Remote Location and 18 Pulse versus Passive Filter 6 Pulse Applications - A Discussion

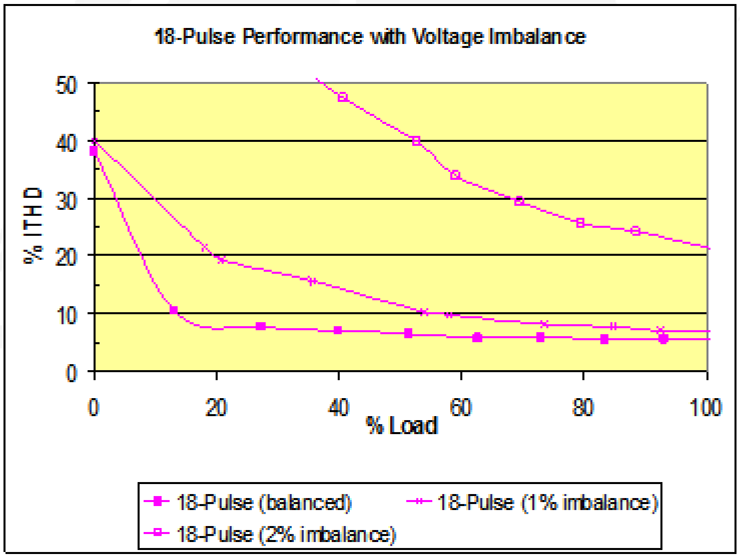
10/7/2014

With the commercial push driving 18 Pulse VFD growth within the industry, the industry is forgetting that an 18 pulse installation is not a good solutions to many installations and projects. This discussion is intended to highlight those considerations that must be made in selecting a VFD package for some of the more challenging installations and applications. This discussion is not forwarded as a qualification of any manufacturer in particular, or a condemnation of the 18 pulse technology. But it is important to understand the effects of actual circuit circumstance on the 18 Pulse Drives operation and performance.

The reality is, in most if not all the electrical circuits I test, I never have balanced Phase to Phase Voltage and I always have some level Background Harmonics (Vd). In addition, the reality of today's economic and engineering climate is that we have to pick a "Green" solution, so energy consumption is paramount. The discussions below are based on real testing data, and verified harmonic modeling.

Phase Imbalance and 18 Pulse Performance versus Mirus Lineators and 6 Pulse Technology

18 Pulse VFD's utilize a phase shift transformer or other magnetic topology in order to offset (phase shift) the current draw of three rectifiers within their topology. In theory and most installations, this technology will work adequately to mitigate the current waveform distortion to well below IEEE 519 Standard, assuming everything is "perfect". But reality says, nothing is perfect… even a 2% voltage phase imbalance (9.6V on a 480V high leg to low leg) can have significant effects on the harmonic mitigation performance of the 18P VFD. Below is a graph of an actual test where a "typical" 18 P VFD was exposed to a voltage imbalance of 1% and 2% respectively and operated over the entire range of loads…



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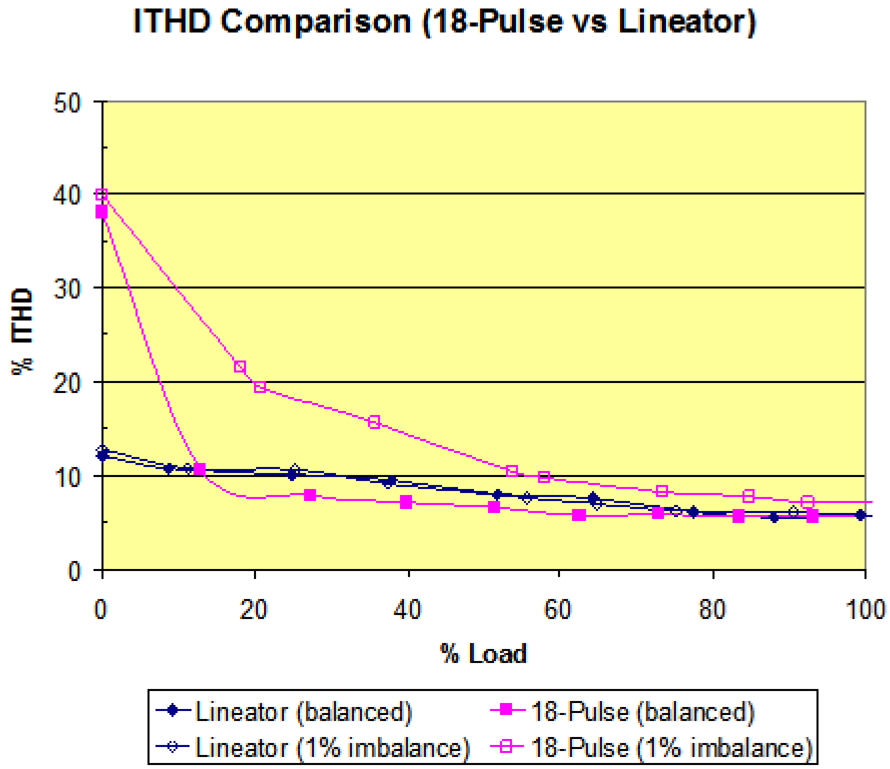
At a 1% imbalance, the performance at lower load levels 50% or less is significant, but from 60% load and up, the performance parallels the balanced performance. But at 2%, the phase voltage imbalance has shifted the current harmonic spectrum well above the IEEE 519 standard.

Now taking this same circuit and placing a Mirus Lineator AUHF series passive filter on the front end of a typical 6 pulse VFD (no reactor), the following graph highlights the performance difference.



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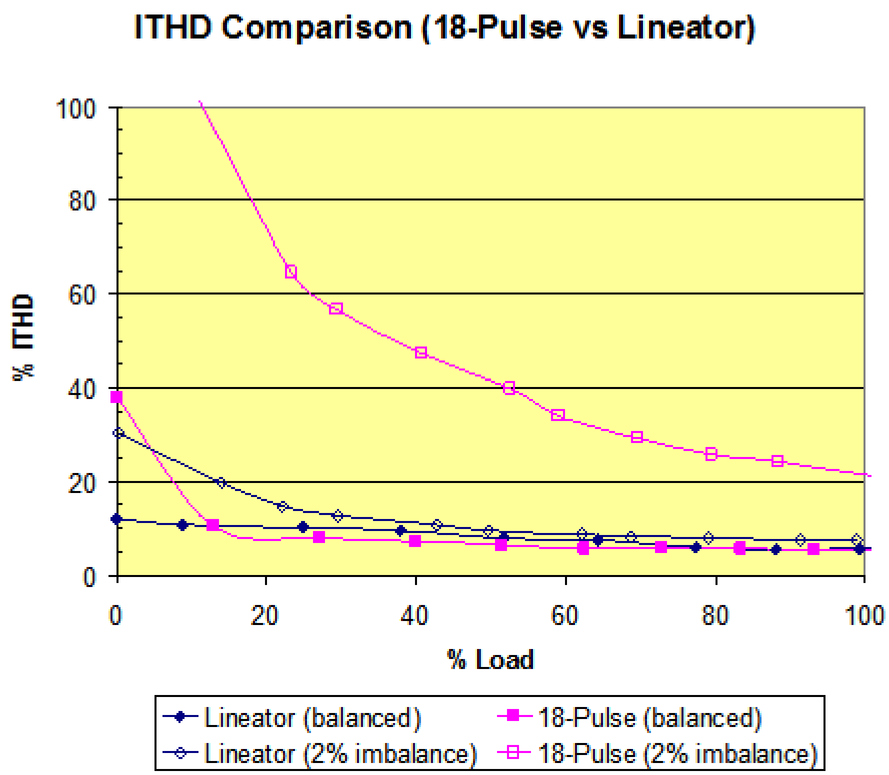


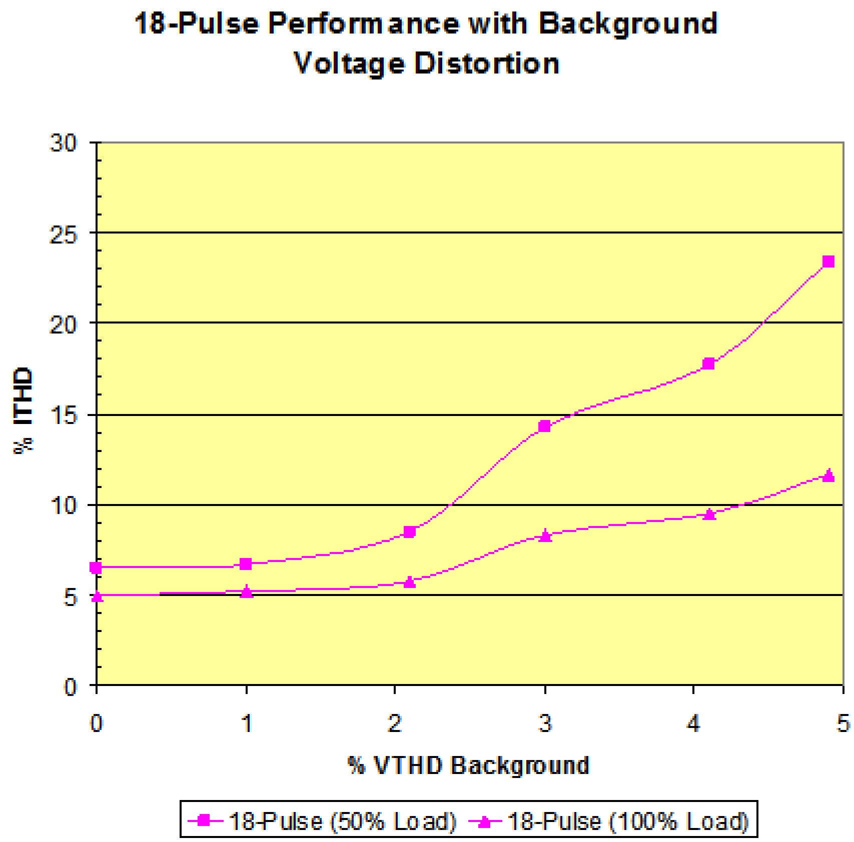
It should be noted that based on a balanced voltage system, at 75% load and up, the passive filter and 6 P Lineator and Drive combination performed as well as the 18P solution. But the performance between the two solutions is dramatic when the imbalance was increased to two percent.

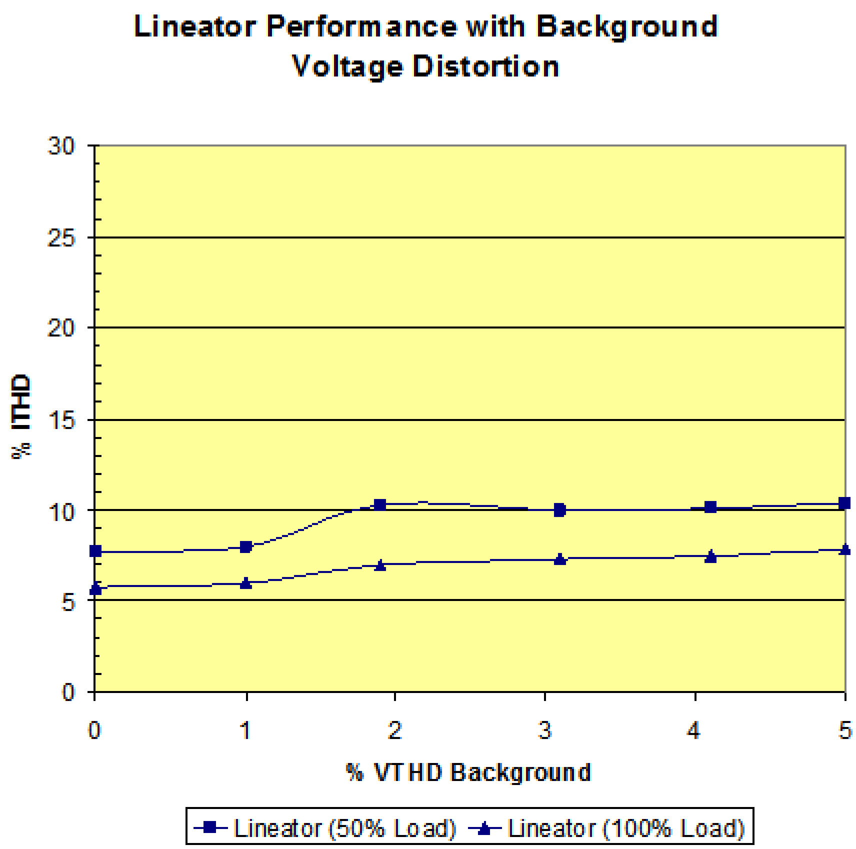
Most remote Utility locations, remote pump stations, and generator installations have a minimum of 1% to 1.5% voltage imbalance from the source. In extreme conditions, I have measured Vimb as high as 4%. Before specification of an 18 Pulse solution, you have to know the background voltage imbalance before considering your VFD options. Assuming you have a balanced voltage is not a sound engineering practice or decision.

Background Voltage Distortion (Vd) and 18 Pulse Performance
versus Mirus Lineators and 6 Pulse Technology

The Background Voltage Distortion (Vd) of the system is also a concern before you specify an 18P solution. IEEE 519 requires a 5% Vthd at the Point of Common Coupling, assuming all other components and equipment tied into the system at that PCC can withstand the voltage distortion level. The ability to withstand versus operate properly are sometimes two different goals. There is a proposal to increase this to 8% which if enacted, will make the analysis of circuit conditions even more important for the proper selection of future VFD topology.

Below is an analysis of an 18P VFD and a 6 Pulse VFD with Mirus Lineator, when we tried to combine the charts, it became confusing… so an imbalance point by point analysis may be required. We measured at two different load point 60 % and 100% load, through 5% Background Distortion.



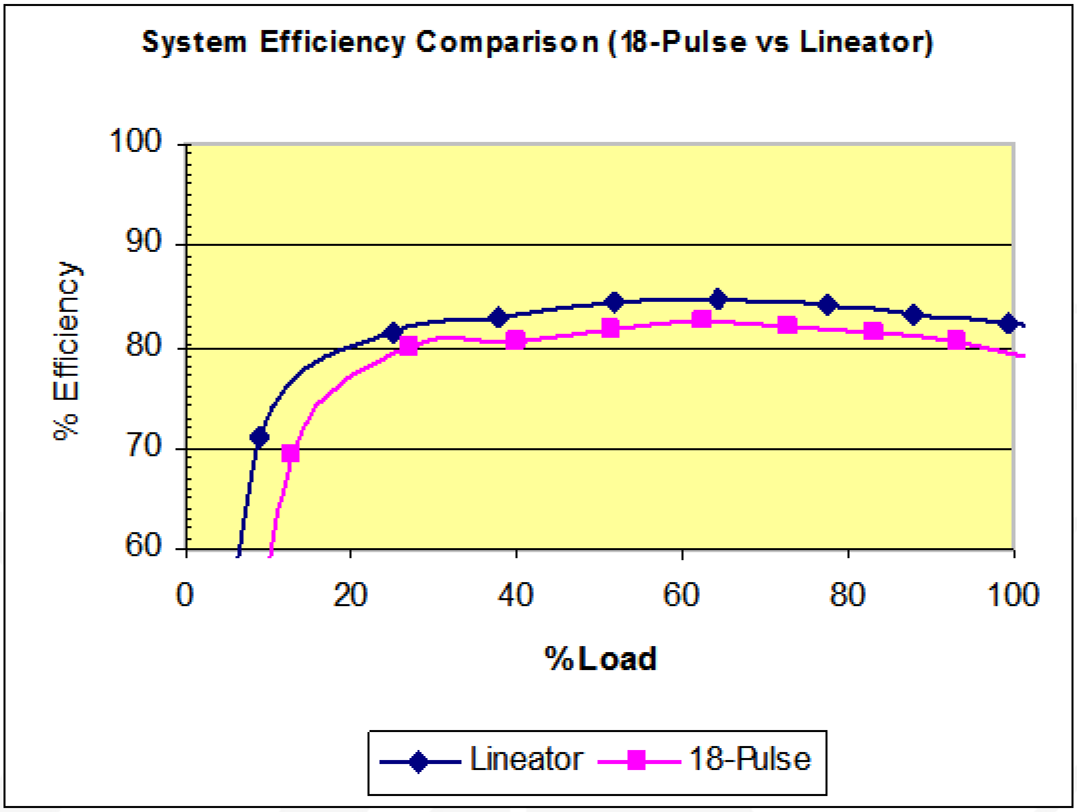


The performance of the 18 P VFD begins to degrade at both load profiles at and above the 2% background distortion level. This would seem to be the effective performance limit. The Lineator feed 6P VFD performance from 2% up through 5% Vd stays stable and performance is well maintained over the range.

This illustration highlights that before you specify the use of a 18 Pulse solution, it is imperative to perform either a harmonic analysis, field measurements, or advanced modeling to ascertain the 18 Pulse package will give you the performance you require to meet harmonic performance guidelines. Recently on a remote pump station, background harmonics were measured on site with a Vd from the Utility of greater than 14%. The Utility/Coop took it under advisement, but to date has done nothing to improve the situation.

Green Considerations - Efficiency Analysis

Component efficiency and system efficiency are two goals of any specification and system engineer. A key component of the efficiency is understanding the impedance structure of the individual device, and that devices performance within the overall system. First we will review a measurement of the net efficiency of a 18 P VFD versus a Passive Filtered 6 P VFD operating based on a load range and assuming balanced voltage and no background voltage distortion:



As can be witnessed, the overall efficiency of both packages is very much influenced based on loading profile, and at 20% load both solutions have reached a stabile efficiency state. But as can be witnessed, the 18 P solution measures about 2 to 3% less efficient over the entire range of 20% load through 100% load. This is easy to understand why, the phase shifted solution involves the use of a relatively high net impedance magnetic. The greater the impedance of the magnetic the greater the losses, and therefore the less efficient.

But taking it one level up within the circuit… efficiency of the overall system is a function of not just the component but also the level of current harmonic injection of the non-linear loads. Below is a model of an 18 pulse versus a Lineator filtered 6 pulse based on 2% voltage imbalance and 2% background distortion. For purposes of this discussion, I have picked these levels since they are fairly common within the Oil and Gas Industry. For comparison, I have ignored linear load content, assumed a 20 kA SC value, and injected the Vimb and Background Vd. I used a 200 HP VFD topology loaded at 100%.

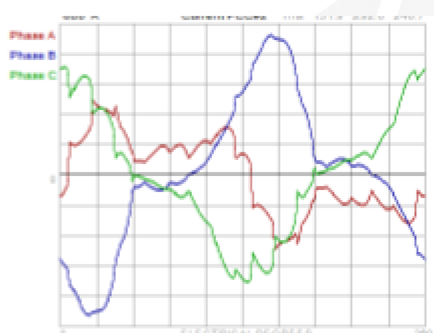
Scenario A: 18 P VFD

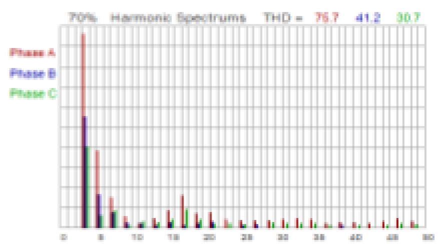
Short-circuit ratio 96.5

Summary of Compliance with IEEE Std 519 Harmonic Limits:

	Calculated Value, %	IEEE-519 Limit, %	
Voltage Total Harmonic Distortion(Vthd)	2.0	5.0	PASS
Max.Individual voltage harmonic	1.5 { 5}	3.0	PASS
Current Total Demand Distortion(Itdd)	49.2	12.0	FAIL
Max.Individual current harmonic <11	67.5 { 3}	10.0	FAIL
11 to 16	6.2 {15}	4.5	FAIL
17 to 22	11.3 {17}	4.0	FAIL
23 to 34	3.3 {33}	1.5	FAIL
>35	3.3 {47}	0.7	FAIL

Based on the information provided, this application will NOT meet IEEE Std 519 harmonic limits





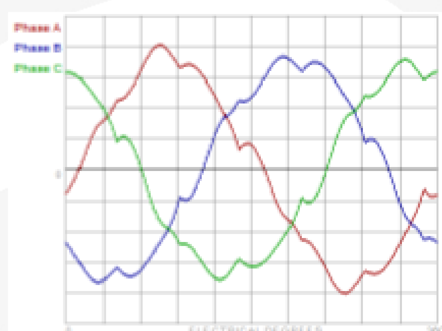
Scenario B: 6 P VFD with Lineator

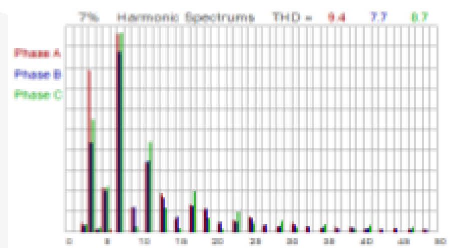
Short-circuit ratio 99.8

Summary of Compliance with IEEE Std 519 Harmonic Limits:

	Calculated Value, %	IEEE-519 Limit, %	
Voltage Total Harmonic Distortion(Vthd)	2.0	5.0	PASS
Max.Individual voltage harmonic	1.5 { 5}	3.0	PASS
Current Total Demand Distortion(Itdd)	8.6	12.0	PASS
Max.Individual current harmonic <11	6.7 { 7}	10.0	PASS
11 to 16	2.3 {11}	4.5	PASS
17 to 22	0.9 {17}	4.0	PASS
23 to 34	0.5 {25}	1.5	PASS
>35	0.2 {37}	0.7	PASS

Based on the information provided, this application will meet IEEE Std 519 harmonic limits





	Scenario A	Scenario B	Difference
Harmonic Voltage Distortion (%)	2.0	2.0	-0.0
Harmonic Current Distortion (%)	49.2	8.6	-40.6
Total Current (Arms)	228.4	201.1	-27.3
Displacement PF	0.997	-0.987	-1.985
True PF	0.880	0.982	0.102
kVA	190.2	167.5	-22.7
kVAR	90.5	32.0	-58.5
Active kW	167.3	164.4	-2.9
Energy Consumption (kWhr/yr)	1465725	1440143	-25582

The issue with some software, it provides you more information than you may want to review… but here, Scenario A performance has been compromised based on the source issues. IEEE 519 Non-Conformance within Scenario A is clear, and the current draw characteristics enlightening. The comparative chart highlights the current harmonic, True PF, and kVAR performance differences with a 25582 kWh/year energy saving between the 18 P and more efficient Filtered 6P scenarios.

Conclusions

18 Pulse VFD solutions can be very effective and a proper solution for many project installations, but system challenges such as Background Voltage Distortion and Voltage Imbalance from the source, can significantly impact the effectiveness and efficiency of an 18 Pulse application. These two factors should be considered, existing system tested, and system modeled before depending on a “Marketing Brochure” approach to the specification decision process. Passive Filtered 6 Pulse VFD topologies in most Industrial and Oil & Gas applications can and will provide a more robust, system tolerant IEEE 519 harmonic solution and maintain a higher level of energy efficiency than 18 Pulse and other “Technological Solutions”, based on supply system conditions.