A DISCUSSION OF ROD LIFT VSD CONTROL PARAMETERS, SETUP, AND CONFIGURATION FOR OPTIMAL OPERATION UNDER VARYING OPERATING CONDITIONS

Peter Westerkamp, Dean Calder
Lufkin Industries

ABSTRACT

A discussion of Rod Lift VSD control parameters, setup, and configuration for optimal operation under varying operating conditions. History shows that many operators utilize only the most basic control parameters when setting up VSDs for rod lift applications. This paper will discuss the VSD and Rod Pump Control parameters necessary for safe, reliable, and efficient rod lift control.

HISTORY

Rod lift Automation has been deployed for many decades to control, monitor, and optimize oil production while protecting the machinery and equipment. The objective usually is to draw the annular fluid level down as close as possible to the pump intake to minimize bottom hole pressure, thus maximize production. When a fluid level is close to or at the pump intake, a well is considered pumped off. As most pumping systems are designed to lift more fluid than a well may be able to produce, it is important not to continue pumping while there is not sufficient fluid available to completely fill the pump as this can result in what commonly is referred to as fluid pound. (Figure 1)

Fluid pound is considered a major cause of downhole mechanical failures. Avoiding or mitigating fluid pound will increase time ~~in~~ between failures and thus lower operating expenses. Additionally, matching pump capacity to the available fluid reduces energy usage . Matching pump capacity to available production typically is achieved by either starting and stopping a pumping unit with a pump off controller (POC), or by continuously varying the pumping speed with a variable frequency drive (VFD/VSD).

This paper will discuss both pump off controller and variable frequency drive parameters for optimal operation. This with a focus on VFD control systems.

PUMP OFF CONTROLLER SET UP (Figure 2)

Pump Off setpoint:

Determines when the well is considered pumped off as there is not sufficient fluid available to completely fill the pump during its upstroke. Adjust the setpoint to the right to minimize fluid pound strokes, while still able to detect a pumped off condition. Be careful not to move this setpoint too far to the right to avoid a loss in production. The dynagraph trace during first part of the downstroke will move gradually from right to left as pump fillage decreases with each pump stroke.

Malfunction Set Point:

This set point is only monitored during the upstroke and is meant to detect a sudden loss of polished rod load, usually due to a rod part. Set inside the dynagraph, at or slightly above the weight of the rod string in fluid.

Peak Polished Rod Load Limit:

This setpoint is meant to identify increasing polished rod loads due to excessive friction or possibly a stuck pump condition. The controller will shut down the pumping unit when this limit has been exceeded.

Set at 15-20% above the peak load under pumped off conditions. It is important to know what the expected peak polished rod load is with the well pumped off. The peak loads will increase as the fluid level is drawn down. If this value is not known, and the dynagraph does not indicate a pumped off condition, set the limit initially at the structural load limit of the pumping unit. Once the well is pumped off, as validated by the dynagraph, move the peak polished rod limit to 15-20% above the observed polished rod load.

Minimum Polished Rod Load Limit:

This setpoint is meant to identify lower than normal minimum polished rod loads due to conditions such as increased down hole friction or rod parts. Minimum polished rod loads will not change much when the annular fluid level changes as it predominantly is a function of the weight of the rod string in fluid and pumping speed.

Consecutive strokes allowed:

This parameter controls how many consecutive strokes must exceed a setpoint before shutting down the pumping unit. This is to avoid nuisance shutdowns.

The recommendation for the pump off setpoint under normal conditions is 2 consecutive strokes before shutting down. When gas interference is present, the dynagraph trace during the downstroke may not move gradually from right to left and may move erratically right to left and back as pump fillage changes. It may be required to significantly increase the number of consecutive allowed strokes to avoid shutting down too early. It is not uncommon to increase consecutive allowed strokes to a value higher than 7 or 8 when gas interference is present.

Idle time or Down time: (Figure 3)

Once the pump off set point has been exceeded, the controller will shut the pumping system off for a pre-programmed period. This is usually referred to as off time, idle time, or down time. It is important to choose an off time long enough to allow the fluid level to recover and to provide full pump fillage operation. Avoid leaving a well off for too long of a period to avoid building up too much back pressure against the reservoir, with lower production rates as a result.

VARIABLE SPEED CONTROL CONSIDERATIONS (FIGURE 4)

A VFD control system offers many benefits over a standard pump off control system. In addition to the standard pump off parameters, a VFD system requires additional parameters to be set up correctly. A VFD constantly monitors pump fillage and controls pumping speed (SPM) to match inflow. It lowers SPM during low pump fillage conditions and increases SPM when pump fillage is high. The result is a near perfect match of pumping capacity with available fluid, which as a result lowers stresses on the pumping system, increases time in between failures, presents a more constant flowing bottom hole pressure, increased production, automatically follows production decline over time, prevents stuck pumps by keeping solids in suspension and additionally allows for advanced control modes by varying pumping speeds within a single stroke.

The VFD can also convert single phase power to 3 phase in areas where 3 phase power is not available.

This paper is not meant to describe in detail the internal functionality of a variable frequency drive. Most VFDs convert AC power into DC power on a DC bus with some limited buffering capability and then by means of insulated gate bipolar transistors (IGBTs) converts DC power into AC power at a specific voltage and frequency combination to operate a motor at the desired RPM. (Figure 5)

It is important to know that an electric motor when forced to spin at a higher rpm than the control speed as commanded by a VFD will generate power. This power will flow back to the VFD and will be buffered by capacitors connected to the DC bus. Once the voltage exceeds the DC bus limit, the VFD will shut down to protect itself.

There are two methods in use to prevent that from occurring, standard VFDs have the capability to divert excess energy to a bank of resistors and dissipate excess energy into heat. (Figure 6) These resistor banks are referred to as a dynamic break resistor (DBR). A DBR must be correctly sized for a given VFD make and HP rating.

An alternate method is to deploy a VFD that can dissipate such excess energy back on to the power grid. These VFDs are commonly referred to as REGEN drives. See figure 7 for two common REGEN drives used in our industry; an active front end (AFE) VFD and a Matrix VFD. REGEN drives have an additional benefit in that these drives are capable of mitigating harmonic voltage and current distortion on the power grid without the requirement of installing passive harmonic filters. (Outside the scope of this paper)

VFD SETUP PARAMETERS:

A VFD rod pump controller monitors the down hole pump card, which is calculated from the dynagraph measured at surface. The desired pump fillage percentage is set and the pump fillage range or dead band is defined. (Figure 4). A controller will command the VFD to increase SPM when the pump card trace exits this dead band to the right, indicating a rising fluid level. Alternately SPM will be decreased when the pump card trace exits the deadband to the left. A secondary minimum pump fillage setpoint avoids excessively low pump fillage while pumping at a minimum allowable SPM. Additional parameters must be programmed to optimize VFD operation.

Scaling Speeds: (Figure 8)

When an analog signal from a controller sets the command speed of the VFD, this output must be scaled correctly and is typically pre-programmed by the manufacturer. See figure 8 for an example. (In this example a 0 -10 V analog signal scales the VFD command speed from 0 to 2,000 RPM (or 0 to 100Hz for a 1200 RPM motor)

The minimum and maximum allowable working speeds are user defined and the controller will not allow the system to operate outside of this speed range. Commonly overlooked are the parameters for speed change increments, acceleration, and deceleration.

Pump Fillage setpoint (%): (Figure 4)

Determines when the well is considered pumped off as there is not sufficient fluid available to completely fill the pump during its upstroke. Set as far over to the right to minimize fluid pound strokes, while still able to detect a pumped off condition. A good starting point is 85-90%. Be careful not to move this setpoint too far to the right to avoid a loss in production. Too far over to the left potentially increases the intensity of fluid pound strokes. The dynagraph trace during first part of the downstroke will move gradually from right to left as pump fillage decreases with each pump stroke.

Secondary Pump Fillage Setpoint:

Set at or above 60-65% to minimize the intensity of fluid pound strokes. This setpoint will avoid excessively low pump fillage conditions while operating at minimum allowable speeds. A pump intake restriction is a common condition that causes excessively low pump fillage, even when operating at minimum SPM. The controller will shut down the system and once the downtime period expires will restart the system, If the alarm condition still exists, the unit will shut down once more. The operator may program how many cycles are allowed before shutting down on a malfunction condition. This requires an operator to evaluate and reset the system prior to start up.

Allowable pump fillage range, dead band:

Programmed as percentage plus or minus the set pump fillage parameter. Ideally set just wide enough to minimize speed changes and maintaining a relatively constant SPM with slightly fluctuating pump fillage. No or little gas interference accommodates narrower dead band settings, excessive gas interference requires a wider pump fillage range.

Set too narrow may result in continuous speed changes, set too wide allows for more speed variations then necessary and when set too far to the left potentially allow more intense fluid pound strokes.

Maximum and minimum working speeds:

The maximum working speed should be fast enough to be able to bring a fluid level down from a high fluid level after an extended period of down time. The minimum working speed should be slow enough to avoid over pumping the well and reduce fluid pound strokes.

Be careful not to set the minimum and maximum working speeds to close together to avoid 2-speed control when a speed change interval parameter is set too high.

Speed change intervals:

Set in SPM or a fraction thereof. Choose a value small enough to allow for multiple speeds between the minimum and maximum working speed limits. A speed increase parameter can be set at different values than the speed decrease parameter. i.e., slowing down quicker may reduce the number of fluid pound strokes.

As a rule, set the combination of maximum and minimum speed limits in combination with the speed change intervals to allow for a minimum of 3-4 different operating speeds.

Acceleration and deceleration parameters:

The acceleration and deceleration parameters are typically set as the number of seconds required to increase or decrease RPM or frequency output by a certain value. i.e., Toshiba and ABB VFDs a default of 10 indicates that it takes 10 seconds to accelerate from 0-120Hz (12Hz/Sec.), a Danfoss VFD on the other hand will accelerate from 0-60Hz (6Hz.Sec.) during that same 10 second interval. It is important to know these parameter settings for a given manufacturer.

Setting acceleration too fast may strain the VFD and exceed its torque and current limits. Keep in mind that commanding the VFD to accelerate the motor too fast, is affected by the inertia in the pumping unit and downhole assembly. A lot of steel must accelerate. Doing so too quickly can result in frequent VFD shutdowns. (Overcurrent/Overload)

Setting the deceleration too fast may result in overwhelming a DBR. The above-mentioned inertia will most likely prevent the motor from slowing down quickly enough and thus overspeed the motor causing it to generate a lot of power during a short period of time. The VFD may not be able to dissipate that energy quickly enough to the DBR. Lowering the speed at which the units must decelerate may mitigate the issue and prevent a nuisance shut down. Proper sizing of the system DBR will limit these issues.

ADVANCED CONTROL POSSIBLE WITH VFD’s.

VFDs offer more advanced control options vs. pump off controllers to mitigate issues such as rod float, fluid pound and gas interference. The capability of controlling multiple speeds within a single stroke or sectional speed control, can be used to to increase average SPM for linear units

Rod float mitigation: a VFD control system can slow down pumping speed when excessive downhole friction prevents the rod string from falling back into the well bore at normal operating speed. A faster upstroke will allow for higher average SPM and significantly increase production. This issue is common when producing heavy crude in combination with steam injection.

Fluid pound mitigation: when a controller can determine automatically at which point during a downstroke fluid pound occurs, it will be able to pro-actively slow down the unit during the next stroke in time to minimize plunger velocity when fluid pound occurs. Pumping speed is increased during the upstroke to ensure that overall SPM is maintained, and production remains constant.

Gas interference: in many cases a downhole pump is more capable handling gas at lower pumping speeds. A VFD provides the capability to operate at higher pumping speeds during up stroke and lower speeds during the down stroke.

Sectional speed control: Linear pumping units have relatively low maximum speed limits. This is due to the limitation at the top and bottom of stroke. A VFD will allow for higher in the up and down stroke while maintaining a safe speed through the top and bottom sections of stroke increasing over all SPM, and thus increasing production capacity by as much as 15 – 20%. (Figure 9)

FIGURES

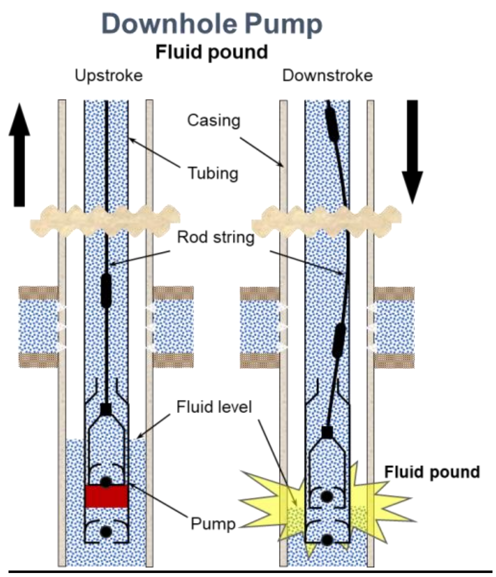

Figure 1, Fluid Pound

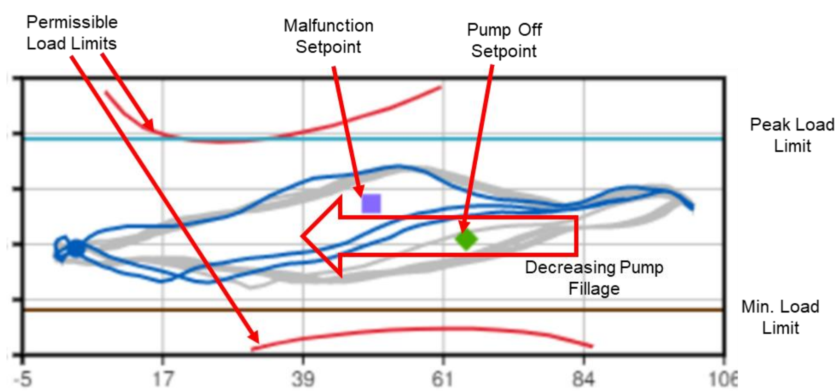

Figure 2, Pump Off Controller Set Up

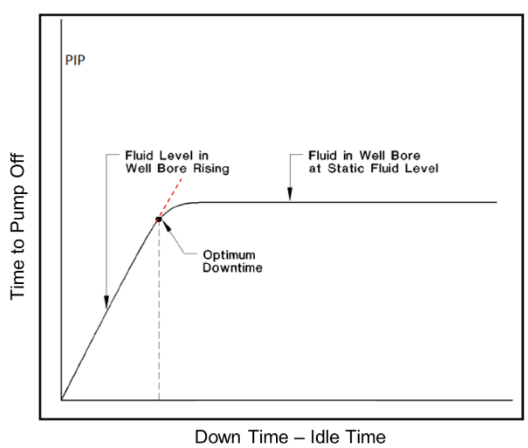

Figure 3, Optimum idle, off time

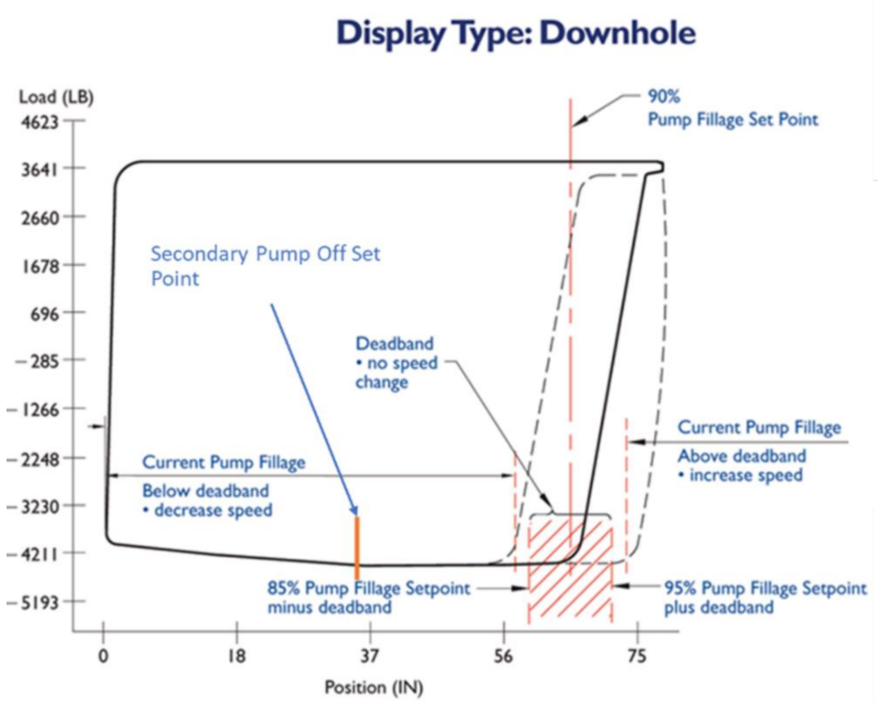

Figure 4, VFD Control

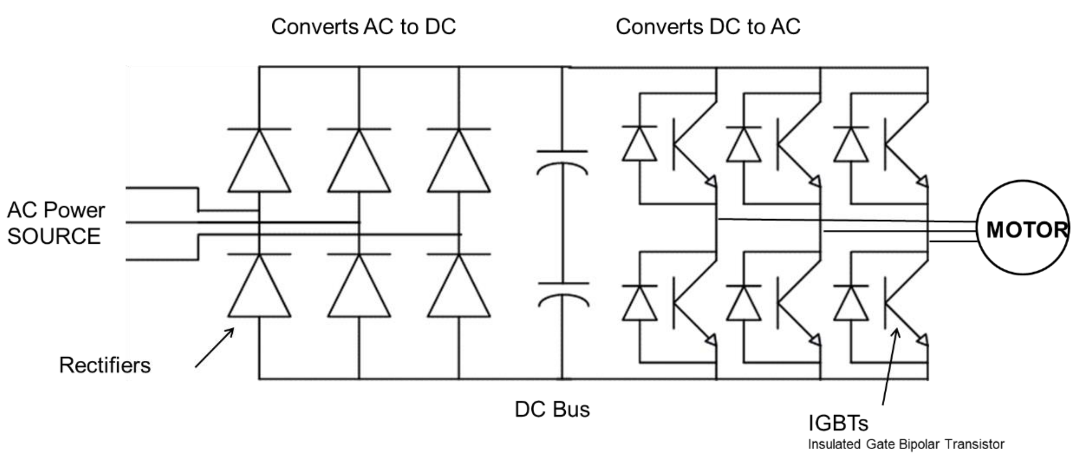

Figure 5, 6-pulse VFD

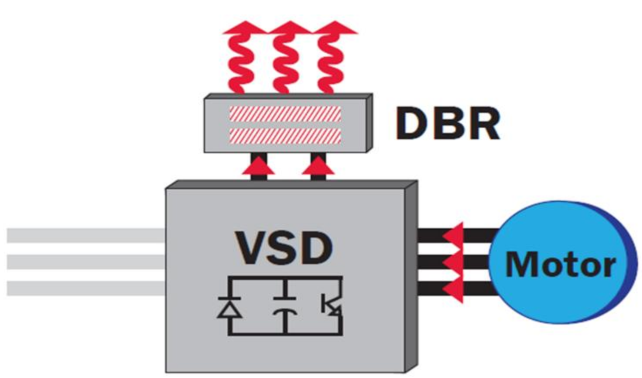

Figure 6, VSD with DBR

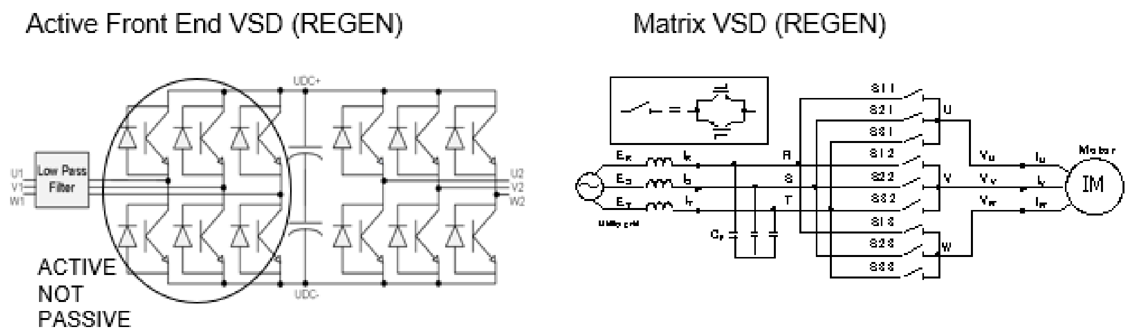

Figure 7, REGEN VSD's

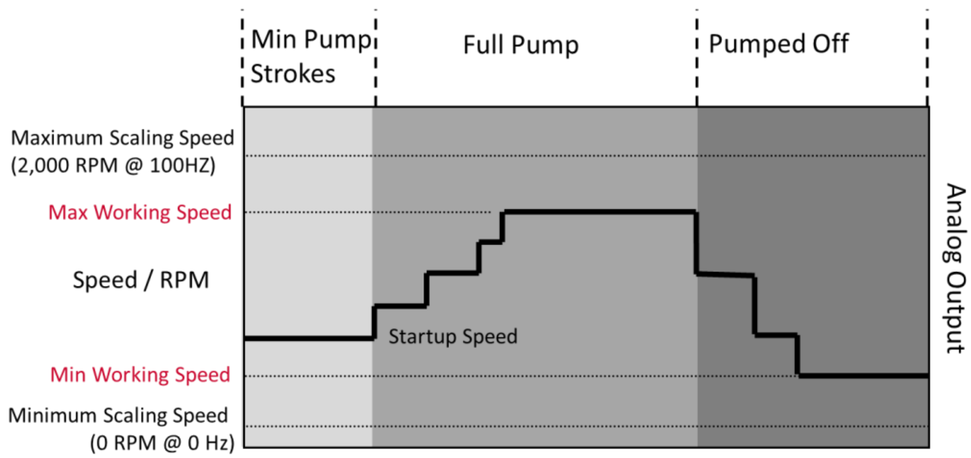

Figure 8, Scaling Speed Settings

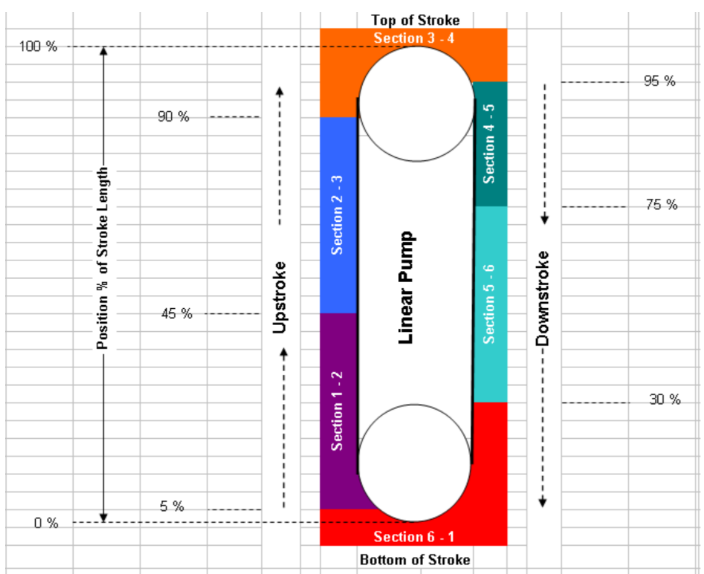

Figure 9, Sectional Speed Control