Understanding Harmonics and complying with IEEE519-2022 on Oil Wells with VFDs

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BACKGROUND

Electric motors have long been used in a wide range of applications within the Oil and Gas Industry. Sucker Rod Pumps, ESPs, Compressors, Disposal Pumps, Shipping Pumps represent just some of the applications where 3-Phase Motors are used, both Induction and Permanent Magnet, to convert electrical energy to mechanical energy and perform work. Increasingly, for reasons including improved process control, reduced mechanical stress, and lower power costs, these electric motors are being controlled by Variable Frequency Drives (VFDs), that allow for controlled starting, stopping, and operation, by providing us with the ability to have the motor operate at a frequency either higher or lower than the nominal grid frequency of 60Hz.

HARMONICS

Variable frequency drives do not draw power from the grid in a sinusoidal fashion the way a motor would in the absence of a VFD. There are switching devices on the Input of the VFD that open and close. This opening and closing causes disturbances to the input AC waveform of both current and voltage on the VFD. These disturbances or distortions can be broken down to their component frequencies using Fourier Analysis. By taking a distorted waveform and applying Fourier Analysis to it, we can measure the specific switching frequencies that are causing Total Harmonic Distortion.

HARMONIC PROBLEMS

As more VFDs are added to an area, the proportion of non-linear to linear load on the power system feeders increases. The increase in harmonic current or harmonic distortion, causes a corresponding increase in the voltage distortion or total demand distortion (TDD) on the power system supplying the loads. All users of a particular feeder line are therefore subject to a decrease in the Power Quality supplied to them by the utility. Utility cables and transformers may or may not have been sized initially to account for this increase in non-linear load. Utilities have developed the standard, IEEE519-2022, to guide both users and equipment manufacturers and Electrical Engineers in the construction of grid compatible systems, and in the measurement and mitigation of harmonics exceeding the limits defined within the standard. Problems occur when the user or Oil Company in our case, has not built their systems to be grid compatible and therefore cause a problem on the power system supplying them that requires mitigation as it has the potential to adversely affect other power consumers.

HARMONIC MITIGATION FOR NEW SYSTEMS

New systems can be built to be grid compatible from day one by design. Any grid compatible VFD system will have a higher capital cost associated with it than a non-grid compatible system. Purchasing grid compatible equipment to begin with will mean that the cost of compliance with IEEE519-2022 will be borne by an Oil Company’s capital budget as opposed to by their maintenance and operating budget. Estimating the harmonic distortion generated by the loads can be done using software as well as details on the incoming utility transformer and a single-line-drawing.

PASSIVE FILTERS

Passive harmonic filters can be fitted to the input of any VFD. This requires additional space and cost. Additionally, the performance of these systems will vary according to changes in the load. With Oil Wells, loads tend to reduce over time, often rendering these systems ineffective in the long run. They also need to be sized to handle the full load current, not just the compensation current. This makes them an impractical solution from a system perspective. The main advantage of this solution is the low initial cost

MULTI-PULSE VFDS WITH PHASE SHIFTING TRANSFORMERS

Multi-pulse VFD input bridges when combined with phase shifting transformers allow for low cost and robust reductions in harmonic distortion. This is typically a good practical solution for large low voltage systems (greater than 300HP) and medium voltage systems (4.16-13.8kv). A minimum of 18-pulses is required for IEEE519 compliance. While effective in their reduction of harmonics, these systems are sensitive to voltage imbalance, are physically large and heavy. They are also very hard to retro fit. They are suitable for single large VFDs.

ACTIVE FRONT-END DRIVES

Active Front-End drives are generally grid compatible. They are very efficient and offer the added benefit of regenerating power to the supply side of the VFD during motor braking. The AFE also results in excellent power factor and is insensitive to network unbalance. The disadvantage is that the VFD may now be large and complex in comparison to the VFDs service staff is familiar with. They may have high losses. Additionally, the grid interaction can be problematic and difficult to troubleshoot should it occur.

HARMONIC MITIGATION ON EXISTING SYSTEMS

Either due to a periodic survey or in response to a complaint, a utility may inform an oil company of their non-compliance with IEEE519-2022 and request that high harmonic current be reduced eliminated on the customer's side of the transformer. To achieve this reduction without replacing existing VFDs, which is impractical, there are two possible solutions. But first measurements should be taken or if not measurements reliable estimates should be generated to determine the size of the harmonic load to be attenuated.

MEASUREMENT

For practical purposes, let's consider the case where measurement will be done on the secondary side of the utility transformer. It is important to note that taking these measurements will place personnel inside an area where arc flash rated PPE will be required. It is very important to ensure that this task is conducted by experienced personnel who understand the risks and take appropriate precautions. CTs are placed around incoming feeder cables or bus bars and connected to a power quality meter which will log the data for at least 24 hours. They will then be removed, and the data will be collected for report generation. The Harmonics report, in combination with the Single-Line-Drawing, will allow us to size and specify the equipment required to bring the system into compliance.

ACTIVE FILTERS

The Active Dynamic Filter is a very proven and common technology in use around the world in many large and critical power systems but is in practice less common in the Oilfield. The provide fit and forget harmonic attenuation, as well as continuous measurement and reporting of harmonic conditions. They are also smaller in size than conventional solutions and easy to retrofit. In addition to harmonic attenuation, an ADF can provide Flicker compensation and resonance elimination. They are sized based on the compensating current rather than the load current.

CONCLUSION

It is almost always the case that the utility will eventually enforce and require compliance with IEEE519-2022 if they are not already doing so proactively. Ignoring our responsibility to build systems that are grid compatible simply defers the cost of compliance from our capital budget to our operating and maintenance budget. Therefore, it is recommended that new systems be implemented with an eye to immediate compliance. For existing systems, the Active Filter is the recommended solution.:

REFERENCES

[1] Persson J. Comparing Harmonics Mitigation Technologies, Lund (2014)