International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 17 (2015) pp 38500-38503

Harmonic Distortion Control technique in Adjustable Speed Drives

Ali A. Abdulzahra[1], R. T. Mohamad[1], Ghassan J. K.[1], Ali K. S.[1], Saif T. H.[1], Hadi F. H.[1], Dawood S. Ahmed[1], S. H. M. Shahril[1], A. A. Zulkefle[1], R. Omar[1], W. A. W. Adnan[2, 3]

[1]Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[2]Department of Computer and Communication Engineering, Universiti Putra Malaysia, 43400 UPM-Serdang MALAYSIA

[3]King Abdulaziz University, Abdullah Suleiman Street, Al Jamiaa District, 80200 Saudi Arabia.

Corresponding author: mohamadrom@utem.edu.my

Abstract- This paper presents a harmonic mitigation technique available to solve harmonic problems in ASDs and provides an explanation of the various harmonics produced by them. In this paper we have described the application of Line Reactor Approach in order to mitigate harmonics in ASDs which is considered the most effective and easiest way to reduce harmonic in ASDs and to improve their performance.

Keywords: Harmonics mitigation, Adjustable Speed Drives (ASDs).

Introduction

Issues related to harmonic currents are already discussed in [2]. However, the cumulative effect has the capability of causing serious harmonic distortion levels especially for large loads. The major causes of current distortion are nonlinear loads due to adjustable speed drives (ASDs), fluorescent lighting, rectifier banks, computer and data-processing loads, arc furnaces, and so on [2]. In this paper we will discuss and analyze the types of harmonics produced by (ASDs) and the ways of mitigating them.

Adjustable Speed Drive

From [1] and [2], we can recognize that 3^{rd}, 5th, 7th, and 9th harmonics are significant in ASDs. For obvious reason, the ASDs are meant to save electrical energy.

Harmonic Mitigation Techniques in ASDs

The following topologies as in Fig. 1 of high pulse converter are used to reduce the harmonics by the phase shift transformers:

All the connections of ASDs produce less harmonic currents than the conventional ones due to the phase shift between the identical current components drawn by each ASD, therefore the resultant current in the main input line will be much better and have lower harmonic components [3]. The following table provided by ABB company lists the total harmonic distortion produced by each type of high pulse drives. Typical total harmonic distortion of high pulse drives can be seen in Table 1.

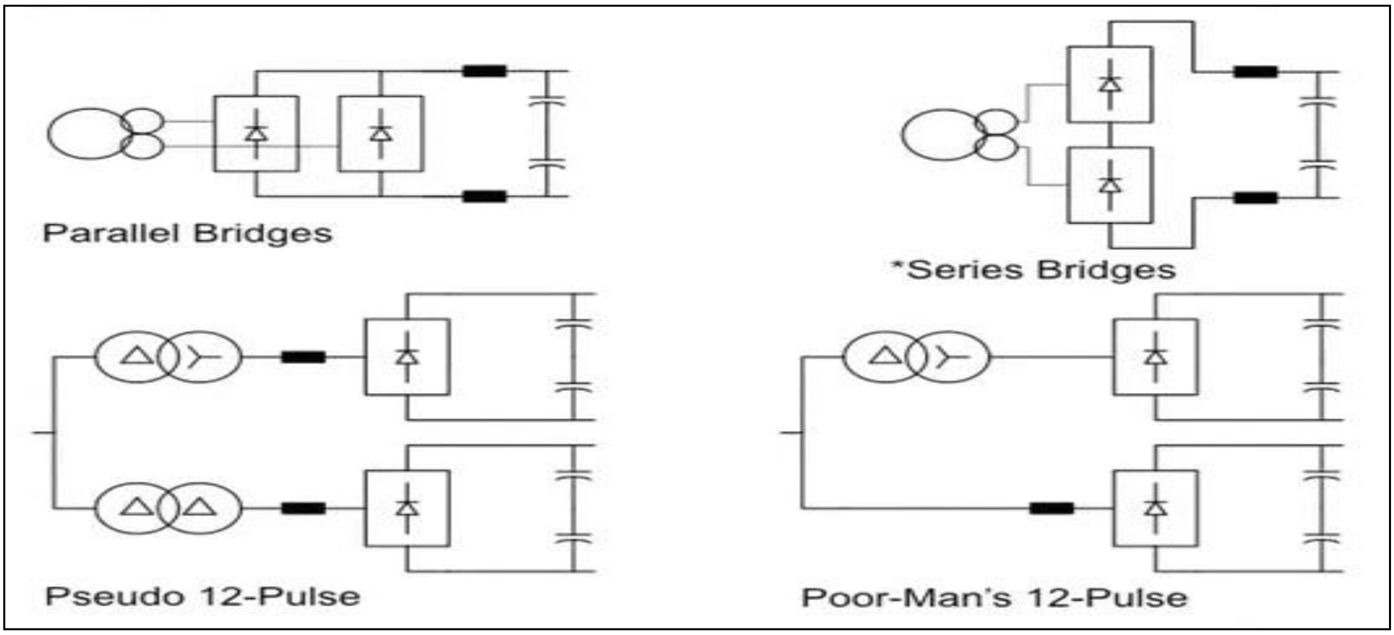
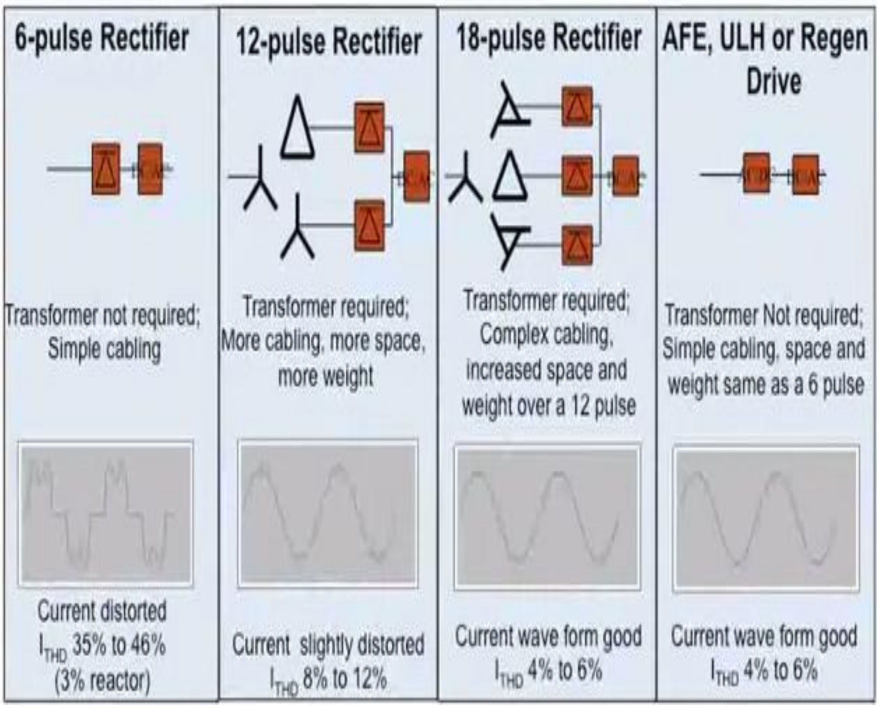


Fig.1. Topologies of High-Pulse Inverter [2]

TABLE 1. Total Harmonic Distortion of High-Pulse Drives [2]



6-pulse Rectifier	12-pulse Rectifier	18-pulse Rectifier	AFE, ULH or Regen Drive
Transformer not required; Simple cabling	Transformer required; More cabling, more space, more weight	Transformer required; Complex cabling, increased space and weight over a 12 pulse	Transformer Not required; Simple cabling, space and weight same as a 6 pulse
Current distorted I_{THD} 35% to 46% (3% reactor)	Current slightly distorted I_{THD} 8% to 12%	Current wave form good I_{THD} 4% to 6%	Current wave form good I_{THD} 4% to 6%

A. Use of isolation transformer

As in Fig. 2, the waveforms of the branches and the input line of pseudo 12-pulse [1] are as below:

The above connection of pseudo ASD includes connection of two transformers. One of them is delta\delta and the other is delta / star transformer which provide a 30 degree phase shift on the primary side [6]. This results in the resultant current of sum the bothe currents drawn by the ASDs in the PCC point much better and has lower distortion.

B. Use of line reactors

It considers the simplest and lowest cost for harmonics mitigation technique in case of small loads. The connection of them is as shown in Figure 3 below:

There are two feasible locations for the reactor: we can connect it in the line input of ASDs or connect it with the DC bus bar near the capacitor [5]. Use of reactors considers very effective to reduce the harmonic and voltage regulation and also provides better input protection because it will add a series reactance to the load and decreases the load current. However, the main problem it may cause important voltage drop due to the load current.

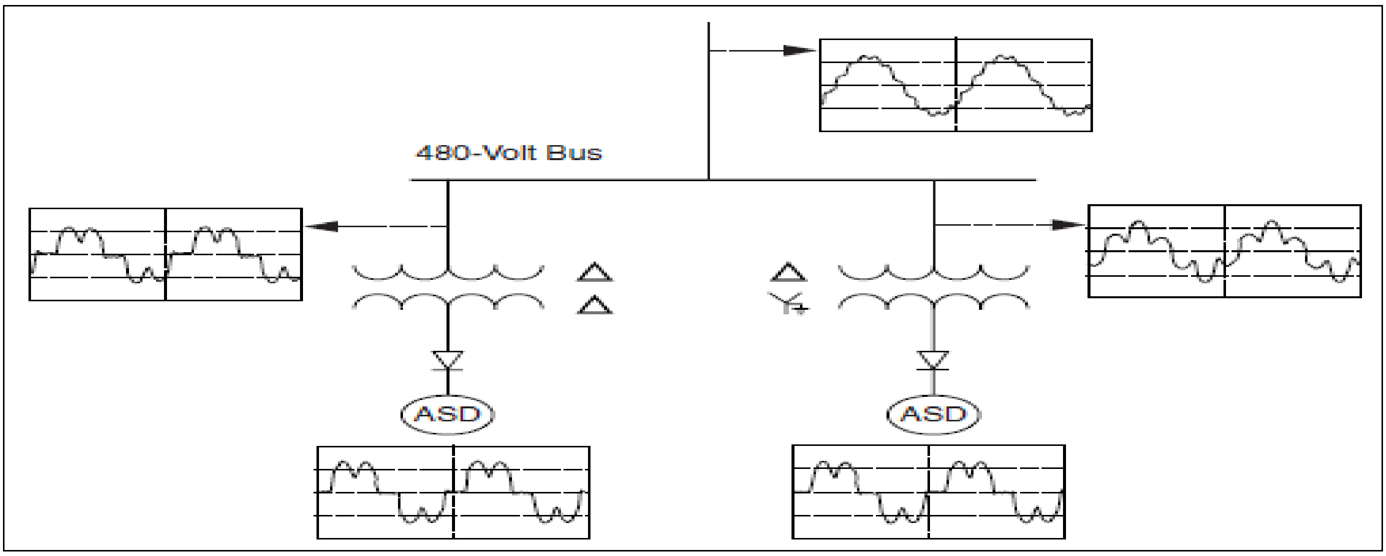


Fig.2. Current waveform of pseudo 12-pulse with two transformers [2]

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 17 (2015) pp 38500-38503

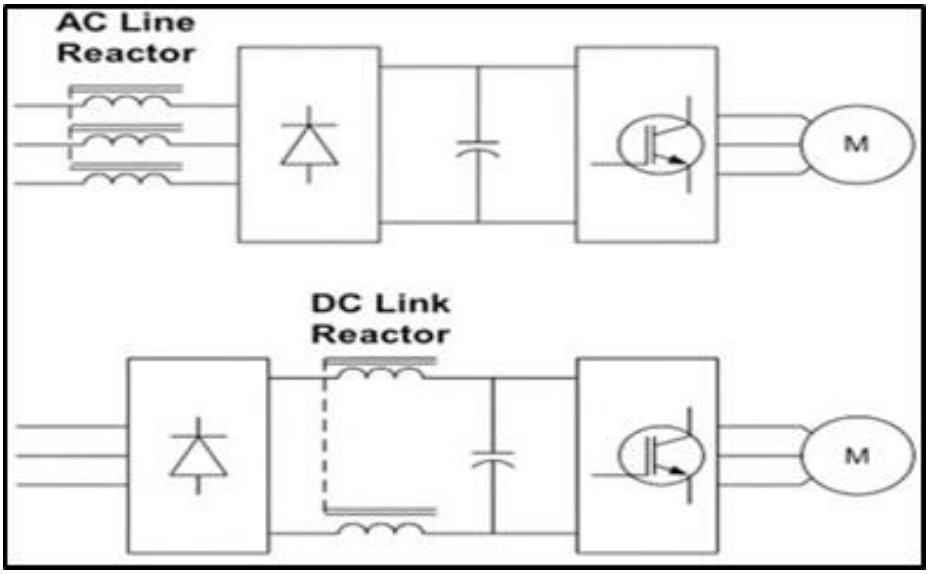


Fig.3. AC and DC line reactors [2]

The following chart as in Figure 4 shows us the characteristic curves of line reactor and the effect of percent ASD's capacity with respect to the source transformer. From the graph below, we can recognize the ITHD reduces from 120% to 45% when use the reactor. By considering the ASD capacity to the power transformer, when the size of the ASD increases from 5 percent to 30 percent of the transformer, the current THD drops from 120 to 35 percent.

Advantages and Disadvantages (Line Reactor vs. Isolation Transformer)

TABLE 2. Comparison between Reactor and Isolation Transformer (courtesy of ABB presentation)

Advantages (line reactor)	**Disadvantages (isolation transformer)**
Reduce harmonic currents	Expensive - 250% more than reactor solution
Reduce drive input currents	Size- separate floor mount 400% or more larger than reactor solution
Electrically isolate drive from the system	Consumers power – draw magnetizing current even with drive off
Provides neutral connection for the system	Adds heat to room
Suppresses voltage transient	
Provides voltage matching	
Compensate unbalance line current	
Reduces transfer of common & differential mode impulses	
Highly reliable (passive solution)	

Results and Discussion

The data used in this analysis is obtained from [7]. Let us assume the data for the transformer supplying power to the ASD provided by ABB is as the following:

High-side Voltage -Y: 12.47-kV/7.2kV;
Low-side Voltage -*Y:* 480-Vl277-V;
Power rating: 1500-kVA.
% Impedance: 5.93 %.
Actual Load current: 507.0883A.

From the above data, the short-circuit current on the secondary-side of the transformer, **assuming an infinite bus** is calculated to be:

$$I_{sc}=\frac{1500*1000}{\sqrt{3}*480*0.0593} = 30.4253\,kA$$

For PCC at the secondary side: $I_{sc} / I_L = 60$
Since the Average Load current is 1804.2195A, then the percentage of loading is 28%.
The following results with assuming 100% non- linear loading of ASD

TABLE 3 Calculated TDD based on the ABB's THD values.

Technique	**THD (current) %**	**TDD (current) %**
No mitigation	72 %	20.2 %
3% line reactor (or equivalent DC line reactor)	39 %	10.9 %
5% line reactor (or equivalent DC line reactor)	33 %	9.24 %
5% line reactor (or equivalent DC line reactor) + 5th harmonic trap filter	12 %	3.36 %

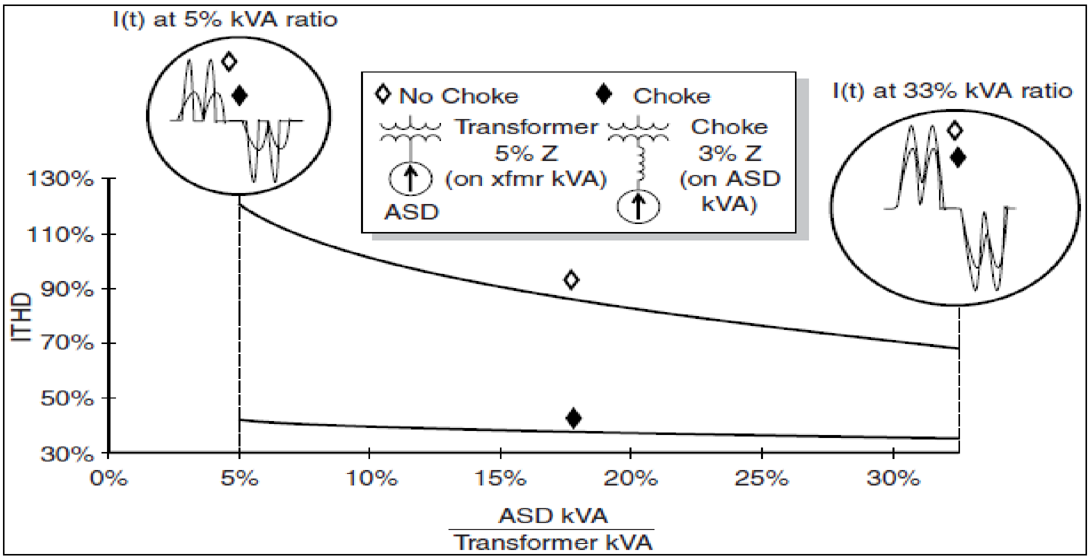


Fig.4. Characteristic Curves of Line Reactors [2]

From Table 3 in [4], the allowable total current demand distortion (TDD) is **12%.** Since the total demand distortion of ASD without mitigation exceeded the limits of IEEE519-1992, which means the mitigation techniques should take place in order to reduce TDD below the limits. Use of 3 % Line Reactor reduced TDD from 20.2 % to 10.9 % which is within limits. Use of 5 % Line Reactor reduced TDD to 9.24 %. Adding 5^{th} harmonic trap filter made TDD 3.36 % which is too much better than without filter.

Conclusion

Problems of harmonics from nonlinear loads continue to grow with the increasing use of adjustable speed drives which may cause the distortion to reach unacceptable levels in future. Designers and engineers are wishing to reduce the level of harmonic pollution on a power distribution network where nonlinear harmonic generating loads are connected. Modeling of adjustable speed drives for harmonic analysis was investigated in this study and classification of harmonic mitigation techniques in ASDs are also presented in this study.

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