APPLICATION OF VARIABLE FREQUENCY DRIVES TO THE ROD PUMP SYSTEM

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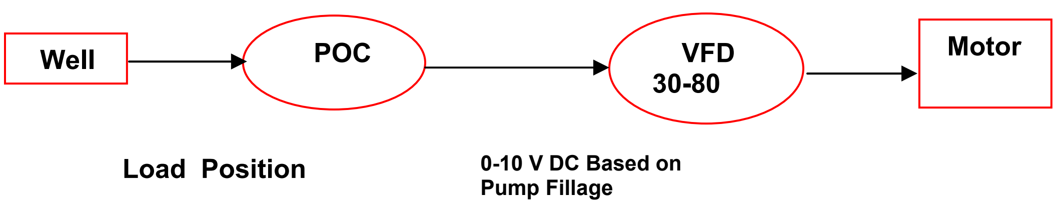
ABSTRACT
Variable Frequency Drive (VFD) technology has been employed in a wide variety of applications in many industries in recent years. Application of VFD to the rod pumping system has allowed pumping speed to be adjusted in real time by the POC, eliminated sheave changes as well conditions change, reduced power consumption, reduced size and cost for some system components, and allowed continuous pumping of wells producing formation solids. This paper will review the installation, operation, benefits and economics of installations on new and existing wells at several locations in West Texas operated by BP America

INTRODUCTION

The use of VFD technology has greatly expanded in recent years with the rapid development of solid state devices capable of reliably serving a wide variety of oil field applications such as pump drives, cooling fans, and electrical submersible pumps. The use of VFD has allowed for continuous optimization of processes far beyond that of fixed speed motors. The optimization has produced both electrical energy and maintenance cost savings since systems can now be operated at a precise operating point with no need to over compensate then "throttle back" a piece of equipment to achieve the desired output.

In the rod pumping system the VFD can be used to maintain a well in a pumped off condition using the output from the well's Pump Off Controller (POC). The strokes per minute (SPM) can be varied as well and down hole equipment conditions change over time.



HOW VFD WORKS

The VFD unit has three sections: a converter, a filter/storage section and an inverter. The VFD takes commercial 460 volt three phase 60 Hertz (Hz) alternating current and converts it to 600 volt square wave direct current using a diode. The filter/storage section then smooths the square wave to a straight, smooth direct current output. The inverter, based on the input from the control device (POC in the rod pump application), using an Insulator Gate Bipolar Transistor (IGBT), converts the direct current into a sine wave pulse width modulated alternating three phase current output at a Hz required to obtain the desired speed from the pumping unit motor. An alternating current motor will respond to this change in input Hz with a change of speed. Motor voltage is not affected by the use of the VFD but current is generally lower.

VFD INSTALLATION ON ROD PUMPED WELLS

The installation of a VFD on a rod pumped well involves inserting the VFD between the commercial power source and the pumping unit electric motor. An analog 0-10 volt DC output from the POC controls the VFD to maintain the set points in the POC. The set points in the POC are established to maintain the well in a pumped off condition while considering other factors such as well configuration and gas interference. The system used on the wells in this study is a Cutler Hammer SV9000 with a Lufkin SAM Pump Off Controller and a Nema B motor. This setup has been installed in several Clearfork wells in the Martin Field in Andrews County, Spraberry Trend wells in Glasscock County and Clearfork wells in Terry County, Texas. The VFD will operate the electric motor over a range of 30-90 Hz. The lower limit is a function of motor fan cooling and the upper limit is a function of the blade tip velocity of the motor cooling fan. Class H insulation is specified for motors in these application due to its ability to handle temperatures of up to 255 degrees Centigrade.

THE BENEFITS OF VFD IN ROD PUMPED WELLS

1. Lower electric power use-The VFD allows the well to be operated at a preset condition. The well is neither over pumped nor under pumped. In many cases the well is operated at very low spm which results in low I^2R losses in the electric motor and wiring system.
2. Eliminates the need for sheave changes-Several of the BP installations were for newly drilled wells where the stable rate was significantly lower than the initial rate. The rod pump system was designed for the maximum expected rate and the POC/VFD system was then allowed to control the unit speed to match the productivity of the well as it declined. No lost time or expense was incurred for sheave changes and wells were operated optimally at all times with little or no on-off cycling.
3. Continuous pumping of wells producing solids-A substantial benefit was realized from the ability to continuously pump new wells. In previous drilling programs, pump changes had been required due to rod pumps sticking after being shut down by the POC. The POC/VFD system has allowed wells to be operated longer, in fact some wells have not required the expected pump change due to solids handling, before requiring their first pump change.
4. Lower field peak electrical demand-A follow up to continuous slow spm operation. Once all the wells in a newly drilled field have reached stable production wells can be operated continuously at low electrical loads reducing the effect of intermittent high loads in on-off cycling on peak electrical demand.
5. Response to changing well conditions-Many of the POC/VFD installations have been on new primary recovery wells which have been fracture treated. The initial production is characterized by frac load recovery, followed by production and decline of flush oil production, and finally by stable, but gassy, low water cut oil production. It is possible to manage these three very different conditions with a single set of set points and then allow the system to operate the well at the optimum speed to maintain maximum drawdown.
6. Soft start of the rod pumping system-Pumping units can be started at very low SPM and then ramped up (example-set point to increase SPM by 10% per stroke) to operating speed lessening shock to pumping units, sucker rod systems, belts (eliminates shock loading and startup slippage). and avoiding current inrush/locked rotor conditions. Conversely, the ramp down can be controlled (example-20% per stroke) as pump fillage drops as well pumps off.
7. Smaller motor used-In conventional installations in areas where VFD is now being used the typical motor was a 40 HP Nema D. The VFD installation for units of the same size and capacity uses a 30 HP Nema B TEFC.

THE DISADVANTAGES OF VFD IN ROD PUMPED WELLS

1. Cost-The average cost for the system installed has been about $48 00. Payout has been achieved in less than one year as demonstrated below. The system had provided little maintenance problems with only two cooling fans requiring replacement in the 23 units installed to date.
2. VFD is usable with the Lufkin SAM only-To date the system has been utilized with the SAM controller only. BP operates other POC devices and additional work would be required to utilize the VFD with other controllers
3. Soft start and reduced SPM can reduce pump efficiency-The soft start will not produce “tagging” in wells which require this to start pumping. The operator, by taking the well off POC control and increasing the output Hz to increase the unit speed can accomplish tagging manually, if necessary. With the VFD operating the unit at low SPM the down hole rod pump over travel is changed, resulting in reduced capacity and efficiency due to the change in valve spacing. The pump must be spaced for the maximum over travel condition and at lower speeds the clearance between pump valves is increased with a potential loss of efficiency, especially in gassy wells,
4. Gearbox lubrication-Some pumping units require special gearbox wipers if operated at very slow speed to assure proper gear lubrication.

FIELD TEST OF VFD

A field test was conducted on a stable well in the Martin Field in Andrews County, TX to determine electrical energy savings possible with the VFD system. A test was run for five days with the well running on the VFD at varying speeds as determined by the POC. The VFD was then changed to run the unit at a fixed speed with the well cycled by the POC. Well production rates and fluid levels remained constant during the test. Electrical consumption was measured with a Kwhr meter. In the example $.058/kwhr is used.

Running on VFD and POC control at Variable Speed

Date	Kwhr	$/day	Run Time	SPM
1 Dec	71	4.12	100%	5 to 8
10 Dec	60	3.48	100%	5 to 8
12 Dec	105	6.09	100%	5 to 8
18 Dec	57	3.31	100%	5 to 8
19 Dec	88	5.10	100%	5 to 8

Average Daily Cost $ 4.42 Annual Power Cost $1613.00

Running on Standard Panel and POC

Date	Kwhr	$/day	Run Time	SPM
15 Jan	430	$24.94	73%	7.86
17 Jan	404	$23.43	88%	7.86
18 Jan	388	$22.50	82%	7.86
23 Jan	409	$23.72	84%	7.86
24 Jan	408	$23.66	94%	7.86
25 Jan	345	$20.01	85%	7.86
30 Jan	315	$18.27	72%	7.86

Average Daily Cost $22.36 Annual Power Cost $8161.9

This field test was performed with the 40 HP Nema D motor.

<u>COMPONENT AND OTHER COSTS</u>

VFD Cost	$4250
Nema D 40 HP	$1619
Nema B 30 HP	$1085
Sheave	$ 100
Labor to change sheave	$ 200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