ESP Workshop

SPE-GULF COAST

VARIABLE FREQUENCY GENERATOR as the POWER SUPPLY for an ESP

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Abstract

Variable Frequency Power with a perfect sine wave and no harmonic distortion, was used to deliver power to a downhole Electric Submersible Pump (ESP) motor by using an engine driven generator, to utilize the variable speed capability of the engine motor to supply the electrical power at a variable frequency, and a variable voltage, that was in direct proportion to the engine speed. Canadian Nexen Petroleum Yemen (CNPY) is operator (on behalf of its partners Occidental Peninsula Inc. and Consolidated Contractors (Oil & Gas) Company S.A.L.) of the Masila block 14 in the Republic of Yemen. CNPY has installed a 660 KW Variable Frequency Generator (VFG) System as the surface power at a well site in Yemen to drive a 760 HP ESP. This technical paper will review the benefits of a VFG System as compared to the current practice of utilizing Variable Speed Drives (VSD) for this application. Field results for operating and maintaining this system will also be reviewed.

A summary of the benefits that will be presented in detail are:

- Increase production by more than 3%.
- Reduce the motor amperage by more than 4% due to perfect sine wave, no voltage spikes, & no harmonics.
- Longer run life predicted.
- Lower maintenance cost predicted.
- Suitable for applications which require a generator on lease to drive the downhole ESP motor.
- No harmonics or voltage spikes. Predicted benefit of less stress on motor, motor lead extension, main cable, and wellhead penetrator, all of which help to contribute to longer ESP run life.

Introduction and Background

Most ESP systems in the world are powered from a power grid to supply high voltage high line power right to the well site. The producer then has the choice of using a Fixed Speed Drive (FSD) or a Variable Speed Drive (VSD), as the surface Drive equipment for the dowhnhole ESP. In the more remote oil production areas of the world, a nearby high line infrastructure is not in place, and subsequently a portable generator (GenSet) is required on the well site to power the ESP. This is the situation at CNPY's Masila operation where over 240 Diesel GenSet's are used on lease to drive the downhole ESP's. Figure # 1 has typical field conditions for Masila Block Production wells.

Using the standard type of 480 Volt Generator that is currently available to the Industry, an 855 HP Diesel Engine, coupled to a 660 KW 480 volt generator, utilizing a FSD c/w Soft Start capability, can just barely start a 400 HP ESP motor. A larger motor could be operated, but getting it started is another matter.

However, by using a VSD, the same 855 HP Diesel Engine, coupled to a 660 KW 480 volt generator, can start and run a 760 HP motor. This is the main reason why CNPY has a VSD on the well site to power the downhole ESP's.

Variable Frequency Generator (VFG)

To overcome the standard GenSet design limitations, CNPY worked with Canadian Advanced Inc. (CAI) to build a custom designed GenSet that was capable of starting large motors, and also capable of operating the motors at a variable speed, which is the VFG that is discussed in this paper.

The VFG unit consisted of the following major components:

1. Diesel Engine rated at 855 Continuous Horse Power at 1800 RPM. Engine capable of operating continuously at any speed from 900 to 1800 RPM (30 - 60 Hz).

2. A Synchronous Generator rated at 660 KW. Capable of 131 Amps and a range of 1,200 to 4,000 Volts. Generator capable of starting a large motor at any frequency from 30 to 60 Hz and also can be operated at any frequency from 30 to 60 Hz.
3. Specialized Electronic Motor Controller Equipment.
4. Soft Start capability at reduced voltage was utilized for all start-up modes tested.

Shop Testing

Prior to installing the VFG in the Field, a shop test was conducted to evaluate the different motor starting methods and the generator to motor loading characteristics for this VFG. A 644 HP ESP motor coupled to a 12,000 bfpd centrifugal pump was selected for this test. For connecting the Generator to the motor, a length of 6,500 feet of #1AWG round main cable was used to simulate Field conditions where the ESP motor is a long way from the surface drive equipment.

A 50 Hz start test at 77% Soft Start Voltage showed that the engine picked up the motor load and stabilized in 3 seconds. The inrush amperage during motor start-up was measured at 2.8 times nameplate amps. The Volts, Amps, HZ and KW response measured are shown in graphs 1, 2, 3, and 4.

A 40 Hz start test at 84% Soft Start Voltage showed that the engine picked up the motor load and stabilized in 2 seconds. The inrush amperage during motor start-up was measured at 2.4 times nameplate amps. The Volts, Amps, HZ and KW response measured are shown in graphs 5, 6, 7, and 8.

A start was also initiated at 40 Hz using 88% Soft Start Voltage while the engine was accelerating the generator from 30 Hz to 50 Hz, and showed a stabilization time of only 2 seconds using this starting method. The inrush amperage during motor start-up was measured at 2.4 times nameplate amps. The Volts, Amps, HZ and KW response measured are shown in graphs 9, 10, 11 and 12.

Once the ESP motor was started, the motor speed was varied from 30 Hz to 60 Hz by varying the speed of the diesel engine.

Upon the completion of the ESP motor starting and running evaluation using the VFG unit, it was sent to the Field for an oil well installation.

Field Production Well Installation

Equipment at the well consisted of the following:

- 760 hp motor, 3760 volts, 123 amps
- 16,000 bfpd centrifugal pump
- 850 KVA VSD
- High Line Power

Measurements at the above well site # 1 while connected to the VSD were:

- 57 hz speed
- 18,250 bfpd
- 114 Amps

The ESP at the well site # 1 was then disconnected from the VSD and connected to the VFG. It is important to note that there were no changes made below the wellhead, only the surface drive equipment to the ESP was changed out.

Measurements at the above well site # 1, while connected to the VFG, were taken for two reference points:

1) VFG at 57 Hz
   - 18,250 bfpd
   - 109 Amps

2) VFG at 114 Amps
   - 19,550 bfpd
   - 59 Hz

Reference point # 1 is for a constant speed comparison between a VSD and a VFG, when connected to the same downhole ESP. When an ESP motor is driven off of a VSD, it uses more power than the same ESP motor driven off of a clean sine wave, such as provided by the VFG. The test verified this by using a constant speed of 57 Hz for both systems, and the amps were measured at 114 for the VSD and 109 for the VFG, for a reduction of 4.5% on the amperage load.

Reference point # 2 is for a constant amperage comparison between a VSD and a VFG. The VFG needed to be speeded up to 59 Hz to draw the same constant amperage as the motor used at 57 Hz on the VSD. Using the data from the Field Production Report, this increase in speed is directly related to an increase in production from 18,250 to 19,550 bfpd, which is an incremental production increase of 1,250 bfpd, or 7.1% increase.

Summary

The VFG unit is capable of starting and running a large ESP motor with the same capability CNPY is used to with its VSD's.

When comparing the VFG to the type of VSD's used by CNPY, the clean sine wave power being supplied by the VFG results in a reduced amperage to the ESP motor for a given ESP motor speed. Conversely, if the well has excess deliverability for a given amperage limit, the ESP motor speed can be increased resulting in additional fluid production.

The clean sine wave provided by the generator produces no harmonics or voltage spikes. It is anticipated that this 'clean' power will help to contribute to longer ESP run lives due to reduced electrical stress on motor, motor lead extension, main cable and wellhead penetrator.

It is also expected that the VFG will have lower maintenance costs than the VSD / GenSet units, but more operational time is required to verify this.

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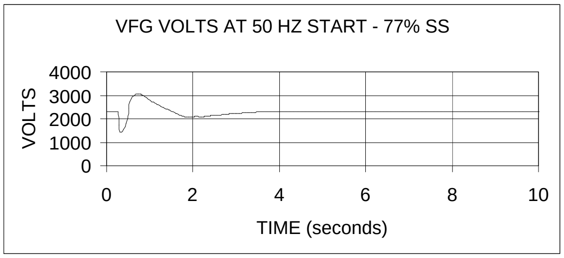
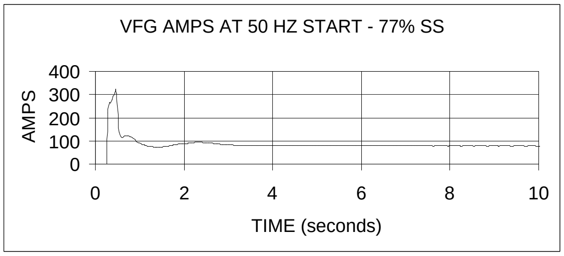


GRAPH 1



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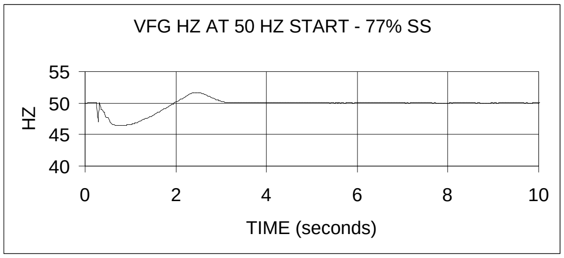

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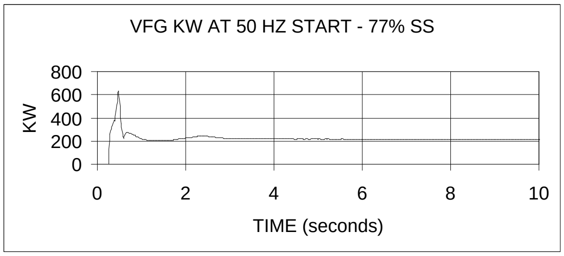

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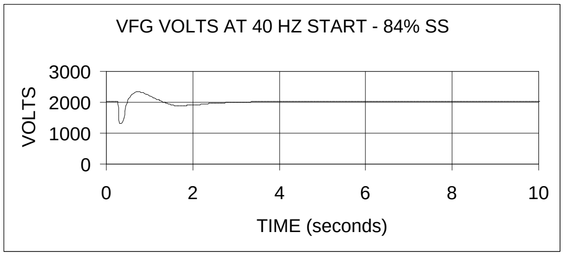

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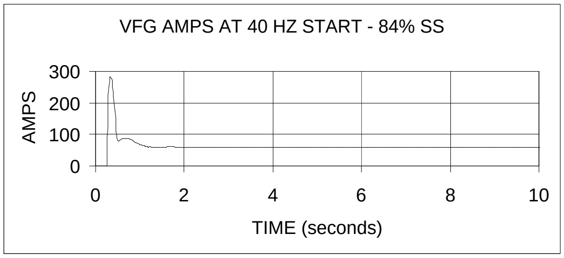

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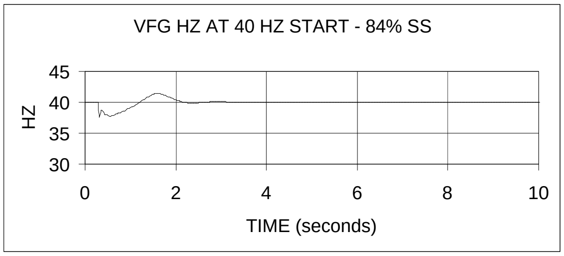

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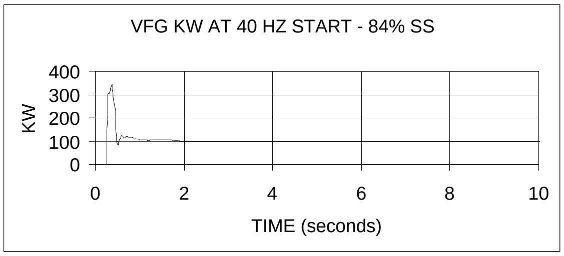

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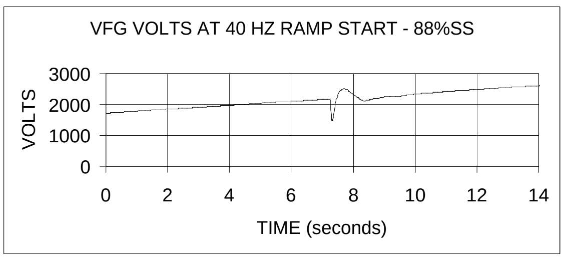

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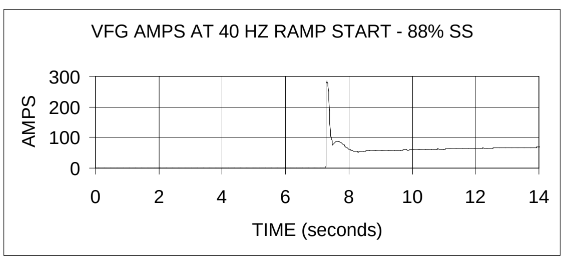

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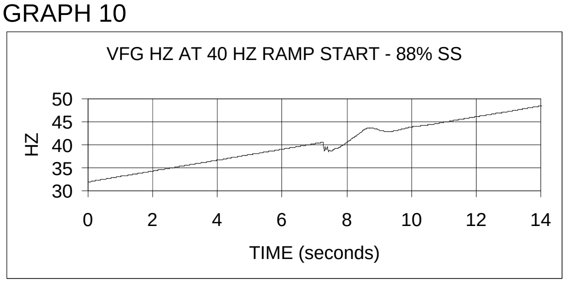

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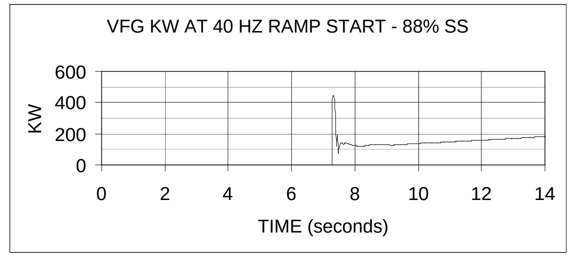

GRAPH 12

FIGURE 1

Masila Block Field Conditions

QUANTITY	FROM	TO
# OF WELLS		362
AVG. BFPD	200	25000
SIBHP, PSI	800	3450
PUMP INTAKE PSI	150	2200
GLR, SCF/STKBBL	7	1200
API, SP.GR.	17	42
BHT, F	160	225
TBG, O.D.(IN)	3.5	5.5
CSG, O.D.(IN)	7.0	9.625
TVD, FEET	5200	11000
MD, FEET	5200	12500
SCALE (LIGHT, ETC)	None	Light
SAND	None	Light
H2S	Trace	1000
CO2	Trace	trace
EMULSION (yes or no)	No	No
ONSHORE/OFF SHORE	Onshore	Onshore