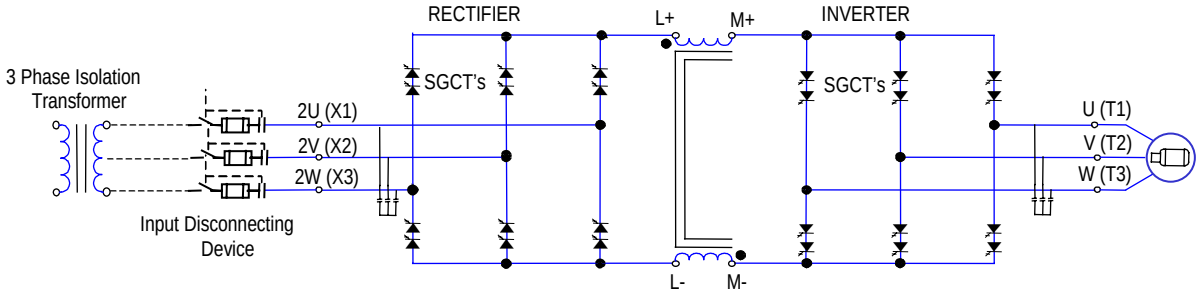

Figure 1 – 4160 Volt Drive with Isolation Transformer and Active Front End Rectifier

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The Active Front End rectifier switching pattern uses a similar control algorithm to the inverter. The pattern used is a 7-pulse selective harmonic elimination (SHE) pattern, which eliminates the 5th, 7th and 11th harmonics. Figure 2 shows the typical rectifier switching pattern with 7-pulse with a single phase representation. This switching pattern is repeated for all three phase shifting 120 electrical degrees. The duration of the on state time will then determine the controlled rectifier voltage to the dc link.

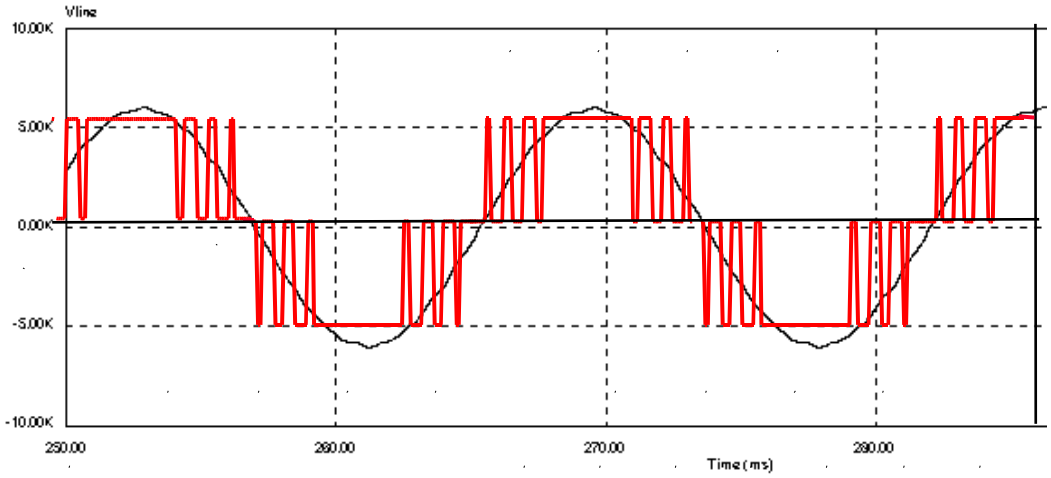

Figure 2 – Typical Active Front End Rectifier Switching Pattern

The drive has a defined firing and applies the above firing pattern to three phases. The drive rectifier has the following firing order: 1, 2, 3, 4, 5, and 6 with the bridge hardware correct hardware configuration as outlined in Figure 3. As shown the 4160 V rectifier uses two (2) - 6500 volt power devices in series to achieve the proper electrical peak inverse blocking margin of 13000 volts for each leg.

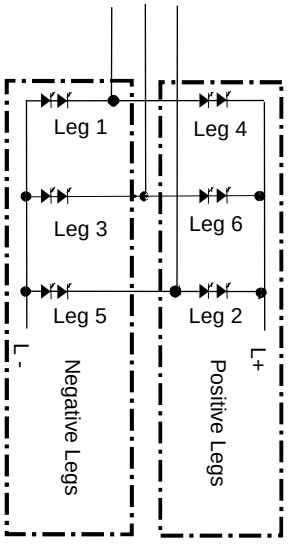

Figure 3 – 4160 V Rectifier

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The input capacitors connected at the input with the rectifier are designed to reduce the higher frequency current harmonics. The inductance/capacitor resonant frequency is placed below 300 Hz where no characteristic harmonics exist. This prevents the excitation of system harmonic frequencies. The capacitor is selected such that a high input power factor is achieved. In most cases a line reactor can be used to provide the required design impedance, giving additional current limiting features to a line side short circuit fault. When operating from a power source that does not require voltage matching to the drive rating, a simple line reactor configuration can be adopted. (See Figure 4)

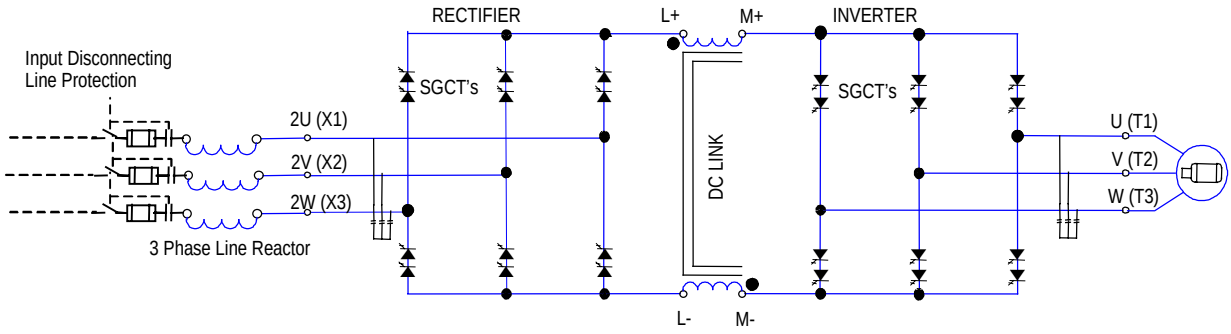

Figure 4 – 4160 Volt Drive with Line Reactor and Active Front End Rectifier

The rectifier input current and voltage waveforms are shown in Figure 5. A current Total Harmonic Distortion (THD) of approximately 5.0 % is achieved. The voltage distortion is based on the customer's maximum short circuit rating (I_{SC}) and maximum demand load current (I_L). With a ratio of 20, the voltage distortion will be less than 3%.

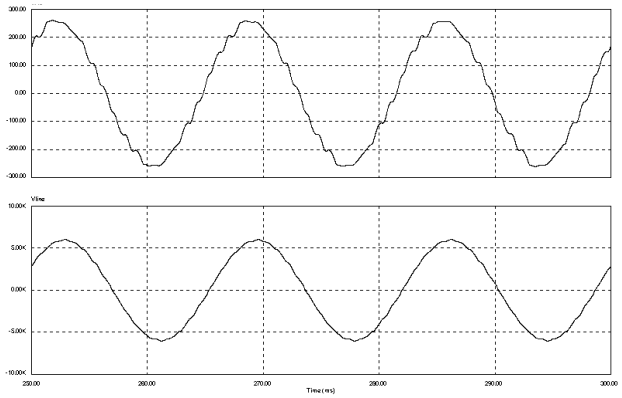

Figure 5 – Active Front End Line Input Waveforms

(Top to bottom: line current and line-to-line voltage at the input of the drive).

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Comparison of Rectifier Types

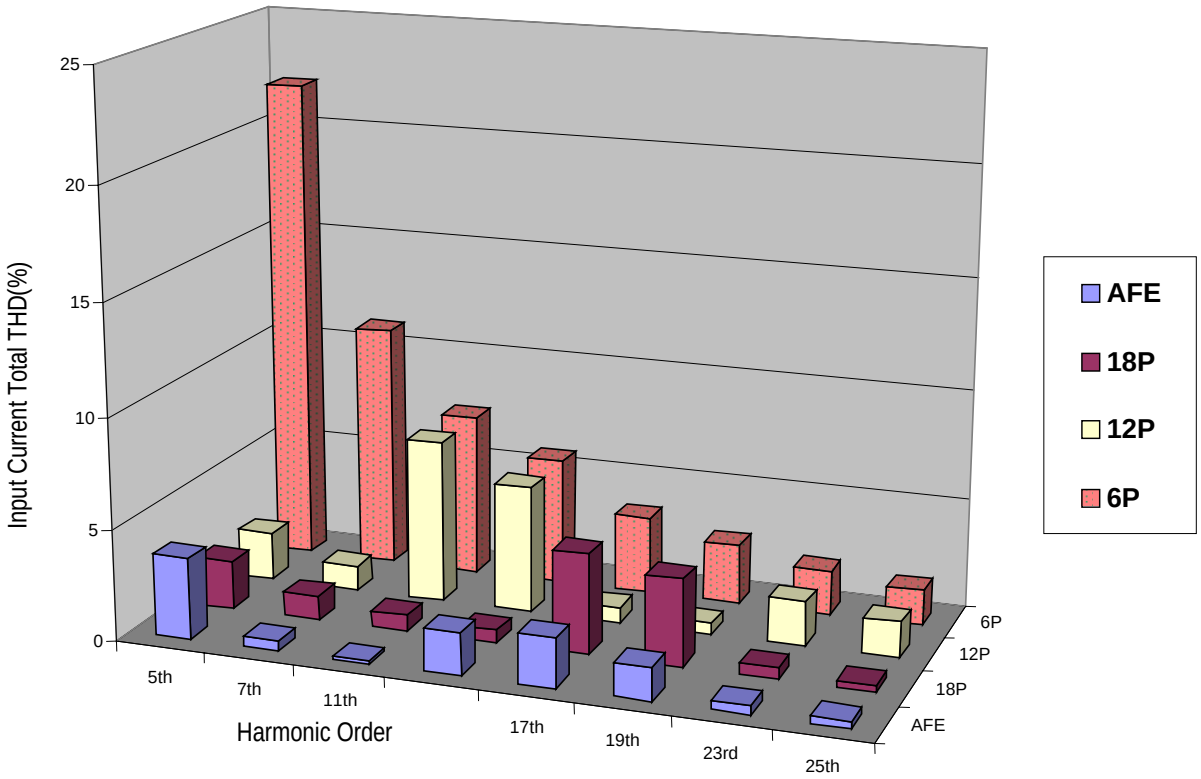

Figure 6 - Input Current Total THD (%) for different rectifier types

Rectifier Type	Total THD
AFE	4-5%
18 Pulse	5-6%
12 Pulse	8-11%
6 Pulse	25-27%

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Comparing the harmonic tables of the different rectifier topologies gives a very quick overview of the individual harmonics produced by different rectifier designs. By comparison the pulse width modulated rectifier provides much lower harmonics when calculating the total harmonic distortion (THD) of all the individual harmonics.

Table B – Harmonics of the different rectifier topologies

Converter Pulses	Harmonic Order								THD
	5	7	11	13	17	19	23	25	Up to 49th
6	0.175	0.110	0.045	0.029	0.015	0.009	0.009	0.008	27.0%
12	0.026	0.016	0.073	0.057	0.002	0.001	0.020	0.016	11.0%
18	0.021	0.011	0.007	0.005	0.045	0.039	0.005	0.003	6.6%
AFE	0.037	0.005	0.001	0.019	0.022	0.015	0.004	0.003	5.0%

Active Front End Rectifier Advantages:

- Simple three-cable entry and exit as compared to low harmonic alternatives using phase shifting transformers that would require at least 9 secondary transformer cables in an 18-pulse configuration to be equivalent in compliance to IEEE 519 -92, EN61000-2-4 and G5/4.
- Line impedance device can be an isolation transformer if the supply voltage of the power system does not match the drive and motor operating system.
- Integral pre-wired line reactor in the AFE drive results in a lower installation cost compared to a phase shifting transformer.
- Efficiency comparison of line impedance device yields increased energy savings. Most line reactors have 99.8% efficiency as compared to phase shifting isolation transformers that are approximately 98.5% efficiency designs. If transformers are installed indoors this results in additional (HVAC) air conditioning requirements. When transformer versions are used, the transformer efficiency is closer to 99.0% due to the lower harmonic content from a PWMR drive.
- True input line power factor is maintained to near unity (> .97) throughout a wide load range (30 to 100%).
- Commonality of rectifier and inverter power devices allows for a reduction in maintainable spares.
- No requirement for a specialized relay for line side transformer protection. Most multi-pulse phase shifting transformers require a specialized line protection relay to protect all the transformer secondary windings.
- Lower component count as compared to most other rectifier technologies.
- Most voltage source inverters require at least an 18-pulse converter technology to meet the IEEE-519-92, EN 61000-2-4 and G5/4 harmonic guidelines regardless of the power system short circuit rating. This always results in a specialized phase shifting power transformer.

With the development of the Active Front End Rectifier, Rockwell Automation once again underlines its innovative strength and capability to provide customers with Advanced Vector controlled drives. This results in having line friendly input waveforms with lower total harmonic distortion.

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