SPECIAL PURPOSE REMOTE TERMINAL UNITS IN PRODUCING FIELDS

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ABSTRACT

In 1982 Texaco USA initiated a study of producing field automation in the Midland Producing Division. As a result of the study, all facets of one producing field were automated. Based on acquired knowledge from this project, Texaco's Midland Producing Division and our Houston Information Technology Department (ITD) initiated the construction of a sucker rod pump-off controller based on available off-the-shelf remote terminal unit (RTU) components. This paper will explain some of the choices associated with the POC application and discuss future RTU applications.

The driving force behind Texaco's development of the Rod Pump Monitor Controller was the need for wellsite information at a central location. Market availability of off-the-shelf pump-off controllers was limited, and the fundamental building blocks for a general RTU based system were readily available. This same general RTU can be used for injection control, automatic well testing, tank battery monitoring and control, and electric submersible pump control.

GENERAL

Texaco's Rod Pump Monitor Controller (RPMC) is a Remote Terminal Unit (RTU) designed to eliminate unproductive pumping when only partial filling of the down-hole pump is occurring. The RPMC also has the capability to detect malfunctions and take the appropriate action. Logging of events, storage of events with time of occurrence, and control are all done by the RTU at location. The RTU can function in a stand-alone mode or report to a Master Terminal Unit (MTU) via radio or hardwire.

When the RPMC detects that motor current, load, and position signals are valid and in range, it will construct a dynagraph and control the well by making pump-off decisions. The unit will also construct an amperage versus position curve. Other well-site end devices can be interfaced to the RPMC such as flow-line pressure, or production rate meters and the correct choice of control can easily be incorporated into the software.

Wellsite information is stored in the RPMC and the history is maintained. In a stand-alone application this data can be accessed with an IBM compatible laptop and Texaco's Portable Input Output (PIOU) software. In facilities with central communication, the historical data is periodically uploaded to the MTU. The PIOU is designed to give on-location data, dynagraphs, and parameter programming capability.

The RTU has the ability to shut-off the motor on the pumping unit and match wellbore inflow with production equipment capacity. The RPMC can control wells with stroke-per-minute rates of 4 to 25. Upon non-fatal failures of an end device or loss of control by the RPMC, it will automatically switch to the historical percent run mode. Fatal failures such as a rod part result in shutting-off power to the motor.

The load is measured with a load cell mounted on the polished rod between the carrier bar and clamp. Strain-type devices can be used if qualitative cards are acceptable. The position information can be acquired from either potentiometer or capacitance devices. Recent developments in the clinometer have made position measurement possible with no moving parts.

The control of the output is accomplished with a relay wired to the existing motor control panel. A liquid crystal display clock for actual run time is displayed on location. The power supply is driven off the 480-volt supply in the motor controller and is used to charge a 24 amp hour battery that provides backup power for 24 hours with communication to the host unit. Health lights are also provided on location for pumper information.

SOFTWARE

Texaco's Information and Technology Department (ITD) in Houston was responsible for the development of the software algorithms. Code was written based on Midland supplied logic tables. The RTU is built on a generic platform and given personality with Erasable Programmable Read Only Memory (EPROMS). The primary non-trivial decision is the pump-off criterion. Texaco's control algorithm is based on integration of downstroke data from top-of-stroke to minimum load on the downstroke. As pump-off occurs, the traveling valve opens later in the stroke and the integrated area increases. The amount of increase required and number of consecutive pump-off strokes required for unit shutdown are selected by the operator. Actions due to other input are also operator controllable and default values are typically sufficient for initial set-up. Fine tuning the system for a given well or inflow situation is possible, yet the default values have been found to be very satisfactory for set-up and control. Limited wellsite input makes installation far more efficient and does not require a large amount of technician time.

HARDWARE

The original prototype was built on the TI 8640 base RTU. The TI 8640 consists of a mother board (MO56) and a termination or interface board (TO51). The microprocessor resides on the mother board. In 1986 Texaco constructed a custom interface to replace the TO51 and produced 400 units. After extensive field testing and analysis in 1988, the interface was modified to drive an Analogic mother board and 600 units were produced in this configuration. Texaco has recently licensed the software and fabrication to Barton Industries. The future units will be constructed on all TI platforms.

The primary function of the termination board is to filter and protect the mother board. The two boards are connected through dual in-line pin-and-socket connectors. This provides for convenient replacement of either board. All field wiring for input and output terminates on the TO51 board. The combination assembly is rated for temperature range of operation from -20 to +70 degrees Celsius.

The 8088 microprocessor is built on complimentary metal oxide semiconductor (CMOS) technology which limits the required power. The on-board lithium battery will provide 800 hours of RAM back-up.

Texaco utilizes 480-volt AC power to supply our typical RPMC installations. The maximum power requirement for the RTU and radio is 5 watts. Solar panel configuring is possible but unnecessary on electrified pumping unit locations. The 480-volt supply is transformed and rectified in an off-the-shelf battery charger system. A storage battery is provided to support communications for twenty-four hours during power interruptions. The volatile memory also has a battery backup and can remain static for 800 hours without loss of information.

The 8640 can be fully populated to accept 4 high-speed accumulators, 8 analog inputs, 16 digital inputs, 2 analog outputs and 16 digital outputs. Due to individual unit requirements, the termination board (TO51) is not being fully populated. The current configuration for population is 2 high-speed accumulators, 4 analog inputs, 8 digital inputs, 2 analog outputs and 4 digital outputs. Reduced population on the interface board and careful selection of the minimum mother board memory is an excellent cost control measure. Analog inputs can be used to measure load, position, current, temperature, pressure, flow and voltage. High-speed accumulators or pulse inputs may be used to measure flow from turbine or kilowatt-hour meters. Digital inputs are used for status knowledge, i.e, yes-no or on-off.

Texas Instruments provides a communication protocol which Texaco declined to use. Texaco's protocol was written in-house and has proven to provide very effective communication.

Several operating systems are available. Texas Instruments supports the RTX multi-tasking operating system. Texaco selected the Intel RMX operating system for flexibility of usage on various platforms. RMX allowed the usage of the Analogic mother board which the RTX operating system will not. The typical scheme for code development is to write the program in C or some other high level language, assemble the code, down load the program into memory, and debug the program.

After the first all TI prototype version had been field tested, a custom interface board was developed to provide additional gain for particular end devices and amplification of weak signals. This essential step allows the RTU to control virtually any 4-20 ma end devices. Texaco had 400 units built with the hybrid board configuration. Long-term testing of the custom interface indicated some drift due to ambient temperature variations. This became troublesome and prompted a redesign in 1988. The 1988 version utilized Analogic's mother board instead of the TI platform. The interface board was re-engineered with simplicity and temperature stability as constraints. Six hundred of the new interface boards were then manufactured, assembled, and field installed with the Analogic mother board platform. Utilization of lower gain series amplifiers on the load cell input has relieved the unit of all temperature related problems. The recent agreement between Texaco and Barton Industries will return to the all TI platform with load and position signal amplification.

The load, current, and position end devices are constrained to 4-20 ma devices. Discrete digital information is accepted from the hand-off-automatic (HOA) switch, flow-line pressure switch, motor status, motor panel torque status, and battery charger status. Additional status points are easily incorporated into the system.

FABRICATION AND INSTALLATION

The fabrication of units until recently was done by a small electronics plant. The construction of the interface was accomplished by the same firm. Texaco has recently entered into an agreement with Barton Industries for manufacturing and support.

The Barton machine is available outside Texaco for the first time. This is essential for ongoing support and field service.

Installation within Texaco has been accomplished with our personnel. The required set-up is minimal and other than end device installation, main enclosure mounting, and electrical tie-in to existing motor contactor, no operator input is required. Since the unit can be set on location, powered-up and control the well without any operator input, well testers are available for their normal duties. Personnel can return to location and fine tune the system when convenient.

Numerous problems were encountered in the development of the RPMC. Load cells from some suppliers were discovered to drift with temperature and totally fail in rain storms. Pulling unit crews had to be educated in the proper handling of load cells. The temperature drift was complicated by instabilities in the amplification which accentuated the load variance. Due to the integration of area under the down stroke in our POC algorithm, drift induced premature pump-off decisions.

Filtering on the termination board was a simple item to correct once the inductance and capacitance input circuits were analyzed. This kind of repair is labor intensive to field personnel, and compounded by distances to RTU locations.

The search for a maintenance-free position transducer will probably end with utilization of capacitance type devices. One-shot position detectors are simple, yet card distortion has been observed on conventional units and variation in up-stroke and down-stroke times will be enhanced in modified geometry units. The "Clinometer" currently in use is a variable capacitance device free of moving parts. Field testing shows this fluid filled device is not adversely affected by temperature extremes.

In one prototype the hydrogen gas output from an overcharged battery was ignited by a relay operation. The cabinet door on our homemade bomb was located approximately one-half mile from location. This prompted the removal of the system battery to a separate enclosure. Battery technology has progressed and non-gas producing batteries are available. This item is of significant concern as most battery chargers typically fail in the overcharge condition. Most normally non-gassing storage devices will produce hydrogen in an overcharging situation. Hydrogen and oxygen in the presence of a switching device can be hazardous with explosive potential. With careful battery selection it is now possible to safely utilize a single enclosure for both components.

HOST BASED SYSTEMS

The heart of the economics of any production automation system is the data collection and reporting capabilities. Field personnel do not have time to examine in detail every card generated. A field with 200 producing wells running at an average of 8 spm for twenty-four hours will generate 2.3 million dynagraphs. Even to scan a summary of the individual cards is an impossible task. Error report alarms are a convenient method of culling. Our 6 a.m. scan is designed to report wells with potential problems. As personnel arrive at the field office each morning, they can initiate diagnostics from the host machine and request on-site inspection if necessary. This option is the number one method of early rod pump system failure detection. Expert systems in conjunction with down-hole transformation will be future areas of investigation to summarize this massive volume of data.

Stand-alone pump-off control has good application in small primary recovery fields. Dynamic inflow in secondary units is usually associated with larger numbers of units and therefore telemetry can be justified. Historically energy savings for reduced run time has been exaggerated and should be considered on a case-by-case basis. The majority of our observed benefits in POC installations are due to finding sucker rod pump and rod failures more quickly.

REMOTE TERMINAL UNITS

Remote Terminal Units (RTU'S) in conjunction with Programmable Logic Controllers (PLC'S) are the natural economic control devices for the nineties. The distinction between these units has continued to diminish. PLC'S are now available with higher level language capability and can now be programmed with more than ladder logic. PLC'S will be more economic in applications requiring large amounts of input/output and situations where growth and contraction of the accessed peripheral information is likely.

Texaco's next application for the RTU used on the RPMC project is for water and carbon dioxide injection control. Water injection control is simplified with the usage of a turbine meter and a high-speed accumulator to totalize accurate water volumes. Carbon dioxide injection control and calculations are far more complicated than simple pulse counting. A disturbance in the line will be used to create a pressure drop. AGA calculations will be used with the delta pressure, a wellhead pressure, and flow stream temperature to determine actual volume going down hole. The RTU can control either pressure or rate for both water and carbon dioxide. Total injection volume in carbon dioxide applications is critical to avoid premature breakthrough.

In this carbon dioxide control application it is possible to configure the mother board (MO56) with a 8087 math co-processor. This will allow square root trigometric functions, and logarithms. The RPMC has not required the math co-processor, but AGA calculations for the carbon dioxide injection controller will necessitate exponential fractions. Use of an 8087 will enhance the performance for some mathematic routines by a factor of 500. Typical sampling rates on digital inputs and analog inputs are in the 2 milliseconds range. High speed accumulators are continuously available for pulse inputs.

Even with the advantage of a host-based master terminal unit (MTU) and communications, provisions must be made for information access at the wellsite. Some pump-off control manufacturers have incorporated a small LCD display in the RTU panel door. Texaco recognizes the need for wellsite information and has simplified the non-machine accessed data to two health lamps and a LCD clock. This allows the pumper to reset the clock and observe the run time since last reset. The health lamps are color-coded red and green. The green light indicates a healthy POC that has passed all internal checks and has no alarms set. The red light is to indicate that an alarm has occurred.

Wellsite communication and programming is accomplished with a Portable Input Output Unit (PIOU). The PIOU can also display dynagraphs and store data for future analysis. The communications to the RTU from the PIOU is on RS-232 to a modem. Several versions of the code for the PIOU are running on IBM compatible machines.

FUTURE TRENDS

The RTU will continue to be a basic building block for remote locations with limited control point requirements. The PLC with high-level language capability will become more applied and user friendly. The most logical place to acquire cost effective automation in producing fields is at the production header. With early warning devices at the manifold, one machine may collect data from many end devices and decrease capital expenditures.

Automation in the recent past has been hampered by physical separation in producing fields. Plants and refineries have observed more economic benefit per dollar expended. As personnel constraints and producing well economic limits conspire, the upstream industry will utilize radio telemetry and consolidate remote information to field offices.