White Paper

Multi-Pulse Rectifier Solutions for Input Harmonics Mitigation

Applicable Product: F7, G7, P7 and E7

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INTRODUCTION

Adjustable speed AC drives are mainly made up of two power sections, i.e., a rectifier section and an inverter section. The AC source voltage is converted into a DC voltage by the rectifier circuit, and then the DC voltage is converted again into a PWM controlled variable voltage AC output by the inverter circuit. The six-diode bridge rectifier is most widely used as an AC-to-DC converter. This diode rectifier has a nonlinear (i.e. non-sinusoidal) load characteristic causing harmonic currents flow into the power source and results in line voltage distortion. Excessive harmonics in a power source raise many practical problems such as;

- The rms current increase and input power factor reduction
- Overheating of grid-connected motors, cables, transformers, and other distribution equipment
- Resonating and harmonic heating of the power factor correction capacitors
- Nuisance tripping of the thermal circuit breakers
- Malfunction of PLCs, computers, and other harmonics sensitive equipment.

The Yaskawa E7,F7,G7, and P7-series drives above 30HP have a built-in DC link choke as a standard easily mitigating input current harmonics. In case of six-diode bridge rectifier, the input current Total Harmonic Distortion (THD) is approximately 40% at a full load condition. The harmonic currents can be further reduced to about 30% with the addition of input AC reactors in combination with a DC link choke. For further harmonics reduction, multi-pulse rectifier topologies are good practical solutions, which reduce input current harmonics to levels below 10%. This paper introduces general features and advantages of Yaskawa's multi-pulse solutions that include 12-pulse and 18-pulse rectifier topologies.

6-PULSE RECTIFIER

The 6-pulse rectifier circuit is adopted in most AC drives because of its simple and low cost structure. However, at full load conditions, the input current THD can exceed 100% with no harmonic filter with the 5^{th}, 7^{th} and 11^{th} harmonics being the dominant harmonic components. Figure 1 shows a six-diode bridge (six-pulse) rectifier with a DC link reactor (DCL) and the input current waveform. Yaskawa drives above 30HP have a built-in DC link choke as a standard, and input current THD is approximately 40% at full load conditions. If additional input AC reactors are combined with the DC link choke, the harmonic currents can be further reduced to about 25%. Practically, there are limitations in reducing the THD below 30 % due to increasing AC reactor size and line voltage drop.

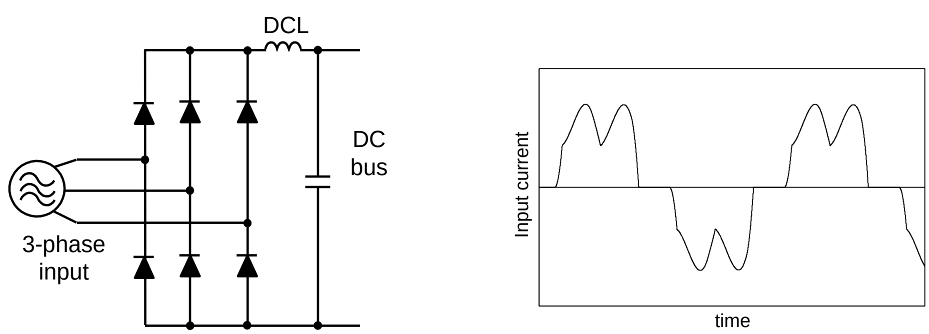


Figure 1. A 6-pulse rectifier power circuit and an input current waveform

12-PULSE RECTIFIER SOLUTION

The Yaskawa drives above 30HP have a built-in DC link choke and a 12-pulse rectifier as standard. The Yaskawa 12-pulse rectifier solution consists of two 6-pulse diode bridges combined with a multi-phase transformer. The output of two diode bridge rectifiers can be connected in parallel through a DC link choke as shown in figure 2 or separately connected to two isolated drives. The multi-phase transformer can be an autotransformer or an isolated transformer with 30° displacement to provide two three-phase voltage sources that cancel the 5^{th} and 7^{th} harmonics. Figure 2 shows a 12-pulse rectifier with a delta-delta-wye isolation transformer and the resulting input current waveform where 11^{th} and 13^{th} harmonics are the dominant harmonic components. The input current THD of about 10% can be achieved. However, the values can vary depending on the source voltage distortion and imbalance.

Two 30° displaced three-phase voltage sources can be achieved by several different approaches that include ;

- a phase-shifting isolation transformer such as a delta-delta-wye or a Zig-Zag transformer
- a phase-shifting autotransformer
- a combination of a half-power transformer and a series reactor directly fed from power source (hybrid 12-pulse).

Each approach has different features and performances. For example, the autotransformer method is a good solution to feed two separately isolated drives. The isolated transformer has the best performance, but is relatively bulky and expensive. Yaskawa provides the best solution which takes into consideration many aspects that include ; customer’s power system environment, input harmonics requirements, EMI noise, and cost, etc.

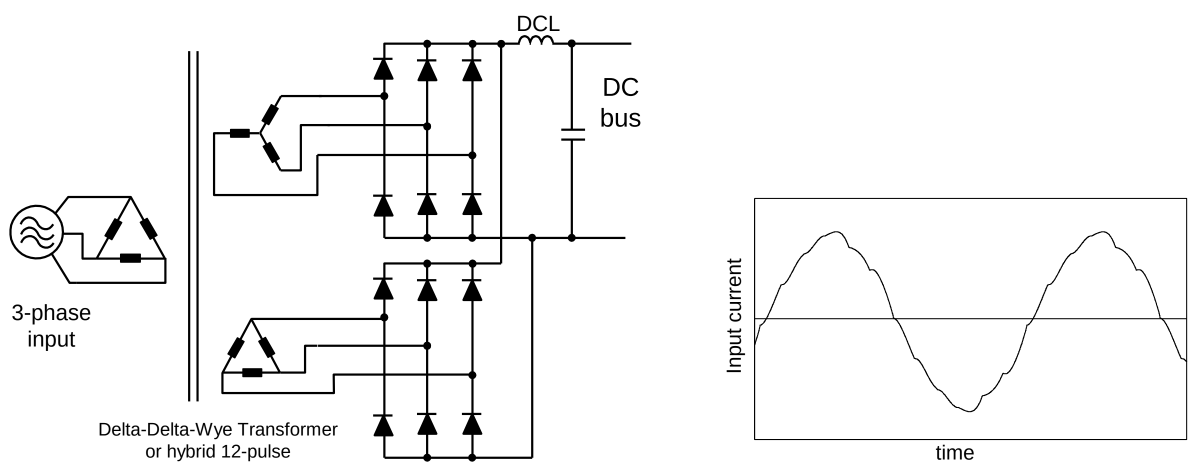


Figure 2. A 12-pulse rectifier power circuit and an input current waveform

18-PULSE RECTIFIER SOLUTION

The 18-pulse rectifier topology consists of a multi-phase transformer and three 6-pulse diode bridges, the output of which are connected in parallel through a DC link choke as shown in figure 3 or separately connected to three isolated drives. In the theoretical 18-pulse system, the three phase-shifted voltage sources connected to the three 6-diode bridges will cancel the 5^{th} , 7^{th} ,11^{th} ,and 13^{th} harmonics and the remaining dominant harmonic components are the 17^{th} and 19^{th}. The multi-phase transformer can be an autotransformer or a phase-shifting isolation transformer with 20° displacement used to provide three three-phase voltage sources that cancel the 5^{th}

, 7th ,11th ,and 13th harmonics. In many cases, a phase-shifting autotransformer is a practical approach when considering the size and cost. If additional input AC reactors are combined with the 18-pulse rectifier, the input current THD is about 5%; however, this can vary based on voltage source distortion and imbalance. This 18-pulse rectifier solution complies with IEEE-519-1992 standard at the equipment level.

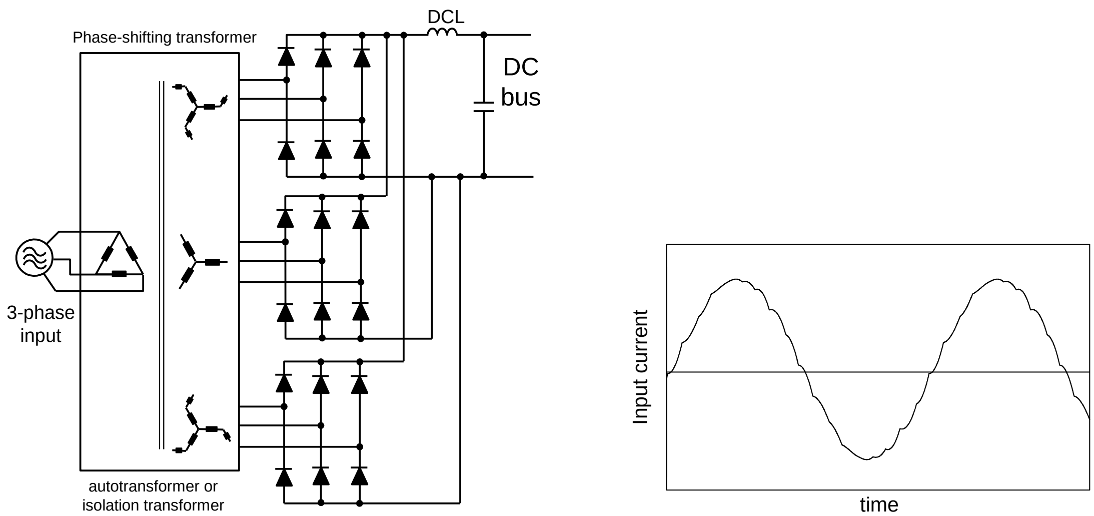
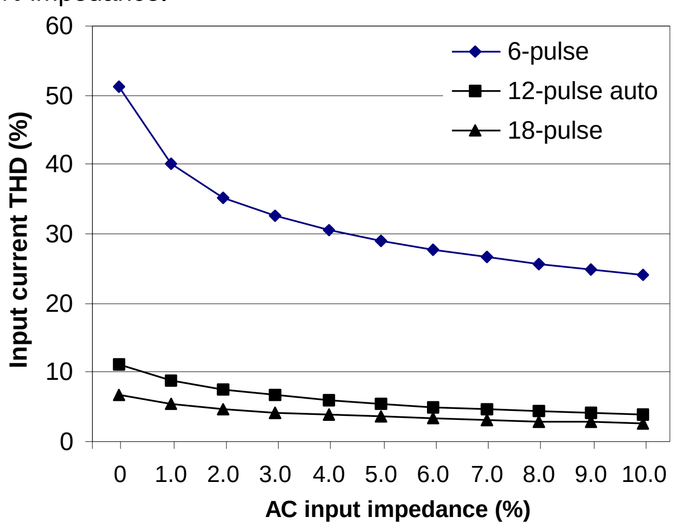


Figure 3. A 18-pulse rectifier power circuit and an input current waveform

MULTI-PULSE RECTIFIER PERFORMANCE

Figure 4 shows the effect of increasing the AC input % impedance on the input current harmonics. The 6-pulse rectifier cannot reduce the input current THD below 25 % even with an input AC reactor with 10% impedance. However, the 12-pulse and 18-pulse rectifiers can achieve an input current THD of less than 10% with the addition of an input AC reactor of 1-2% impedance.



Note : Values may vary depending on the power system environment.

Figure 4. Input current THD according to the rectifier types, input AC reactor size, and a 3% DC link choke.

Figure 5 shows the input current THD of three different rectifier topologies according to the short circuit current ratio of the power distribution system at the PCC [1] assuming all nonlinear loads. IEEE 519-1992 distortion limits are a guideline for the total current THD at the PCC. Thus, linear (i.e., sinusoidal) loads in the distribution system will reduce the THD value at the PCC. Figure 6 shows the input voltage distortion created by the harmonic currents that flow into power source. As can be seen from Figures 4-6, the 12-pulse and 18-pulse rectifier solution provides good harmonic reduction. Especially figures 5-6 show that the18-pulse rectifier complies with IEEE 519-1992 distortion limits in most cases if the voltage distortion and imbalance are negligible.

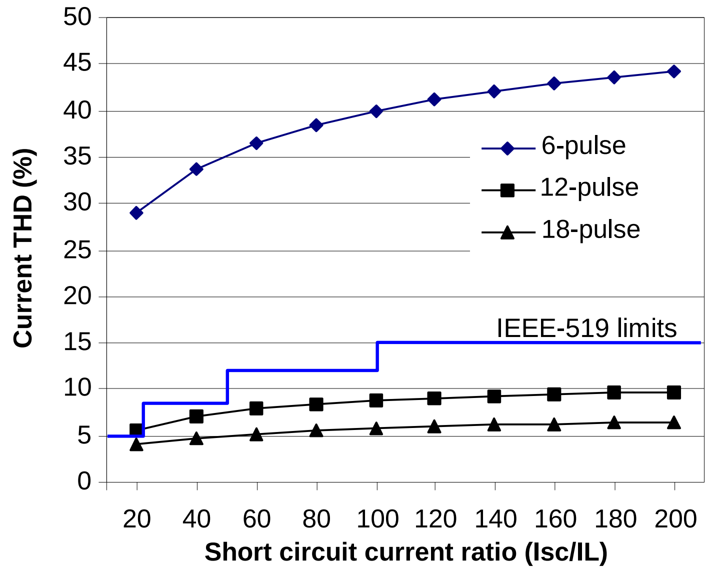
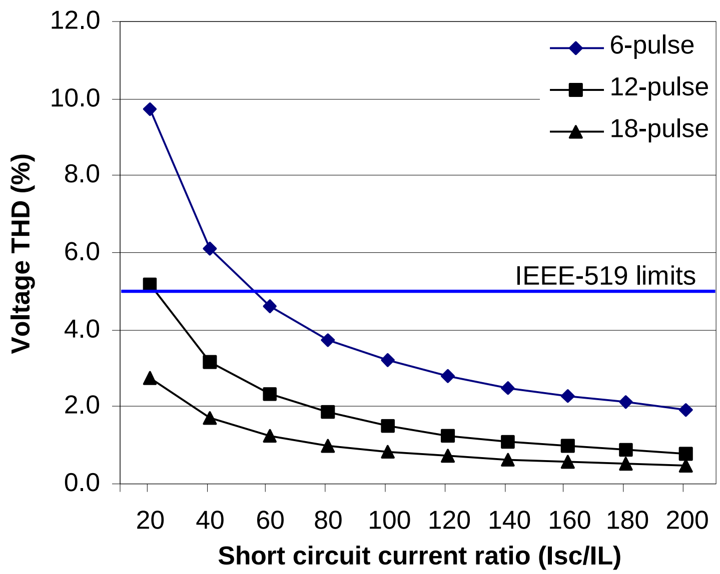


Figure 5. Input current THD according to the rectifier types, the short circuit current ratio, and a 3% DC link choke.



Note: Values in figures 6-7 may varies in figures 6-7 may vary depending on the power system environment.

Figure 6. Input voltage THD according to rectifier type, the short circuit current ratio, and a 3% DC link choke.

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SUMMARY

Yaskawa provides multi-pulse input current harmonics mitigation solutions. The 6-pulse diode rectifier on Yaskawa drives above 30 HP have low input current harmonics of about 40% due to a built-in DC link choke. The combination of the built-in 12-pulse rectifier and a DC link choke circuit from 30 HP above also help to easily implement the12-pulse rectifier solution. Both 12-pulse and 18-pulse solutions can effectively reduce the input current THD to less than 10% when combined with an additional input AC reactor. The18-pulse rectifier has a input current THD of about 5% and it provides a solution that complies with IEEE 519-1992 standard at the equipment level if input voltage imbalance is negligible.

■ Table 1. Multi-pulse Rectifier Comparison

Rectifier type	Input current THD *1	Remarks
6-pulse with no DC link choke	110 %	High input rms current and large harmonic components.
6-pulse with *2 DC link choke	40 %	Simple and low cost but large 5^{th},7^{th} , and11^{th} harmonic components.
12-pulse *2 (package)	10%	Relatively low harmonics. 11^{th} and13^{th} harmonic components are dominant.
18-pulse (package)	5%	Very low harmonics. Compliance with IEEE 519-1992 standard.

*1 Values may vary depending on the power system environment.

*2 The 6-pulse and 12-pulse rectifier with built-in DC link choke are standard on Yaskawa drives 30HP and above.

REFERENCE

1. IEEE519 working group web site : Go to http://grouper.ieee.org/groups/519/
2. IEEE-Std 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, IEEE Inc., New York, NY, April 1993.
3. Yaskawa Electric America, “Power line harmonics and installation considerations for AC and DC drives,” Go to https://www.yaskawa.com/links?type=documents&docnum=AN.AFD.04&name=