INTELLIGENT ESP CONTROLLER

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ABSTRACT

The use of an intelligent ESP control unit (IESP) aids in remotely operated and "trouble" wells. Inputs from a number of end devices are used to determine the condition of the well bore and the equipment. Based on these inputs the mode of start-up or operation is "decided on" by the IESP. Control commands are then sent to the Variable Frequency Drive (VFD), switchboard controller, or back-pressure valve to achieve the desired mode of operation. This paper will discuss the concept and IESP design behind the initial project.

INTRODUCTION

Close control on the operation of submersible installations can be very critical. There are some instances were the normal route of the pumper or operator is not frequent enough for the proper control on these installations. Some of the reasons for this are:

- Remote locations that are either difficult or dangerous to get to. reducing the frequency of visits to the location.
- Prolific producers, of which any down time results in large losses of revenue.
- Trouble" wells due to:
  - "Dirty" power.
  - Cyclic reservoirs.
  - Solids production.
  - Scale formation.

Some fields can posses more than one of these characteristics. The field that initiated the development of the IESP is both a remote location and contains "trouble" wells due to sand production. The IESP is not the only component involved in the solution. but it is an integral component. The development of the solution has been under way for nearly a year and the first field test is slated for second quarter of this year. This paper will not deal with the other components of the solution. Another paper will be written in the future that will deal with this.

THE INTELLIGENT CONTROLLER

The IESP has been developed on the EXS-1000 Remote Terminal Unit (RTU) platform. Some of the standard features of this RTU are:

- Eight digital inputs and eight digital outputs.
- Eight analog inputs and two analog outputs.
- Two RS-232 serial ports. expandable to four or six.
- Controls up to 2 PID loops.
- Eight channel data logger with up to 240 records per channel.
- User programmable via Automatic Control Logic (ACL).
- Communication packages including Cellular Digital Packet Data (CDPD).

Once the electrical submersible pump (ESP) firmware is installed on this platform. the RTU can communicate and control a number of standard ESP controllers and end devices. Following are some of the third party device interfaces already available. others can be developed as necessary.

- Motor Controllers:
  - Keltronics fixed and variable speed
  - Centrilift ICM
  - Vortex VMC 100
  - CTI
- Micromotion NOC
- Down-hole Gauges:
  - Phoenix
- MPF

- Choke Control:
  - Worcester
- Sand Detection:
  - Corr Ocean

With the standard features of the EXS-1000 and the additional interfaces ofthe ESP firmware, the IESP can perform a multitude of functions. Some of these include.

- Intelligence distributed at the well-site.
- Access to continuous real-time data.
- Twenty-four hour local optimization.
- Single point interface to SCADA and MIS systems.
- Stand alone capability.
- Informed decisions.
- Multi-channel real time data logging.
- Interrogate and/or configure remote instruments.

POSSIBLE APPLICATIONS

The utilization of the IESP can range froin simple (data logging and communication) to complex (complete control). The use will depend on the end-devices available and actual application. Here we will discuss some ofthe applications from the simple to the complex.

It is very important to understand the IESP is not a motor controller and will not replace these devices. Installing the IESP to perform the functions of existing motor controllers would not benefit the operator.

Some of the uses are:

- Data Logging: The majority of motor controllers on the market have either none or limited data logging capabilities. If the data from these controllers is not being brought into a host system with data logging or trending capabilities. critical data will be lost.

  At times power problems. variances in voltage or amperage. can be very difficult to troubleshoot without rapid arid continuous monitoring and data storage. If the existing motor controller is capable of monitoring all three phases of voltage and amperage. this data can be brought into the IESP and captured for evaluation. By using the ACL available for the IESP data collection can be "fine-tuned" for more effective evaluations. For example the voltage and amperage data could only be captured at high sampling rates when either varies a certain percentage from normal.

  Any data that is being monitored at the well-site can be similarly brought into the IESP and captured. such as down-hole pressure or temperature or tubing discharge pressure. With the ACL one can "trigger" the capture of one end device based on any conditions that may be seen froin that end device or another end device. This functionality makes the IESP a very powerful trouble shooting device.

- Multiple End-Devices: The data from the motor controller is brought into the IESP via a serial port. Basically any data the motor controller monitors can be sent to the IESP as long as the storage registers in the controller are known. This leaves the eight digital and eight analog inputs free to bring data in from other end devices. Some ofthe end devices that inay be utilized include:
  - Down-hole Gauges
    - Intake and Discharge Pressures
    - Intake and Motor Temperatures
    - Vibration
    - Flow Rate
  - lubing and Casing Pressure Transducers
  - Turbine or Flow Meters
  - Surface Temperature Transducers
  - Vibration Switches

- Pressure or Level Shutdowns
- Discretes (i.e. Chemical Pump On/Off Status)
- Sand Probes
- Valve Position

Once this data is brought into the IESP there are several possible actions that can be utilized. The data could be simply logged as mentioned above: up to eight channels can be logged. If the operator has a centralized SCADA or host system the IESP can be used to gather all the end device data and then pass it along to the system. This can be very beneficial for systems that use radios or CDPD to transmit the data, as only one sending unit will handle a multitude of end devices.

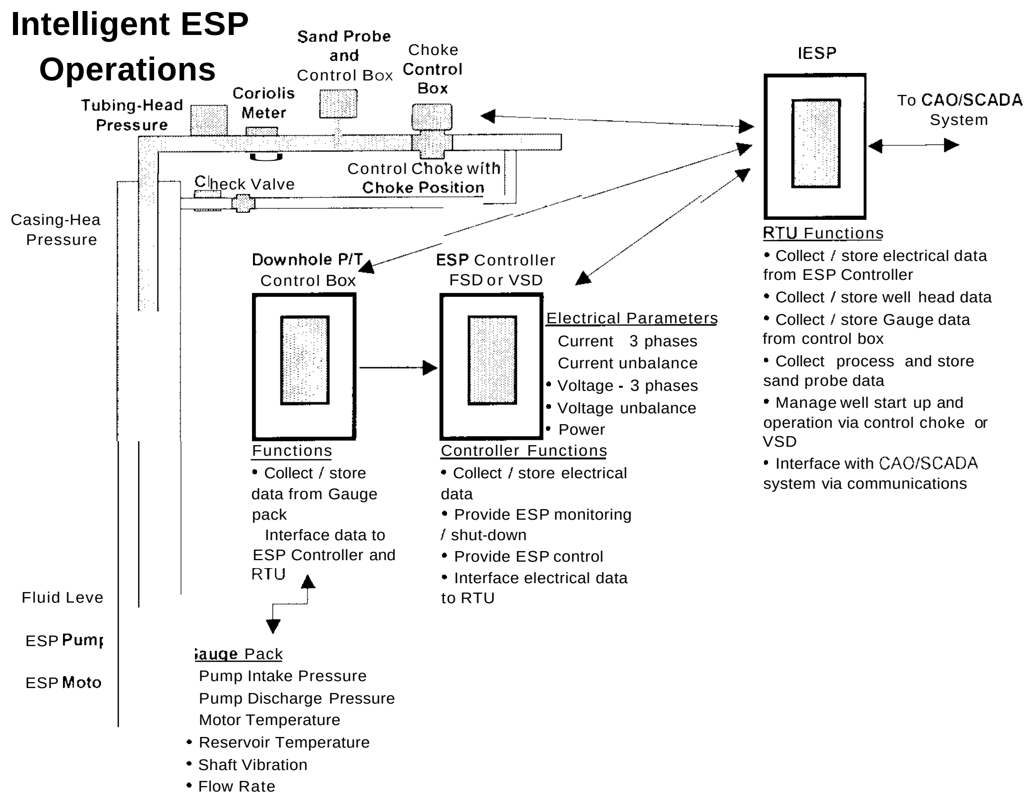
- Remote Instrumentation: Any end device that has parameters that are set manually can be updated remotely from a central host system using the IESP. If the end device is set up properly in the IESP the individual parameters can be interrogated by the user. If changes to any of the parameters are needed the user can update them on the host system and download the new data to the IESP. The IESP will then update those parameters in the end device as necessary. For instance, the required under-load shut-down may need updated due to changing well conditions. Instead of driving to location to update this item. the IESP could be used to make the change remotely. This is very useful for wells that are remote and difficult or time consuming to get to.

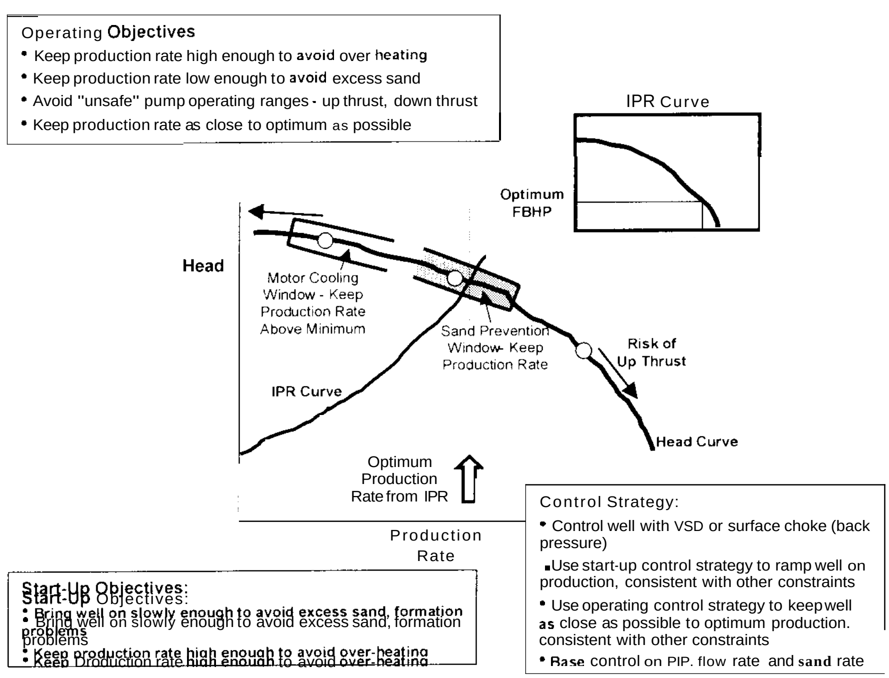
- Local Control: This is the most powerful and potentially useful function of the IESP. The concept is not to replace existing man-power. but to augment and increase the efficiency of such. As mentioned in the introduction there are several reasons local and/or continuous (24 hour) control is necessary. The main goal is to optimize operations by reducing down-time or increasing equipment life. Also sufficient and timely data will aid in immediate decisions and future designs and installations.

  There are a multitude of possible control scenarios that may be required. depending on the well conditions. They may be as simple as not allowing the ESP to restart until a certain pump intake pressure is measured by the down-hole gauge. The IESP has three main attributes that makes it a powerful control device. Following is a listing of the attributes:
  - Multiple Inputs: This was discussed earlier.
  - Multiple Outputs: The IESP comes standard with eight digital and two analog outputs, and has the capability to control two PID loops. This allows for control in addition to changing parameters in various end devices. The IESP may shut down the ESP through the motor controller, increase or decrease operating frequency. pinch back a control valve on the tubing discharge. etc.
  - ACL Programming: With this relatively simple programming language and the 16-Mhz CPU the IESP becomes very flexible. The ACL is basically a string of "if-then" statements and can be as simple *as* if the pump intake pressure (PIP) reaches a value x then slow down the ESP by 0.5 HZ, wait y minutes and check PIP again. The ACL can be very complex *as in* the original project. In this case there are a large number of start-up and shut-down scenarios and the ACL is several pages long.

EXAMPLE

The attached figure shows a graphical presentation of a very complex system. This layout is actually being worked on and should be operational by year end. The graph following the figure gives an example of some of the objectives the operator is trying to meet with this system. A joint paper will be considered once the system has been implemented and fully tested.


Intelligent ESP Operations
Sand Probe and Control Box
Choke Control Box
IESP
Coriolis Meter
Tubing-Head Pressure
To CAO/SCADA System
Control Choke with Choke Position
Check Valve
Casing-Hea Pressure
RTU Functions
• Collect / store electrical data from ESP Controller
• Collect / store well head data
• Collect / store Gauge data from control box
• Collect process and store sand probe data
• Manage well start up and operation via control choke or VSD
• Interface with CAO/SCADA system via communications
Downhole P/T Control Box
ESP Controller FSD or VSD
Electrical Parameters
Current 3 phases
Current unbalance
• Voltage - 3 phases
• Voltage unbalance
• Power
Functions
• Collect / store data from Gauge pack
Interface data to ESP Controller and RTU
Controller Functions
• Collect / store electrical data
• Provide ESP monitoring / shut-down
• Provide ESP control
• Interface electrical data to RTU
Fluid Leve
ESP Pump
ESP Moto
Gauge Pack
Pump Intake Pressure
Pump Discharge Pressure
Motor Temperature
• Reservoir Temperature
• Shaft Vibration
• Flow Rate


Operating Objectives
• Keep production rate high enough to avoid over heating
• Keep production rate low enough to avoid excess sand
• Avoid "unsafe" pump operating ranges - up thrust, down thrust
• Keep production rate as close to optimum as possible
IPR Curve
Optimum FBHP
Head
Motor Cooling Window - Keep Production Rate Above Minimum
Sand Prevention Window- Keep Production Rate
Risk of Up Thrust
IPR Curve
Head Curve
Optimum Production Rate from IPR
Production Rate
Control Strategy:
• Control well with VSD or surface choke (back pressure)
• Use start-up control strategy to ramp well on production, consistent with other constraints
• Use operating control strategy to keep well as close as possible to optimum production. consistent with other constraints
• Base control on PIP. flow rate and sand rate
Start-Up Objectives:
• Bring well on slowly enough to avoid excess sand, formation problems
• Keep production rate high enough to avoid over-heating