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Site: Sample Site

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Date: 27/04/2020

Notes/comments on harmonic survey

Voltage:

The voltage magnitude is within limit. The voltages are all balanced. About the voltage distortion THDV is shown that it is just under the distortion limit of 5 % according to G5/4-1, except the third phase to neutral voltage where it is above limit, based on the maximum values. However, it is not above 4.3 % between lines and not above 4.8 % between the phase and neutral, during steady state. With more than one drive running, the voltage distortion is estimated to be above the limit when two or three drives run simultaneously, because more harmonic current will flow on the lines that will create voltage drop again, increasing the total distorted voltage, see Table 1. Also, from the graphs it seems that there was a power cut on Tuesday around 09:50 am, that is why the zero voltage.

Our priority is to have clean voltage waveform close to the pure sinusoidal waveshape. But harmonic currents contribute to the distortion of the voltage when distorted currents create voltage drop on the system impedance and this voltage drop gets superimposed on the harmonic-free voltage waveform. Thus, the result is a distorted waveshape that is applied across any load connected to that bus bar, adversely affecting the other loads, such as malfunction of the electrical and electronic equipment, PLCs, relays, capacitors and on other linear loads. That is why there are limits for both the voltage distortion and the current distortion.

THDV Levels when various number of VSDs in operation			
	One VSD	**Two VSDs**	**Three VSDs**
THDV AVG Level (%)	3.74	6.21	8.32

Table 1: THD of the voltage with regards to the number of drives running simultaneously

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From Table 1 it can be seen that although, with one drive running there is no issue about the voltage distortion, the limit is expected to be crossed when more than two drives are in operation.

From my last visit on site I remember that the pumps were running on softstart and obviously there is no reference to adjust the speed of the drives. With that being said, the pumps will always run at a constant load/speed. Therefore, the voltage distortion will be the same at any time of the day when drives are operating and can be affected from the rest of the supply system network.

Although, with one drive running the THDV is within limit, this does not mean that there is no issue with the current distortion. Harmonic currents have been recorded to be above limit as shown on the graphs and analysed below in the current section.

Current:

The line currents are all balanced, (there slightly unbalance between the phases, but without any issue). The current distortion THDI is at 47 % and the calculated total demand distortion is TDD is the same 47 % and this is the case when the pump runs at full load all the time, however, both very high and above the limit. The THDI is high when there is light loading, however, this is not an indication that there is actually severe current distortion. For this reason, it is used the TDD term, it is the ratio of the harmonic currents to the total load demand current at the fundamental frequency (50 Hz). By checking the current in the software, the total current is 171 A, of that 154.8 A is made of the fundamental current (at 50 Hz), and 72.7 A is the harmonic current (the sum is in vector not algebraically). Harmonic currents overload the cables and increase the losses that are proportional to the square of the current and to the square of the frequency, overheat the transformers, create resonance condition with capacitor banks and with the system capacitance, can cause nuisance tripping of protective devices, among many other issues.

Table 2 shows the harmonic currents when a number of drives run at the same time. As mentioned above, the harmonic current was found by calculation to be $I_H = 72.7\ A$. Estimating the total harmonic distortion of the current THDI when more than one drive is operating, it is found from studies to be reduced slightly when more drives operate with the same load. Therefore, the THDI in this case it will be around the same value or just below 47 %, see Table 2. But again, above limit. The harmonic current obviously will be twice or three times accordingly with the number of drives running at the same time.

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THDI Levels when various number of VSDs in operation			
	One VSD	**Two VSDs**	**Three VSDs**
THDI Level (%)	47	45.7	44.7

Table 2: THD of the current with regards to the number of drives running simultaneously

Frequency:

The frequency is within the limit, there is no reason for concern. It is shown though that it has a drop, but this happened during the power cut. Therefore, nothing to worry about.

Power:

The power flow within the lines is symmetrical. The Displacement Power Factor (DPF) or otherwise $\cos\varphi$ is DPF=0.985 LG, with fundamental reactive power of 19 kVAr. DPF is the phase displacement between the voltage and current at the fundamental frequency. The true power factor including harmonics is PF=0.878, which is the Distortion Factor (DF) times the DPF and it is always less than DPF. Therefore, to bring the PF to unity it requires both to filter the harmonic currents and supply capacitive reactive power.

CF:

The crest factor is the ratio of waveform's peak value of either voltage or current to their rms values. In pure sinusoidal waveshapes the CF is equal to $\sqrt{2} = 1.414$. Since the drives draw non-sinusoidal currents, the peak current value will be high, like a pulse. It can be seen that the current has high CF of more than 1.414. Even the voltage is shown signs of distortion with the CF deviating from the pure sinusoidal waveform of 1.414. In other words, it is an indication of the distortion of waveshapes compared to the ideal shape of their signals and the ability of the source to supply that peak current.

Recommendations/Solution:

The DPF is very good, it is recommended to be as a minimum of 0.95 if not unity which in this case meets the requirements. The harmonic currents should be mitigated to avoid further voltage distortion, that will potentially lead to other problems mentioned above, even tripping the VSDs, since VSDs are susceptible to distorted supply voltage. In this case it would be recommended to install an active harmonic filter AHF. It is the best technology used in the industry. It will mitigate harmonic currents by injecting the current for each harmonic

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component in phase opposition on a wide spectrum, it will provide reactive power compensation and it can provide current balancing between phases, it does not create any resonance condition with the system capacitance. Its high performance lies in its ability to monitor all the time the voltage and current and have very high speed of response since it has electronic semiconductors that their switching frequency is very high.

It will be required different filter size depending on how many drives will run at the same time. It can either be one filter per drive or one big filter for all the drives. Table 3 shows the minimum current rating of each filter depending on the number of drives running simultaneously, for both harmonic current mitigation and improving the DPF to unity.

AHF minimum current rating when various number of VSDs in operation for both harmonic current mitigation and for DPF correction to unity			
	One VSD	**Two VSDs**	**Three VSDs**
Current rating (A)	78	156	234

Table 3: Current rating of active harmonic filter with regards to the number of drives running simultaneously for both harmonic current reduction and improving the DPF to unity

Table 4 shows the minimum current rating of each AHF filter when a number of drives run simultaneously, to only mitigate the harmonic currents.

AHF minimum current rating when various number of VSDs in operation for only harmonic current mitigation			
	One VSD	**Two VSDs**	**Three VSDs**
Current rating (A)	72.7	145.4	218.1

Table 4: Current rating of active harmonic filter with regards to the number of drives running simultaneously for only harmonic current reduction

From both Table 3 and Table 4 it could be concluded that either install an AHF filter per drive or install on the feeder of all three drives a bigger size filter for two or three drives operating simultaneously.

To conclude, based on the DPF value it will not be needed to do both reactive power compensation and harmonic current distortion. Only harmonic current mitigation is recommended in this case. Based on the data logger monitoring about the voltage level/magnitude it is recommended to install shunt AHF filter. If we were going to install passive broadband filters in series (for each drive), it would increase the losses and create further voltage drop when the drives would run and also, it would not guarantee THD levels below the limits, not to mention it would require more installation job and time and space. However, for more efficiency reasons then you could always perform both functions mentioned in Table 3 and go for those current rating AHF filters.