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USING A VFD TO TROUBLESHOOT PUMPING PROBLEMS

FOUR CASE STUDIES UNDERSCORE THE IMPORTANCE OF UNDERSTANDING YOUR SYSTEM WHEN TROUBLESHOTING

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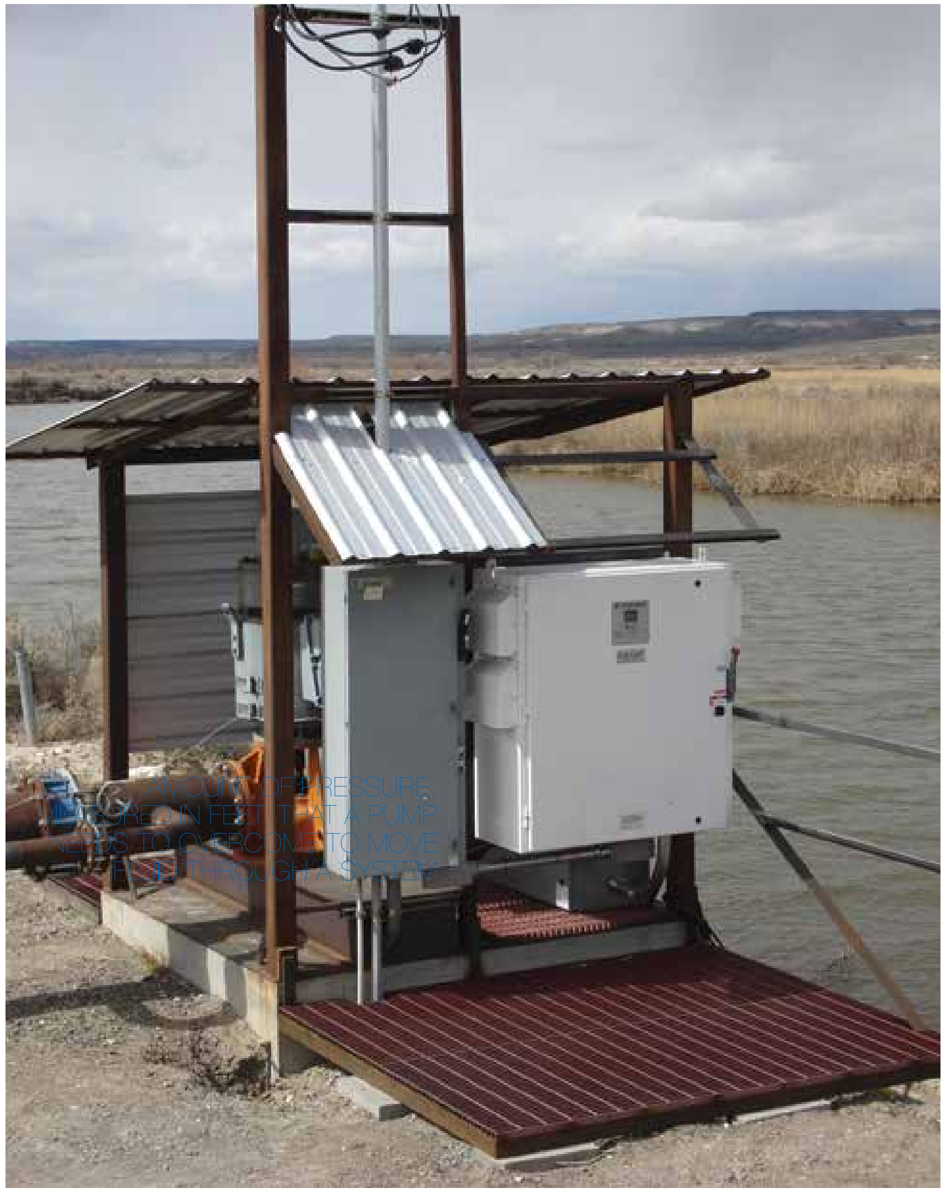
This document covers troubleshooting techniques with VFDs on pumping systems and stresses the importance of understanding the variables in a pumping system to properly troubleshoot the source of the problem. Four field case studies are presented to illustrate how the VFD is frequently the indicator of a problem and how to use the functions and monitors of the VFD to isolate the source of the problem.

It is important to realize that the VFD is only one part of an overall system

In order to achieve its operational purpose, all the parts of a system must be installed and utilized correctly and operated within their individual limits



OVERVIEW

One of the most important lessons I have learned in over 30 years of working on, applying, and technically supporting Variable Frequency Drives (VFDs) is that the VFD is only one part of an overall system. The overall “system” has a desired operational purpose and in order to achieve this operational purpose all the parts that compose the “system” must be installed and utilized correctly and operated within their individual limits. The system can be simple, with only a few components and variables or complex with multiple variables and a complex assembly of various components.

Fortunately most water pumping systems are relatively simple compared to others.

In order to understand the “system” I am eternally grateful to many professional geologist, metallurgist, hydrologist, chemist, well drillers, and operators who have contributed to my overall knowledge of this application. I encourage everyone in this industry to attend some of the professional lectures available to hear these people speak firsthand about how individual parts of the system can have a profound influence on the operational results of your system.

Misoperation of a VFD-controlled pumping system may have nothing to do with a malfunctioning drive.

UNDERSTANDING THE VARIABLES OF THE SYSTEM

Again the "system" means anything that can affect the desired result of operating the system. Even the simplest of well water systems would include:

- The borehole construction and efficiency, including depth and pump setting
- Electrical supply
- Borehole geology
- Static water level and pumping level
- Overall size of the system, single family home or a large pivot farm
- Type of pump
- Size and frequency of demand changes
- Friction losses from valves, elbows, and the piping itself
- Any other pumps that can influence the system that this pump supplies, such as booster pumps

In my decades of experience I have found numerous instances of misoperation for VFD controlled systems that had nothing to do with a malfunctioning VFD.

CASE STUDY 1: REMOTE SUPPORT FOR INCONSISTENT FLOW RATE ON A PUMP SYSTEM

In a conversation with an end user who had used their VFD controlled submersible pump system for several years, the user reported that he was not getting the same flow rate that he previously achieved at a given motor speed.

This would be a typical circumstance where the VFD would get the blame. However, if the pump is in fact going the same speed as before. but the output has changed, something in the "system" has changed.

Some of the possible causes for this might be:

- **Pump wear**: the pump not operating to its specifications
- **Screen fouling down hole**: occurs when debris, scale, or other materials accumulate on the pump's screens, restricting water flow and potentially damaging the pump
- **Water table level falling**: increases demand on the pump to produce the required flow.

In this case, it was determined that the pumping level of the well had dropped significantly. This condition increased the total dynamic head, the amount of pressure the pump needs to overcome to move fluid, that was required to produce the same flow as in previous years. This is a condition of physics and the only way for the VFD to compensate is to increase speed in order to maintain the required flow rate of the system.

What was thought to be a problem with the VFD was in fact a problem with the water level in the well. This is one good example of the importance of understanding the overall pumping system in order to troubleshoot the application. The VFD was actually operating exactly as it should in this scenario

CASE STUDY 2: REMOTE SUPPORT FOR DELAYED FEEDBACK

In troubleshooting a system with VFDs, you must always make sure you know all of the variables of the system.

One late Friday afternoon, as I was preparing to leave the office for the weekend, I received a phone call from one of our best salesmen. I immediately realized my weekend would be delayed, but felt this was minor compared to being in a dark field somewhere with a customer who wanted his brand new system to work.

Initially it appeared to me that this would be a simple PI tuning issue that would only require a little adjustment. However, once I exhausted my little bag of proven tricks without positive results after an hour or so, I felt stumped.

At that point, I decided to have them run the system in a manual mode (Hand mode) so that the pump speed could be fixed at a known safe speed. This removes the PI function from the equation while still being able to observe the feedback and pressure.

Once the pressure stabilized I had them drop the pump speed a small amount, about 2 Hz (120 rpm on a 2 pole 60 Hz motor), enough that it should drop the pressure feedback slightly.

I had several questions that I hoped could be answered by observing this process:

- Does the drop occur evenly and settle on a new feedback level
- What kind of time does it take for this change to occur?
- Does the feedback remain stable or does it bounce around?

After the speed had been dropped, I asked if the feedback had fallen and was told that it hadn't. However, about a minute later, the feedback did fall, which to me was very unusual. But once it did fall, it was noted that it did so in a very smooth and controlled manner.

I then had him increase the speed back to the original speed setting and got the same result in time to increase the pressure. When I told him that I did not understand the result, he casually said it might be due to the pressure transducer being located at the pivot sprinkler, which was some miles away from the discharge of the pump.

It was actually so far away, they used a radio link to send the signal back to the VFD. This meant that the time to reflect any speed change to the PI controller was delayed by the distance or overall length of the "system".

This was the first time I had run into this type of situation and it was a powerful lesson for me in troubleshooting, especially remotely. The lesson learned was to make sure to understand the "system" and what the user's goal for operation is with the system.

The final solution was a balance of acceleration/deceleration time, PI tuning, and placing a limit on the PI integrator. This solution only cut about an hour more into my weekend.

Refer to application note Introduction to PID Control (AN.AFD.18) for more details on PID control.

If maintenance operations like well rehabilitation are not conducted, there is a high likelihood there will eventually be pump failure, which is not related to the VFD

CASE STUDY 3: ON-SITE SUPPORT FOR DECLINING PUMP PERFORMANCE

One of my on-site technical support calls came from a farmer with a 300 hp vertical turbine pump. His complaint was that his VFD was not working as well as before with water production down from previous years. We were able to attach a tachometer to the motor and determined it was running at rated maximum speed. We also observed that the water table had not dropped enough to account for the reduced production.

After asking questions about the time interval of well rehabilitation, I was told that it had never been done. So I asked if we could look at the filter screens to see if they may be clogged. Once removed, we found the screens to be mostly clear with the only debris being small 1 to 2 inch strips of black plastic resembling machine shavings.

While the farmer could not explain their presence in the screen, I assured him this was not the fault of the drive and was certainly not a product of geology. I suspected a serious pump problem and advised him that in order to resolve this, he would need to consult a pump technician immediately.

CASE STUDY 4: REMOTE SUPPORT FOR OVERVOLTAGE FAULT

A distributor called looking for assistance in troubleshooting a large, 800 HP, vertical turbine pump with a 150 HP booster pump, stating that the VFD would go into overvoltage protection mode and occasionally an overcurrent shut down when operating near full capacity.

Overvoltage faults on water pumping systems are rare, but can result from overly aggressive PI settings or downhill pumping. I had started this system up some time ago and did not observe any issues at the time. After some time with the distributor on site and experimenting with different settings for acceleration/deceleration, S-Curve settings, and PI settings without improvement, I had him watch the VFD monitor displaying the DC bus voltage. He reported that it appeared to vary widely up and down and was not stable. Normally we expect to see a drop in voltage by 20 to 30 volts to a lower stable value under load, but this was not the case.

Sometimes, in order to properly troubleshoot a system, it is necessary to look outside the actual system.

I finally asked him to look at the utility pole transformers that supply power to this system and had him read off the kVA values listed on them. After calculating the kW available, I found the supply to be woefully undersized to supply the expected maximum load of 950 HP. So I supplied the calculations to the customer and ultimately to the utility company engineer. The utility company engineer was adamant that the system had worked fine for the previous VFD of the same size and that the farmer was going to be liable for the $25,000 it would cost to upgrade the system. My only reply to him was to inquire if he found any mistake in my calculations. if not, the only reasonable conclusion was that the transformers were undersized for this load.

VFDs often get the blame for failure of a pumping system

However, there are a variety of other issues that are often the root cause of the failure.

OTHER POINTS OF FAILURE (FROM MY EXPERIENCE)

These case studies are examples of applications where it was incorrectly assumed that the VFD had malfunctioned. Below is a list of other points of failure in a system that are not directly tied to the VFD.

1. Pressure Transducers

- Incorrect scaling
- Incorrect positioning, such as too close to valves
- Miss connected wiring
- Fowling of orifice

2. Motor Issues

- Wired in reverse rotation (submersibles)
- Miss wired, such as incorrect winding connections for the operating voltage
- Loose connections or wire nuts

3. Pump Issues

- Pump is wore out or damaged
- Miss sized, generally too small for the application

4. Borehole Problems

- Bio fowled screen and/or gravel pack
- Poorly designed and constructed borehole
- Lack of regular rehabilitation and maintenance

5. Electrical supply issues

- Transformers too small
- Voltage imbalance
- Impedance imbalance supplying the VFD, such as open delta supplies
- Distorted and unreliable utility supply, brown outs, phase loss, spikes
- Lightning

If you are the troubleshooter, you need to understand the system and if it is outside your understanding, ask for assistance.

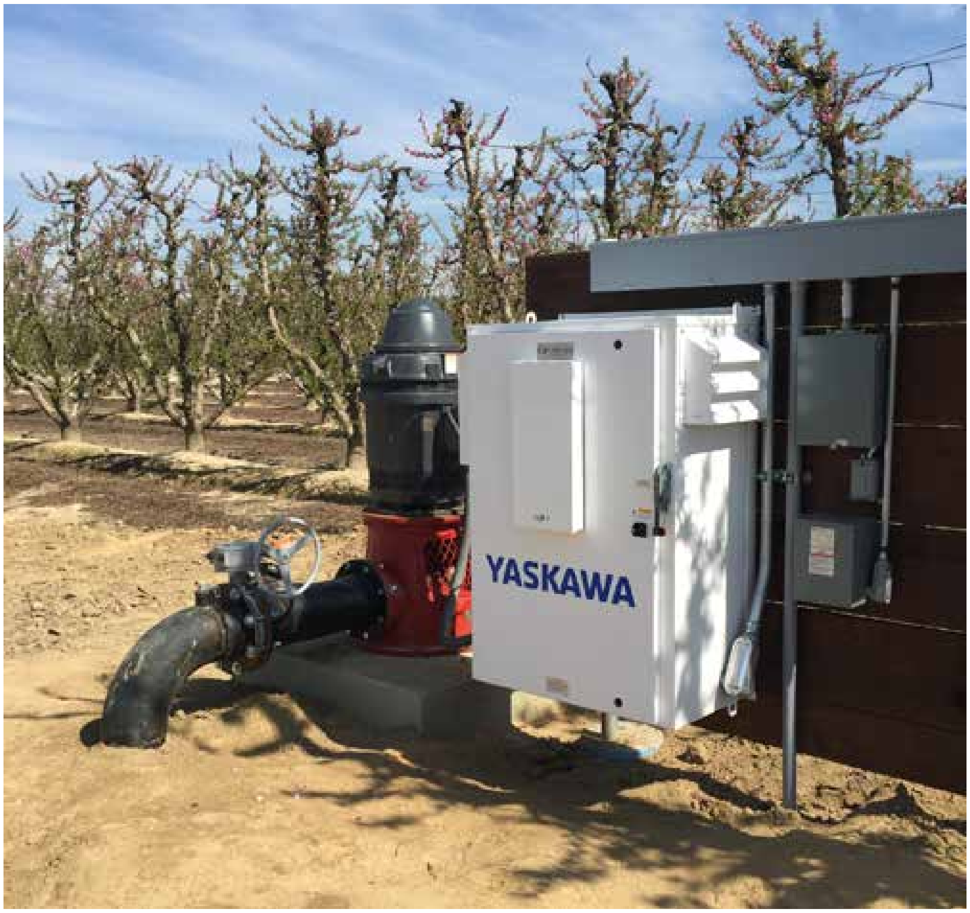
CONCLUSION

While a VFD will add a level of complexity to your pumping system, the value added in being able to control your system and scale delivery to meet the demand outweighs this challenge. While a VFD does not guarantee energy savings, it will allow you to use only the water you need and only the power needed to produce it.

In closing, remember that a VFD is only a single part in an overall system and all parts must work together to achieve your operational goals. If you are the troubleshooter you need to understand the system and if it is outside your understanding, ask for assistance.

Troubleshooting Basics

1. Understand the system
2. Understand the history of the problem
3. Isolate components if possible to see if the problem is effected positively or negatively
4. Use a manual speed mode (Hand) to eliminate PI issues and observe system response time to changes
5. Check the electrical supply system
6. Check that electrical connections are correct, secure, and routed correctly
7. Evaluate borehole condition, I have found the lack of regular maintenance common
8. Call for assistance if you are stumped



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