Solid State Phase Conversion
Sucker Rod Pumping Applications

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Innovative Control Solutions for Industry

Solid State Phase Conversion
Sucker Rod Pumping Applications
Overview

- Introduction to Phase Converting SRP Drive
- Benefits of Phase Converting SRP Drive
- Operator Interface
- Overview of UEdit® Embedded PLC
- Embedded SRP Drive Software Features
- Overview of WPR Well Report Generator
- Review of a Typical Well Report
- Well Optimization & case study
- Internet based Global Monitoring and Control, GMC
Solid State Phase Converters

- Combines:
  - Phase conversion
  - Motor control
  - Embedded application software
  - Diagnostics and fault log
  - Well Reporting
  - PLC
  - Serial communications
  - Display and Keypad

  Into one quiet, efficient, compact unit

- Operate larger 3 phase AC induction motors on 1 phase lines saves cost
Solid State Phase Converters

- Two modes of operation
  Variable frequency – Variable Speed
  Vector control – Torque & Speed
- Rugged outdoor packaging, UL
- Precisely balanced 3 phase output currents and voltages for long motor life and predictable performance
- Full torque at zero speed
- High Efficiency 97% nominal
- Motor and load protection, soft starts (typically less than motor nameplate FLA) plus much more!

This 1 phase AC motor has “800%” inrush
A 5% voltage unbalance reduces motor insulation life by 25% and currents can be over 40% unbalanced: loss of torque and increased heating/insulation failure.

Refer to NEMA MG-1 specifications.
Solid State Phase Converter HP Range

- HP Range
  - 230/240 VAC 1 phase service drop
    - 100 Amp Service -> 20 HP AC motor
    - 200 Amp Service -> 40 HP AC motor
    - 250 Amp Service -> 50 HP AC motor
  - 460/480 VAC 1 phase service drop
    - 100 Amp Service -> 40 HP AC motor
    - 200 Amp Service -> 75 HP AC motor
    - 250 Amp Service -> 100 HP AC motor

- Add a simple transformer to boost 230 VAC to 460 VAC to run larger motors on 230V service (higher HP’s are also available)
Solid State SRP Drive Package

- Heavy-duty enclosure designed for outdoor environments
- Door mounted keypad/display and circuit breaker operator
- Power line circuit breaker
  - Operator interlocked with enclosure door is suitable for use as service equipment (SUSE)
- Inverter DSP control module: One board does it all for all HP’s
  - Motor Control
  - POC
  - Communications and serial ports
Operator Interface

- Standard LCD 2-line by 24-character display for easy-to-read text and graphics.
- Optional GLCD 16-line by 40-character graphics display with charting capabilities.
- Password protection prevents unauthorized access to drive parameters.
- On-line setup instructions, prompts, warnings, bar graph displays, and logical data groupings for quick start-ups, smooth operation, and minimal downtime.
DSP Control Module and Communication

- Drive DSP Control Module (same DSP for all HP's)
- AnyBus® Interface
- RS 485 Modem
- MaxStream Radio
- Mass Memory
- RS 485
- Local Uedit ®
- Well Report
- Modbus RTU
- Terminals for inclinometer feedback, pressure transducers, and other sensors

- RS 232
- Head End Software
- Modbus RTU
- CASE®
- Theta®
Power Electronics

- Incoming single phase AC is rectified to DC
- DC link choke provides near unity overall power factor and low harmonic line currents at all motor speeds
- DC Buss Capacitors filter the rectified DC voltage and provide energy storage. Essentially buffers the motor from the mains.
- IGBT transistors (switches) are PWM controlled with state of the art Digital Signal Processor (DSP) to provide transducerless Flux Vector Control of a 3 phase AC motor (fancy name for an electronic torque wrench)
UEdit is a PLC which runs inside the DSP and consists of a suite of tools for customizing, monitoring and managing SRP software.

**Project View**
Project View reveals the architecture of a UEdit™ project at a glance. User-defined tasks, such as ladders and function blocks, are grouped according to the clock levels assigned to them. This allows code to be partitioned into meaningful segments that can be displayed simultaneously during monitoring or simulation.

**Chart Recorder**
The Chart Recorder monitors drive performance in real time. Four channels can be displayed simultaneously in several user-definable formats. Predefined signals, data, and I/O from varying clock levels may be monitored. Chart data can also be exported to a file for use by other programs such as Excel.

**Ladder Editor**
The Ladder Editor lets users build ladder logic to control or modify embedded drive functions. The graphical editor provides both on-line monitoring and off-line simulation modes. Standard programmable controller features, such as contacts, coils, timers, and data read and write functions, are supported.

**Function Block Editor**
The Function Block Editor extends programming flexibility by allowing mathematical computations, boolean logic, counters, comparisons, timers, and other functions to be included in applications. More than 70 predefined function blocks are provided, and users can create their own. The editor features an intuitive drag-and-drop environment.

**I/O View**
The I/O View displays the status of application inputs and outputs and lets users manipulate them. Bits can be viewed by name or graphically by word. Individual bits may be set, cleared, or forced on or off.

**Data View**
The Data View displays all setup and readout parameters in a device along with their values and other attributes. Parameter units may be changed globally within a device with the click of a button. Variables may also be dragged to the function-block or ladder-editor windows when programming. A complete record of drive data can be permanently archived or printed for safekeeping and restored to the drive in the event of a failure.
- The SRP controller is compatible with both Case Services and Theta Enterprises head end software packages.
Typical SRP Installation
SRP Family

Example Pumping Units Supported

- Conventional Crank Balanced
- Conventional Beam Balanced
- Reverse Mark ®
- Air Balanced
- Mark II ®
- Rotaflex ®
Example Pumping Units Supported

HG Bent Beam

Linear Rod Pump
SRP Modes of Operation

- Single Speed
  - Same Upstroke and Downstroke Speed from a single speed source.

- Dual Speed
  - Different Upstroke and Downstroke Speeds from separate speed sources.

- Optimize
  - Controller chooses optimal Upstroke and Downstroke speeds.

- Speed Limiters
  - Upstroke: *upstroke minimum spm* and *upstroke maximum spm*
  - Downstroke: *downstroke minimum spm* and *downstroke maximum spm*
  - Cornering speed limit: *cornering speed maximum spm*
Well Report - WPR

- Comprehensive Well Reporting
- Inferred Well Production
- Gauged Production Data
- Surface and Down-hole Dynamometer Plots
- Measured Gearbox Torque
- Pumping Unit Balance Assistant
- Predicted Surface & Down-hole Plots
- Valve Check, and more…

Just connect your laptop and run the program, excel based
# SRP Well Report

## Pump Optimization System

### Pumping Unit Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Rated Power</td>
<td>460.00 HP</td>
<td>500.00 HP</td>
</tr>
<tr>
<td>Unit Connected Power</td>
<td>460.00 HP</td>
<td>500.00 HP</td>
</tr>
<tr>
<td>Unit Rated Flow Limits</td>
<td>36,000 gpm</td>
<td>38,000 gpm</td>
</tr>
</tbody>
</table>

### Loading Statistics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump inlet pressure</td>
<td>325.00 psi</td>
<td>330.00 psi</td>
</tr>
<tr>
<td>Pump outlet pressure</td>
<td>100.00 psi</td>
<td>100.00 psi</td>
</tr>
<tr>
<td>P.S.I. (at 100% of Flow Limit)</td>
<td>15,000 psi</td>
<td>15,000 psi</td>
</tr>
<tr>
<td>M.P. (at 100% of Flow Limit)</td>
<td>5,000 psi</td>
<td>5,000 psi</td>
</tr>
<tr>
<td>M.P. (at 80% of Flow Limit)</td>
<td>4,000 psi</td>
<td>4,000 psi</td>
</tr>
</tbody>
</table>

### Flow and Pump Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Weight</td>
<td>4,000 lb</td>
<td>4,000 lb</td>
</tr>
<tr>
<td>Motor Weight at Full Load</td>
<td>11,000 lb</td>
<td>11,000 lb</td>
</tr>
<tr>
<td>Motor Weight at 80% of Full Load</td>
<td>9,600 lb</td>
<td>9,600 lb</td>
</tr>
<tr>
<td>Motor Liquid Motor</td>
<td>3,000 lb</td>
<td>3,000 lb</td>
</tr>
<tr>
<td>Pump Liquid Motor</td>
<td>3,000 lb</td>
<td>3,000 lb</td>
</tr>
<tr>
<td>Motor Liquid Flow</td>
<td>15,000 gpm</td>
<td>15,000 gpm</td>
</tr>
<tr>
<td>Pressure Riser</td>
<td>60.00 psi</td>
<td>60.00 psi</td>
</tr>
</tbody>
</table>
| Fluid Production Data
  - Horsepower Efficiency           | 65%      | 65%                     |
  - Percent of Pump                  | 284%     | 284%                    |
  - Horsepower Efficiency           | 65%      | 65%                     |
  - Percent of Pump                  | 284%     | 284%                    |

### Performance Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gage Cycles</td>
<td>4,000 psi</td>
<td>4,000 psi</td>
</tr>
<tr>
<td>Gage Diameter</td>
<td>13.00 in</td>
<td>13.00 in</td>
</tr>
<tr>
<td>Gage Depth</td>
<td>20.00 ft</td>
<td>20.00 ft</td>
</tr>
<tr>
<td>Gage Diameter</td>
<td>13.00 in</td>
<td>13.00 in</td>
</tr>
<tr>
<td>Gage Depth</td>
<td>20.00 ft</td>
<td>20.00 ft</td>
</tr>
</tbody>
</table>

### Diagnostics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horsepower Efficiency</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Percent of Pump</td>
<td>284%</td>
<td>284%</td>
</tr>
<tr>
<td>Horsepower Efficiency</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Percent of Pump</td>
<td>284%</td>
<td>284%</td>
</tr>
</tbody>
</table>

## Measured Surface and Downhole DynaCards

![Graph of Measured Surface and Downhole DynaCards](image)

## Measured Gearbox Torque

![Graph of Measured Gearbox Torque](image)

### Feature List

<table>
<thead>
<tr>
<th>Feature</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gearbox Torque Limiting</td>
<td></td>
</tr>
<tr>
<td>Simple Pump Off Controller</td>
<td></td>
</tr>
<tr>
<td>Dual Thrust Controller</td>
<td></td>
</tr>
<tr>
<td>Slew Rate Controller</td>
<td></td>
</tr>
<tr>
<td>Power Limiting</td>
<td></td>
</tr>
<tr>
<td>Power Factor</td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td></td>
</tr>
<tr>
<td>Balanced</td>
<td></td>
</tr>
</tbody>
</table>

---

*Note: All data is preliminary and subject to further analysis.*
SRP Well Report
Pump Optimization System

Reference Input

- Pump Direction
- Reference Input
- Calibrate Instrument
- Crank Angle

In: Calibrate instrumenter agian should have the same shape as SRP Reference input.
Understanding DynaCards

- Rod stretch
- Rod stroke
- Rod dynamics
- Gross pump stroke
- Net pump stroke
- Tubing stretch
- Pump fill
- Pump load
- Buoyant rod weight
- Gas compression
- Gas or fluid pound
Valve Check Test

- Automated, Unmanned Test
- Can be performed locally, remotely, or preset to automatically run once per day
- Automatically adjusts leakage term of BPD production estimate
Gearbox Torque Protection

Selectable torque output limits torque output to protect the gearbox.

Without Control:

With Control:

Gearbox Torque Limit
SRP Features

Standard Controls

- **Pump-Off Controller**
  - Simple POC Mode
  - Dwell Mode
  - Use as a lower limit only. Reduces daily operation time

- **Cold Start Controller**
  - cold start current limit
  - cold start torque limit
  - cold start spm
  - cold start cycles

- **Power Limiting**
  - Protect the Motor
  - Protect the Dynamic Brake Resistors
  - Reduce Power Consumption

- **Rod Load Control**
  - Modulates speed to reduce upper and lower limits on Rod loading
  - Lower limit used for Bridle Separation avoidance
  - May not be as effective if torque is being otherwise limited by motor power limiter, gearbox torque limit, power economizer or motor max torque limit

- **Speed Profiler**
  - Reduces gas breakout in the pump
  - Reduces violence of fluid pound

- **Flat Power**
  - Eliminate Peak Power Demand
  - Allow SRP Operation With Generator

- **Power Economizer**
  - Reduces peak power draw while allowing some speed control.
  - Reduces energy consumption

- **Bridle Separation**
  - Reduces speed to limit the violence when re-engaging
  - Sensor less (when using Load method)
  - Use Rod Load Control to avoid actual separation
Faults, Warnings and Events

- High and low torque fault thresholds
- High and low speed fault thresholds
- Event data-logger
- Power-up restart delay
- Auto-Restart
- Well Reports
- Fault log
Fluid Level High

- Optimizer will increase speed to \textit{up maximum spm} and \textit{down maximum spm}. It will maintain this speed until \textit{pump fill monitor} falls below \textit{maximum target fill}.

Pump Fill in Desired Range

- Optimizer selects appropriate speed to maintain pump fill within the target range.
- Over time, \textit{pump fill monitor} will settle at or about \textit{minimum target fill}.
- Over time, the casing fluid level will stabilize.
- **Pump Fill Low**
  - Pumping capacity exceeds the reservoir inflow rate, or gas breakout in pump.
  - Optimizer will decrease speed.
Case Study: Optimizer stabilized

**SINGLE SPEED**

- pump fill monitor: 60%
- pump average spm: 8.0 spm
- pump rate monitor: 256 BPD
- maximum rod load: 21,000 lbs

**OPTIMIZED OPERATION**

- pump fill monitor: 85-100%
- pump average spm: 5.2 spm
- pump rate monitor: 270 BPD
- maximum rod load: 19,500 lbs
Rod Load Control

Without Control:

With Control:
Soft landing speed control reduces fluid pound for pumps operating at low pump fill percentages without losing average pump speed.
Case Study: Minimize Fluid Pound
Global Monitoring and Control capabilities of phase converters with SRP software:

- Monitor, Diagnose and Control via Internet
- Cellular or Satellite modems, RF communications
- Email, pager, cell phone outcall notification, reduce windshield time and operating cost with remote monitoring. Allows well tenders to save time by concentrating efforts on wells with problems
- Trend production, mechanical loads, archive data to assist in troubleshooting and PM
- Multiple user, instant access from internet

**Sucker Rod Pumps**

<table>
<thead>
<tr>
<th>Name</th>
<th>State Detail</th>
<th>Faults</th>
<th>Pump Fill</th>
<th>Pump Speed</th>
<th>Average Fill</th>
<th>Average Speed</th>
<th>Pump Flow</th>
<th>FOP Monitor</th>
<th>Gas Flow</th>
<th>Water Production</th>
<th>Oil Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTO RUN</td>
<td></td>
<td>0</td>
<td>88 %</td>
<td>3.19 spm</td>
<td>88 %</td>
<td>2.96 spm</td>
<td>16 bpd</td>
<td>0 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUTO RUN</td>
<td></td>
<td>0</td>
<td>87 %</td>
<td>2.46 spm</td>
<td>75 %</td>
<td>2.46 spm</td>
<td>13 bpd</td>
<td>0 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUTO RUN</td>
<td></td>
<td>0</td>
<td>89 %</td>
<td>6.40 spm</td>
<td>87 %</td>
<td>6.26 spm</td>
<td>34 bpd</td>
<td>0 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUTO RUN</td>
<td></td>
<td>5</td>
<td>84 %</td>
<td>3.59 spm</td>
<td>84 %</td>
<td>3.88 spm</td>
<td>37 bpd</td>
<td>0 ft</td>
<td>mcfd/da</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trend Example
Inflow increasing: SPM response

Stroke Analysis

Parameter Trends
- Pump Speed
  - 4.01 rpm
  - High: 4.12, Low: 3.81
- Pump Flow
  - 23 bpd
  - High: 25, Low: 15
- Pump Fill
  - 66%
  - High: 70, Low: 40
- Maximum Rod Load
  - 12,404 lb
  - High: 12,721, Low: 12,242, Average: 12,438
Automatically adjusts SPM/production to constantly changing well inflow conditions.

- Trend Analysis

- Pump Speed (spm)

- Pump Fill %

- Pump Load (lb)

- Pump Production (bbl)
Review

- Solid State Phase Converters provide all variable speed pumping benefits 3 phase systems offer from single phase power lines.
- Greatly improved control and efficiency compared to other types of phase converters & internal combustion engines.
- Add embedded SRP features to optimize production for greater revenue and fast payback.
- Operate pump systems at design load without pounding fluid, generally increases mechanical life lowering workover frequency, saving cost and increased uptime.
- Convenient availability of data: BPD: Water & Oil plus Gas (with flow meter) production, loads, dynacards. Schedule work for wells that are not operating correctly with continuous internet monitoring of field data from anywhere if equipped with a modem (cellular data plans typically run $10/month/well).
Thanks for attending!

- Solid State Phase converters with SRP software features are field proven with over 25,000 successful installations worldwide and still growing.

- REMEMBER: “Cheap is no substitute for economical.” You can identify, drill and complete a well absolutely perfectly but unless you produce a well optimally you are losing out on additional revenue.
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