WATER AND WASTEWATER SPOTLIGHT: A SINGLE PHASE SOURCE HARMONIC SOLUTION FOR THREE PHASE DRIVE APPLICATIONS

A difficult application for proper equipment coordination and harmonic mitigation is the operation of a three phase drive load structure with a single phase source. Many pump manufacturers have standardized on 3 phase drive and motor/pump configurations for their own convenience. But in reality, real world applications are rarely '*standardized*'. In many circumstances, smaller lift stations, irrigation ESP installations, and other pump installations only have a single phase 240V or 480V source available due to the distribution grid configuration. In these scenarios, a 3 phase VFD can be used to supply a 3 phase motor but, the equipment must be derated to avoid installation and applicational challenges and the harmonic content in the current drawn will be much higher.

When applying a 3 phase drive and motor package to a single phase source, it is important to properly derate the drive and motor package to function properly and dependably. There is a lot of confusion on the subject of deration for this application… some drive and information sources suggest a 1.73x to 2x or greater deration factor. This is easy to understand since the drive will now be handling the full current load of the motor based on the single phase equivalent, i.e. square root of three, and then upsized one frame size if a marginal condition exists. For instance, if a 30 HP motor is required, then the normal 3 phase current would be around 80A at 230V and 40A at 480V. But to size the three phase drive being fed from the single phase source, you would have to size the drive based on a minimum current of 138.4 amps at 230V and 69.2A at 480V. The VFD sizing would then require a 60 HP rating, 154A at 230V and 77A at 480V since the required current rating is marginally above the 50 HP rating. Couple this deration requirement with the significant harmonic contribution created by the 3 phase drive operation on a single phase source, and the challenges are complicated for the VFD/ASD and the harmonic condition of the distribution system.

Lowering of the proper deration criteria and harmonic mitigation can be achieved by the application of a Mirus Lineator 1Q3 filter. The Lineator 1Q3 has been designed to address the problems associated with single phase supply on 3 phase ASD applications. This is achieved by accepting a single phase input source voltage and providing a quasi 3 phase supply to the ASD. This will significantly lower both input harmonic current distortion and DC ripple current within the ASD. The reduction of the phase current seen by the VFD/ASD, as well as DC bus ripple will allow you to reduce the deration factor for the drive. Typically we see the deration factor lowered to around 1.5x the VFD/Motor HP rating. In addition, the current harmonics are significantly reduced, and Displacement Power Factor (dPF) and True Power Factor (TPF) are improved, as well as overall system efficiency enhanced.

Harmonic and Energy Saving Solutions

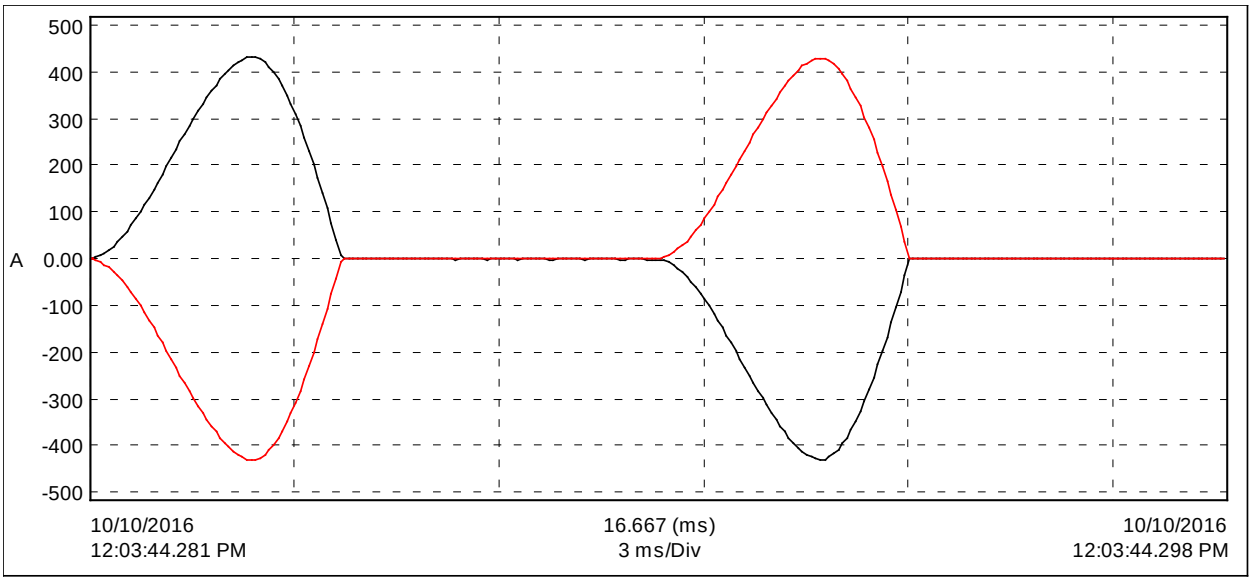
MIRUS International Inc.

100 HP Case Study: Outside of Clayton, NM
Comparative Analysis of a standard Single Phase Installation versus a 1Q3 Lineator Filter

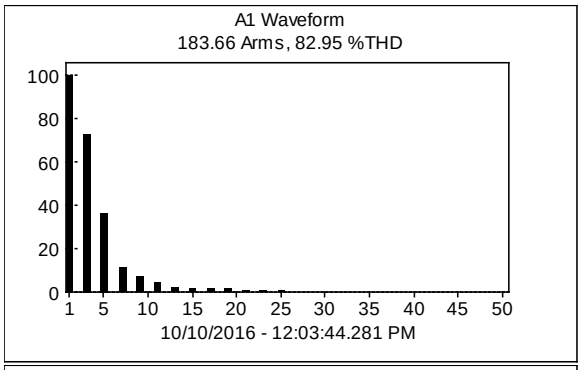
An irrigation installation outside of Clayton NM was chosen to test and verify harmonic mitigation claims by Mirus International as to "Rightsizing" VFD and Harmonic filters to single phase service applications in a real world installation. Measurements were taken with and without the Mirus Lineator Series SUHF 1Q3 Harmonic Filter. The drive was nameplated at 200 HP and the motor rated 100 HP; the operating voltage was 480V class. The motor was surface mount, in a hollow shaft pump application. The nominal operating speed of the drive was 60 Hz.

The normal FLA of a 200HP VFD is around 325A (Variable Torque) at 480V. Typically, the existing 3 phase drive would be sized at 2x the motor HP rating per the manufacturer's instructions, since the single phase source current limitation of the VFD would be around 187A @ 480V. Based on the actual installation, motor load/speed… the data as measured on the front end of the VFD is shown below:

VFD with a 3% line reactor: 60Hz operating speed, 100HP Motor, 200HP VFD

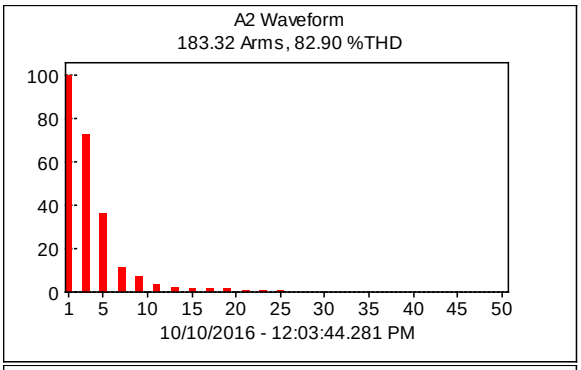


A1 Waveform	183.7	Arms
A2 Waveform	183.3	Arms



A1 Waveform

	(%)		(%)		(%)
H01	100.0	H18	0.1	H35	0.4
H02	0.5	H19	1.5	H36	0.0
H03	73.0	H20	0.1	H37	0.4
H04	0.3	H21	1.0	H38	0.0
H05	36.4	H22	0.1	H39	0.3
H06	0.2	H23	0.9	H40	0.0
H07	11.4	H24	0.0	H41	0.3
H08	0.2	H25	0.7	H42	0.0
H09	7.5	H26	0.0	H43	0.2
H10	0.1	H27	0.6	H44	0.0
H11	4.3	H28	0.1	H45	0.3
H12	0.1	H29	0.5	H46	0.0
H13	2.3	H30	0.0	H47	0.2
H14	0.1	H31	0.5	H48	0.0
H15	2.1	H32	0.0	H49	0.2
H16	0.1	H33	0.5	H50	0.0
H17	1.4	H34	0.1		



A2 Waveform

	(%)		(%)		(%)
H01	100.0	H18	0.1	H35	0.4
H02	0.5	H19	1.5	H36	0.0
H03	73.0	H20	0.1	H37	0.4
H04	0.3	H21	1.0	H38	0.0
H05	36.3	H22	0.1	H39	0.3
H06	0.2	H23	0.9	H40	0.0
H07	11.4	H24	0.0	H41	0.3
H08	0.2	H25	0.7	H42	0.0
H09	7.5	H26	0.0	H43	0.2
H10	0.1	H27	0.6	H44	0.0
H11	4.2	H28	0.1	H45	0.3
H12	0.1	H29	0.5	H46	0.0
H13	2.3	H30	0.0	H47	0.2
H14	0.1	H31	0.5	H48	0.0
H15	2.1	H32	0.0	H49	0.2
H16	0.1	H33	0.5	H50	0.0
H17	1.4	H34	0.0		

The actual current measured was close to the VFD/ASD max current rating at 60 Hz VFD operating speed. The current harmonic was quite high at approximately 83% of fundamental with a high triplen harmonic due to the single phase configuration of the source.

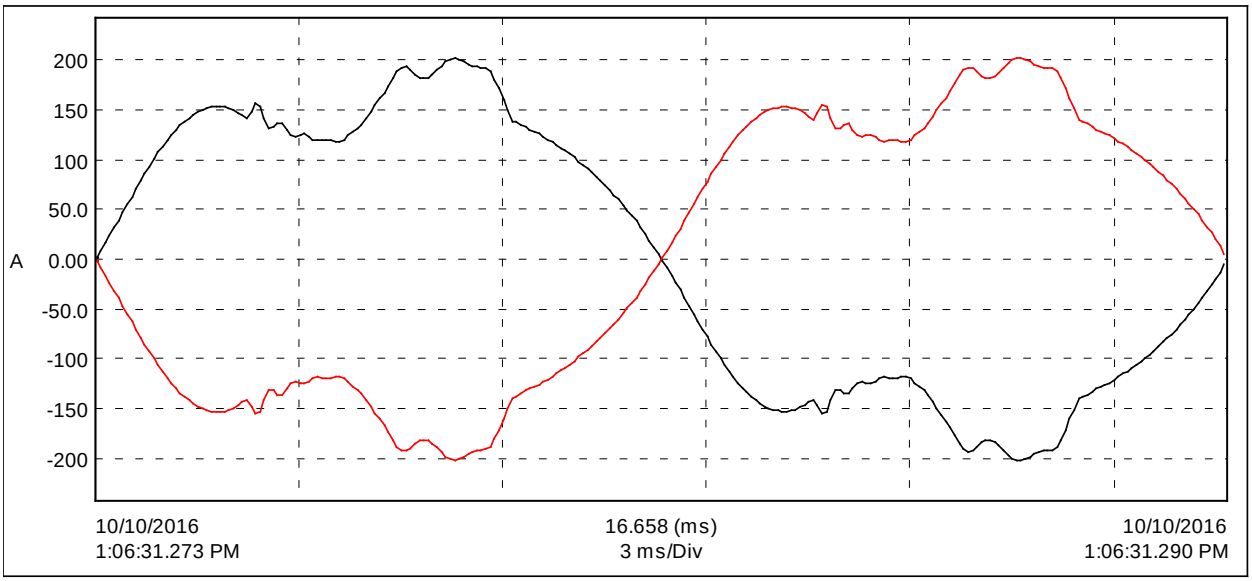
VFD with 1Q3 Mirus Lineator Filter 3% line reactor removed from the circuit: 60Hz operating speed, 100HP Motor, 200HP VFD

After installing the 1Q3 and isolating the line reactor from the circuit which was no longer necessary, the first test at the site was to measure the current on the three phases of the drive, at nominal speed:

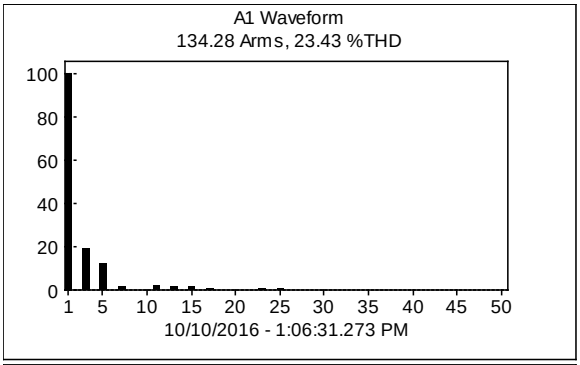
A1 Waveform	84.89	Arms
A2 Waveform	78.46	Arms
A3 Waveform	120.1	Arms

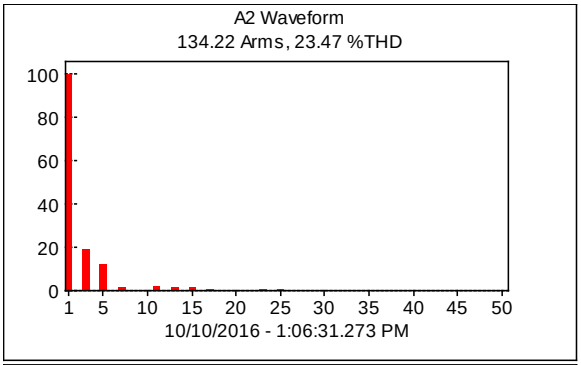
The individual current draw on the phases were lowered from the 183A previously recorded to a maximum on one phase of 120A. This reduced the individual phase current draw by roughly 34%. Based on this level of current draw, a 125 HP VFD (<150A at 480V) fed by the 1Q3 filter would have been possible, i.e. a 1.25x deration factor. The drive could have been right sized for the installation, saving initial equipment cost on the VFD, and further improving efficiency and harmonic levels. In most applications, derating of the drive by 1.5x rather than 2x or more will allow for full load operation of a 3 phase drive on a single phase supply.

Current Harmonic Analysis: Line Side of the 1Q3 Lineator Filter, 200HP VFD @ 60 Hz Output Speed



A1 Waveform	134.3	Arms
A2 Waveform	134.2	Arms





A1 Waveform

	(%)		(%)		(%)
H01	100.0	H18	0.1	H35	0.2
H02	0.2	H19	0.5	H36	0.0
H03	19.4	H20	0.1	H37	0.4
H04	0.1	H21	0.4	H38	0.0
H05	12.4	H22	0.1	H39	0.4
H06	0.1	H23	0.9	H40	0.0
H07	1.6	H24	0.1	H41	0.2
H08	0.0	H25	1.0	H42	0.0
H09	0.3	H26	0.1	H43	0.4
H10	0.0	H27	0.5	H44	0.0
H11	2.2	H28	0.0	H45	0.4
H12	0.1	H29	0.7	H46	0.0
H13	2.0	H30	0.0	H47	0.5
H14	0.1	H31	0.3	H48	0.1
H15	1.4	H32	0.0	H49	0.4
H16	0.1	H33	0.3	H50	0.0
H17	0.7	H34	0.0		

A2 Waveform

	(%)		(%)		(%)
H01	100.0	H18	0.1	H35	0.2
H02	0.2	H19	0.5	H36	0.0
H03	19.5	H20	0.1	H37	0.4
H04	0.1	H21	0.4	H38	0.0
H05	12.4	H22	0.1	H39	0.4
H06	0.1	H23	0.9	H40	0.0
H07	1.6	H24	0.1	H41	0.2
H08	0.0	H25	1.0	H42	0.0
H09	0.3	H26	0.1	H43	0.4
H10	0.0	H27	0.5	H44	0.0
H11	2.2	H28	0.0	H45	0.4
H12	0.1	H29	0.6	H46	0.0
H13	2.0	H30	0.0	H47	0.5
H14	0.1	H31	0.2	H48	0.1
H15	1.4	H32	0.0	H49	0.4
H16	0.1	H33	0.4	H50	0.0
H17	0.7	H34	0.0		

The third harmonic is still present, but the overall current harmonic presented by this load has dropped from approximately 83% to 23.5%. Even more interesting was the comparative analysis of the energy consumption and power factor improvements when a side by side review was performed.

VFD Harmonic Treatment : 1Q3 SWEC Case Study

LINEATOR™ 1Q3 Single Phase Universal Harmonic Filter

100 HP Case Study: Outside of Clayton, NM

	Unfiltered Install	SUHF Mirus Filtered Install	Difference	% Change	Notes
Current Harmonic	63.8%	22.8%	41.0 points	64.26%	We established a limit of 25%
Voltage Distortion	5.2%	3.10%	2.10 points	40.38%	Mirus Filtered Unit is IEEE 519 compliant
Displacement pf	0.968	0.979	0.011	1.14%	Improved, but functionally unchanged
True pf	0.730	0.952	0.222	30.41%	Significant Improvement in True Power Factor
kW	63.7kW	61.98kW	1.7 kW	2.78%	Improvement in straight kW
kVAR	59.0kW	20.0kW	39.0 kW	66.1%	Improvement in the Reactive Power Component
kVA	84.5kW	65.07kW	19.43 kW	22.93%	Improvement on the Apparent Power

Direct Comparative Chart: (I used the Median values for current and voltage distortion for the analysis)

All Harmonic and Energy Factors Have Been Significantly Improved By The Use Of a Mirus 1Q3 Lineator Filter

All aspects of the line side harmonic performance and energy consumption of the installation was improved. Of particular interest is the improvement of the True Power Factor. Due to the high harmonic kVAR of running the drive without harmonic mitigation, the TPF improved to 0.952 from 0.73, which means a power factor penalty by the Utility was no longer in jeopardy. This improvement was a direct result of lowering the Reactive Power consumption of the load from 59.0 kVAR to 20kVAR, a 66.1% improvement.

The Mirus 1Q3 Lineator filter, will allow 'Rightsizing' of the VFD/ASD equipment, reduce harmonic contribution to the distribution grid, lower reactive power consumption, and increase TPF as measured by the Utility, reducing or eliminating power factor correction surcharges from this particular load. Typical deration factors for the 3 phase drives is reduced to 1.5x of the drive motor HP rating, saving initial drive equipment costs and optimizing the load profile of the system.

For more information or assistance with the specification or selection of a 1Q3 Lineator filter for your application, please feel free to contact us directly.