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Name & Phone No. Randy Peden, (806) 897-2069

Address P. O. Box 10, Whiteface, Texas 79379

B. DOE PATENT COUNSEL ACTION

☐ Patent clearance for release of the above-identified document is granted.

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Title: **Enhanced Recovery Utilizing Variable Frequency Drives and a Distributed Power System Final Report**

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Principal Authors: **Randy Peden, Peden Energy**

Sanjiv Shah, RIO Technical Services, Inc.

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Name and Address of Submitting Organization:

Randy Peden	**RIO Technical Services, Inc.**
Peden Energy	**4200 S. Hulen Street**
P. O. Box 10	**Suite 630**
Whiteface, Texas 79379	**Fort Worth, Texas 76109**

Abstract

This report describes complete results of the project entitled “Enhanced Recovery Utilizing Variable Frequency Drives and a Distributed Power System”. This demonstration project was initiated in July 2003 and completed in March 2005. The objective of the project was to develop an integrated power production/variable frequency drive system that could easily be deployed in the oil field that would increase production and decrease operating costs. This report describes all the activities occurred and documents results of the demonstration.

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Executive Summary

Peden Energy was selected by the National Petroleum Technology Office (NPTO) to develop an integrated power production/variable frequency drive system (VFD) that could easily be deployed into the oil field that would increase production and decrease operating costs. For this demonstration, Peden Energy used its existing production lease site, D. S. Wright "C". This site is located approximately three miles southwest of city of Whiteface in Cochran County, Texas.

This demonstration was broken down into the following three phases: 1) Baseline data collection, 2) VFD demonstration, and 3) Microturbine demonstration. During the baseline data collection, Peden Energy collected all pertinent oil and gas production data as well as power usage data for the existing field conditions. In phase two, Peden Energy installed variable frequency drive with a computerized pump off controller onto the pump jack that adjusts and varies the pumping speed of the well based upon downhole torque demand. In phase three, Peden Energy installed a 30 kilowatt microturbine to operate the entire field using the wellhead gas. This gas contained up to 3% hydrogen sulfide.

An integrated 30 kilowatt microturbine/variable frequency drive was successfully installed into the operating oil field. The demonstration was able to 1) successfully show that a variable frequency drive is a useful tool to minimize power consumption of a pump jack and 2) that the production field was able to run without grid power. The final phase of the demonstration also involved adding a gas sweetener to the natural gas to comply with Texas Environmental regulations to decrease sulfur dioxide emissions. Addition of the gas sweetener was unsuccessful and negatively impacted the performance of the integrated microturbine/VFD. The demonstration was terminated due to failure of the gas sweetner.

1.0 Introduction

The objective of the project was to develop an integrated power production/variable frequency drive system that could easily be deployed into the oil field that would increase production and decrease operating costs. This demonstration was conducted at Peden Energy's existing production lease site, D. S. Wright "C". This site is located approximately three miles southwest of city of Whiteface in Cochran County, Texas. This field contains two oil and gas producing wells. Its gas conveyance lines are also connected to adjoining field (operated also by Peden Energy) to supplement natural gas requirements for operation of the microturbine.

2.0 Demonstration Design

This demonstration included three (3) phases. These phases were: 1) Baseline data collection, 2) VFD demonstration, and 3) Microturbine demonstration.

During the baseline data collection, Peden Energy collected all pertinent oil and gas production data as well as power usage data for the existing field conditions.

In phase two, Peden Energy installed Variable Frequency Drive with a computerized pump off controller onto the pump jack that adjusts and varies the pumping speed of the well based upon downhole torque demand. The greater the torque the slower the pumping, as torque demand decreases, the pump speed increases.

In phase three, Peden Energy installed a 30 kilowatt microturbine to operate the entire field using the wellhead gas. This gas contained up to 3% hydrogen sulfide. The original objective of the demonstration was to run the microturbine directly with the wellhead gas. However, due to environmental regulations, Peden Energy had to clean-up the gas first to limit sulfur dioxide emissions to a maximum of one pound per hour.

3.0 Demonstration Results and Discussion

3.1 Phase 1: Baseline Conditions

For about four (4) months at the beginning of the demonstration, Peden Energy collected data on baseline conditions for the oil field. This included oil and gas daily production data, and power usage data. Table 1 summarizes the baseline conditions.

Table 1: Phase 1 Oil and Gas production and Power Usage Data

Period (Month)	Combined Average Oil Production (bbl)	Combined Average Gas Production (MCF)	Combined Average Electrical Consumption (kwh)
November 2003	1.23	4	53.83
December 2003	1.22	4	52.33
January 2004	1.69	4	50.93
February 2004	1.39	4	45.78

3.2 Phase 2: Variable Frequency Drive Demonstration

During Phase 2 of this project, Peden Energy installed two variable frequency drives with computerized pump off controllers onto two pump jacks. A Variable Frequency Drive adjusts and varies the pumping speed of the well based upon downhole torque demand. The greater the torque the faster the pumping, as torque demand decreases, the pump speed is decreased.

This pump control ability is expected to accomplish the following: 1) Automatically adjust pumping speed to match the well productivity, and will automatically prevent pumping off and shutting down. By maximizing stroke speed during low torque demand, the total strokes per minute are increased and can lead to a 10% or greater increase in oil production. 2) With a variable speed drive, motors are started at minimum frequency (soft start, therefore reducing mechanical stress) and (increases) ramps smoothly to full power. Capital expenses can also be reduced as smaller horsepower electric motors can be used because of the soft start capability. 3) By slowing the beam during peak power demand and increasing the speed during low torque demand on motors, an optimum matching of production capability and lowest power cost can be achieved. Through this process a small independent can reduce power demand, maintain minimal power usage per stroke, and realize energy savings of up to 50%.

VFD Installation

VFD installation is a relatively simple process. A VFD comes from the manufacturer in an electrical style panel box and is mounted to a pole near the electrical control panel of the pump jack or to the same pole that the existing electrical controls are mounted too. A VFD installation does not require any down-hole or subsurface activities.

A typical pump jack for this demonstration utilizes 480V three-phase electric service. The VFD input is connected to the electrical service and the output is connected to the pump jack AC motor. The VFD also requires a simple electrical ground. This demonstration used a standard copper wire earth ground. Note that some pump jacks require a specific rotational direction (clockwise or counterclockwise) in order not to damage the pump jack gear box.

VFD Start-Up

The start-up of the VFD required direct programming into the VFD control panel for initialization of the unit. The information to be input into the VFD control panel is:

- AC motor amperage
- AC motor voltage
- AC motor horsepower
- AC motor maximum allowable RPM
- Pump jack gear ratio

Once this information was programmed into the unit, the VFD was ready for operation. The VFD has a three way control switch that allows the selection of Hand Operation, Automatic Operation, or Off. The VFD is then placed in the Hand Operation mode and the pump jack should begin to function.

VFD Demonstration

The VFD's used in this demonstration were installed in March 2004. The VFD's functioned during this demonstration time with minimal to no problems. The VFD's are critical for the regulation of the power draw to the microturbine and the use of a microturbine would not be possible without VFD's. This is discussed in detail in section 3.3 below. Table 2 summarizes oil and gas production data and power usage data during Phase 2.

Table 2: Phase 2 Oil and Gas production and Power Usage Data

Period (Month)	Combined Average Oil Production (bbl)	Combined Average Gas Production (MCF)	Combined Average Electrical Consumption (kwh)
March 2004	1.23	4	16.30
April 2004	1.45	4	27.17
May 2004	1.53	4	24.47

3.3 Phase 3: Microturbine Demonstration

Microturbine Installation

Microturbine installation is a fairly complex process. For this demonstration, a Capestone microturbine was used. The Capstone microturbine can be purchased in either a weatherproof or non-weatherproof model. The non-weatherproof model used for this demonstration requires a building or other enclosure to protect the microturbine from the elements and weather. A 10 foot by 13 foot metal building was constructed at the demonstration site tank battery. This building has a 7 feet wide roll-up door, a 3½ feet wide regular door, and two windows. An exhaust fan was installed in the rear of the building behind the microturbine. The fan allows constant cooling which provides the microturbine electronics to stay at ambient air temperature. The turbine requires a solid, secure, and clean foundation. In this demonstration a concrete floor was used.

The microturbine unit is approximately 4 feet long, 3 feet wide and 5 feet tall. The microturbine input connections consist of a sour gas supply line in this application. The sour gas line has three critical features. The first is a fuel shut off ball valve. The second is a pressure regulator. The regulator is set to 55 psi. An inline filter is also in place to separate any liquids from the sour gas. These three components need to be installed as close as possible to the fuel inlet on the microturbine. The output connections consist of a 480V three-phase electric power line that is connected to the VFD discussed above in section 3.2. For safety, an output power disconnect was installed on the rear of the building.

Microturbine Start-Up

The start-up of the microturbine requires direct programming into the microturbine control panel for initialization of the unit. If all connections and settings are correct microturbine should be in operation.

Microturbine Demonstration

During the initial test phase of running the pump jack with the microturbine it was discovered that the VFD did not produce a steady power draw. When the A/C motor is On Load (pulling the sucker rods up) it was consuming 15 kw. When the A/C motor is on Off Load (slowing the sucker rods on the way back down the A/C motor is acting as a break) it was using only 5 kw. This is a concern because the power swing is too great for the microturbine to handle. The microturbine is equipped with a load follower which enables it to produce only the power required. By nature, a turbine generator is very slow to respond to power swings. Because the A/C motor is pulling 15 kw and then dropping to 5 kw within 3 seconds, the microturbine is off loading to the batteries and break resistor. This causes the break resistors and batteries to over heat. Another complication due to slow reaction of the microturbine is that the batteries must supplement the power load required to run the A/C motor. This will eventually destroy the batteries because of the constant draw and charge.

To fix the problem VFDs were adjusted to increase and decrease the speed of the pump jack. The pump speed increased while the A/C motor was in off load cycle, therefore increasing the power draw of the A/C motor. During the on load cycle the speed of the pump jack was decreased therefore pulling less power. This stabilized the power draw to a 4 kw which the microturbine could handle, but still not a suitable operating state. The next step to reduce the power swing was to balance the pump jack. This brought the power swing down to 3 kw. After consulting with an engineer from Capstone, the decision was made that 3 kw was acceptable and not harm the microturbine, but would have a negative impact on the battery life. It should be noted that the change in increasing and decreasing speed of the AC motor change our peak power draw from 15 kw to 7 kw. The advantage of this is the ability to run more pump jacks on the microturbine if necessary. Discussing the issue with Pumps and Services, a vendor of the Capstone microturbine, they suggested a battery pack made up of eighteen industrial car batteries which would support the current power swing. Pumps and Services have been using this set up for two years without complication on another installation.

Microturbine Performance

The microturbine was run for three consecutive weeks 24-hrs a day, at the end of this period the unit faulted and shut down. While the unit was in operation it experienced flame outs which progressively got worse. While trouble shooting the unit after failure it was discovered that the igniter had ruined because of over use. During each flame out the igniter was used to restart the combustion because the fuel to air ratio was inadequate. To overcome the flame out situation, the BTU content was adjusted to medium verses the normal setting which our gas analysis and Capstones recommendation was. The fuel indexes were also changed. Fuel Index One was change from .99 to 1.05. This also is contrary to Capstones original recommendations. After replacing the igniter and making fuel changes the unit ran fault free.

Gas Sweetener

A Gas Sweetener was installed to remove H_2S (Hydrogen Sulfide) from the sour gas supply to comply with environmental regulations for sulfur dioxide emissions. This is a proprietary unit provided by Surfside Environmental, Inc (SEI). The unit has a three stage process. During the first stage, it charges the water with a proprietary compound that attracts H_2S. In the second stage the sour gas is passed through multiple tanks that contain the charged water. In this stage the H_2S is removed from the gas, the gas is separated from the water and stored in a pressurized scrubber. Final stage of the gas sweetener is to circulate the contaminated water through a charcoal filter which removes contaminants from the water and the process begins again.

Gas Sweetener Performance

The gas sweetener was a failure on multiple counts. The water level in the tanks would not stay at a consistent level. Over a 24-hour period, all the water would be pushed to the pressure scrubber. This would leave the tanks dry so they would not have the ability to remove any H_2S from the sour gas. Water that was pushed into the pressure scrubber is also a liability, because any moisture introduced into the microturbine would ruin the smart proportional valve causing the unit to shut down. Another fault of the gas sweetener was its inability to endure a cooled weather environment. As a consequence, the unit froze and blew out the ball valves and the water filtration system. After some corrective actions, the unit still would not perform properly. At this point it was determined to bypass the gas sweetener for the safety of the microturbine.

However, this was not acceptable under the environmental permit that the demonstration was operating under. The permit allowed only 1 lb/hr of SO_2 emissions that could not be maintained when direct wellhead gas was used. At this point the demonstration was concluded.

4.0 Conclusions and Recommendations

Based on this demonstration, Peden Energy concludes that variable frequency drive is a useful tool to minimize power consumption of a pump jack. We were also able to prove our stated objective to run a production field without grid power. However, to operate this type of unit in the state of Texas, it has to be run with a gas sweetener. The sweetener supplied by SEI was not suited for this application. It is recommended that research be conducted to develop a field deployable sweetener for treatment (primarily removal of H_2S) of small quantity of gas of up to 20 MCF. Combined with such a sweetener, field deployed microturbines can be utilized to operate remote fields.

List of Acronyms and Abbreviations

NPTO	National Petroleum Technology Office
VFD	Variable Frequency Drive
bbl	barrels
MCF	thousand cubic feet
kwh	Kilowatt hour
psi	Pounds Per Square Inch
A/C	Alternating Current
kw	Kilowatt
BTU	British Temperature Unit
SEI	Surfside Environmental, Inc
lb/hr	Pounds Per Hour
V	Volts