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WELL SITE CONTROL SYSTEMS FOR TODAYS MULTI WELL PAD AND THE DIGITAL OIL FIELD

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ABSTRACT

Over the past few decades we have seen major advancements in the technologies that are involved in reservoir engineering, drilling, fracking, analytics and operation of Oil & Gas wells. Those technologies improve production by optimizing equipment and personnel, all the while decreasing environmental impact and improving safety.

Equipment efficiency and optimized functionality have brought about a need to change the once simplistic vertically drilled single well pad fields into laterally drilled multi well pads. These multi well pads consist of typically four to 12 wells, with some extremes of 28 to 32 wells. Surface production equipment designs and control of that equipment vary widely and have increased in complexity. Ultimately we find that this major increase in the size and scope of the multi well pad control effort has created the need for operators to revisit traditional control architectures and modify, or radically change, their decades-old control systems for more advanced systems capable of handling the scalable architectures required by these modern well pads.

The goal of this paper is to dive more deeply into the history of the single well control solution. We will discuss evolution of data and application requirements in the upstream world. We will offer insight into the future Digital Oil Field and discuss how the varying applications, hardware and standards can come together today in a highly scalable solution with capabilities for the future.

INTRODUCTION

By 2040 the United States Energy Information Administration (EIA) predicts that the expected world energy consumption of Oil and Gas (O&G) will steadily increase to nearly 450 quadrillion BTU per year (Figure 1 US EIA “EIA projects 48% increase in world energy consumption by 2040). With this steady increase in demand for O&G, producers will undoubtedly be challenged to find new and innovative ways to capture the valuable energy resources from below the earth’s crust. All the while, producers must manage dynamic pricing as well as their cost of production. The most successful producers will be the ones who can adopt, and adapt to, ever changing technologies and take command of those technologies to reduce the cost of production.

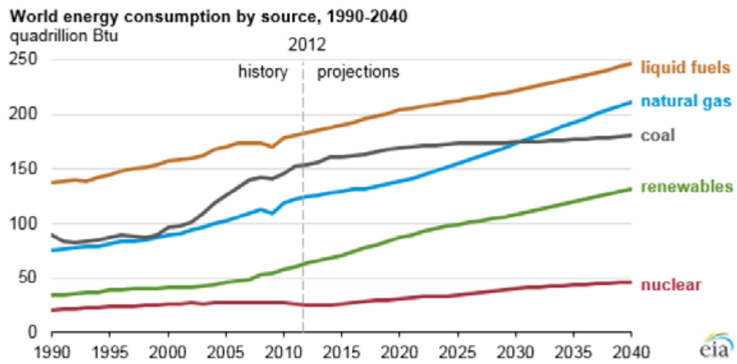

Figure 1: EIA World Energy Consumption Estimate 1990-2040

We are seeing evidence of the benefits of adopting technological advancements all over the world. Most notably we have seen advancements in drilling techniques and fracking techniques that increase production from O&G wells. Not only have the advancements increased production but they have also made production in unconventional areas possible. Additionally, directional drilling enhancements have allowed for producers to decrease the footprint of land required to produce by placing multiple wells on a single location. With the decreased footprint comes a denser populated area of equipment with varying control requirements.

Technology advancements in well site controllers have also improved over the years. Providing real-time data, historical data, and alarming to operators and engineers enables them to increase the productivity and efficiency of these wells. Through remote communications, SCADA servers, and internet connectivity the well site data can be analyzed by the personnel who need the data in a timely manner.

In the following sections we will discuss well site control in the early years. We will illustrate that controllers used in early well site automation have been adopted for today’s more sophisticated control requirements and how those technologies are not ideal for the modern digital oil field. Finally, we will present a more modern approach to well site automation that takes into account complex control requirements, analysis and prediction to allow producers to implement scalable, powerful multi well site control systems.

Well Site Control: The Early Years

Early on the operation of O&G wells was a highly mechanical process. Much of the automated control of the site was accomplished through pneumatic controllers. Pressure, temperature, and level recordings were often manually entered into an operator’s daily log sheets where they were later entered manually into a computer where, through various means, that data would reach some sort of central database.

These early well sites were often located remotely throughout a field. Well operators often scheduled their day to day activities by mapping out their daily route so that they could visit each of the wells they are assigned. Poor weather would prevent well operators from visiting a site, or responding to safety and environmental containment issues.

Remoteness also played a factor as to whether the site was electrified or not. Running electricity to some remote sites often would be too expensive. Not having adequate electricity at a site limited the types of artificial lift methods that could be used as wells aged and required lift assistance. Natural gas engines were used to drive compressors and even sucker rod pumping units. Again, the lack of electricity available introduced maintenance issues with engine driven equipment because of the need for battery maintenance and solar charging system repair.

Critical measurements at the point of sale were also manually entered, or charted by an electronic chart recorder. Operators and truck drivers manually strap tanks to determine the levels. Truck load out often resulted in a paper ticket being generated and then placed in a mailbox at site for later collection and yet another manual data entry into the financial system.

Many inefficiencies were identified in early well site control. Mechanical processes require a skilled hand to adjust. Manual data entry proved to be inaccurate and inconsistent. Scheduled well routes were time consuming to personnel. And critical financial data points were not able to be received on demand.

Adoption of RTU Technology for Well Site Control

In the 1960's the implementation of the Remote Terminal Unit (RTU) proved to be useful in addressing some of the inefficiencies that O&G producers were facing. RTU's were built into enclosures that were suitable for the environment they would be installed in. They focus on communication over low bandwidth (300 baud) networks. Simple telephone networks could provide dedicated communications to the remote O&G sites. Later, through the use of Microwave communications, wireless data collection became possible at a fraction of the cost of telephone line installation (SANS, "An Abbreviated History of Automation & Industrial Control Systems and Cybersecurity).

Cost of implementing the RTU devices, as well as the lack of the technical ability of O&G personnel to program them caused early RTU's to be highly specialized devices on the well pad. RTU devices were set up as simple data acquisition and control devices. Only critical data points were monitored and the shutdown was tied to a single device (solenoid operated valve, for example) to bring the well site to a safe state. The RTU device could alert SCADA systems of alarms and operators began to rely on these systems to more efficiently operate remote assets.

As time and technology moved on the capabilities of RTU's allow for more features: IO, Communications, IEC-61131 programming. These features allow for O&G companies to monitor more data points, log history and alarms, and add more complex calculations into the RTU. Some of the complex calculations include PID control loops and AGA / API gas and liquid flow computers. Equipment manufacturers and engineering firms also began to develop specialty applications for well head Artificial Lift controls with proprietary microprocessor controllers.

RTU's proved to be a valuable asset for remote well site operation. Many different types of RTU's and customized applications began to spring up in the industry. It seems that every artificial lift manufacturer has their own RTU to control and optimize their respective solutions. And for each manufacturer there is a handful of other companies that have their own methods that can also control with a slightly different application. Not to mention the various different instrumentation manufacturers with instruments to measure just about any process point required. The instruments often have their own proprietary protocols used to pull not just process data, but also instrument configuration and calibration data. Technology advancements allowed the industry to place higher and higher demands on RTU devices. So what is the effect of having increasingly powerful algorithms, instrumentation and intelligent assets running in RTU devices?

RTU Hardware Demands

As RTU control and data acquisition demands increase for well site control the industry is realizing that multiple RTU's are required on a well site to control and optimize asset performance. While some advancements have been made in RTU technology since the 1960's the ever demanding requirements of the modern day O&G industry have recently started to exceed the capabilities of modern day RTU's. Figure 2 shows how the addition of upstream applications can exceed RTU hardware memory capacity.

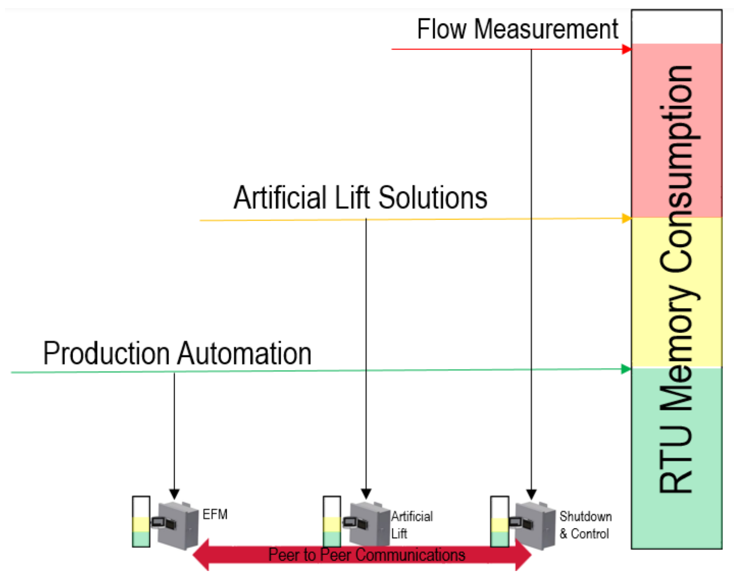

Figure 2: RTU Hardware Demands from Upstream Applications

Well pads have more data and control requirements in today's upstream environment. Often there are multiple wells drilled in a single well pad. Each well requires artificial lift, flow measurement and equipment control and level measurement. Eventually we add enough IO and control demand to a single RTU that O&G producers are forced to purchase additional RTU's (due to memory, CPU and IO restraints) and break out the functionality of application and site control to each separate RTU. O&G producers have had some success in implementing multiple RTU controllers on a well pad, however, we find that all of these producers run into common problems with these architectures:

- Change management of multiple configurations / programs at each well pad.
- Communication management of the many RTU's on site (peer to peer communications).
- SCADA communications to multiple vendor's hardware.
- Unreliable execution of custom programs in the RTU's.

The ultimate demand on RTU technology comes when much larger multi-well pad control is needed. Many producers are utilizing advancements in fracking and lateral drilling techniques to place ten or more wells on a well pad. Some customers are looking at developing 32 well pads, and in the USA a fifty-two well pad has been completed and is producing in Garfield County, Colorado.

As we look at these multi well pad implementations that O&G producers are installing we find that the higher density of wells on a pad also increases the equipment required on site. It is very common to see on these well pads that each well has its own separator, for example. Also, it becomes more economical, because of the high rate of natural gas produced from the pad, to install pipeline compression, VRU's, several VRU towers. LACT units, water transfer and chemical injection are also common to see on these well pads.

Electrically we find that customers are investing in Electrical buildings (E-House). These E-House buildings house main utility power distribution, Motor Control Centers (MCC), network switches, uninterruptable power supplies (UPS) and are often environmentally controlled.

When we walk the actual well pad we are finding that instead of direct burying wires underground between the E-House and well head customers are installing cable trays, junction boxes and running cable for IO and power through these IO and cable routing systems.

Increases in equipment, field instrumentation, and applications compound the common problems with RTU architectures. So how can we address the increasing demand on well site control hardware? In the following sections we will look at one solution to the ever increasing control requirements.

Modular, Scalable Control Systems for Multi Well Pads

If we had to describe early well pad control in one word an appropriate word may be; simple. Simple control requirements, field device interaction, and communications were easily handled by RTU's. However, we are finding that the modern day multi well pads are not so simple where concerning control, IO and communication requirements. Often on a multi well pad there are multiple RTU's (as described above) to control artificial lift, flow, shutdowns, ticketing…etc. Adding all of these RTU's means that there are multiple application configurations and programs to maintain. Also, it means that multiple vendors must be managed. Multiple devices from different vendors require that your work force have the required training and experience to support those systems.

Some producers are fully staffed with the trained personnel that are required to handle the maintenance of the well control systems. However, many are not. These producers must rely on manufacturer support or contract engineering support to maintain their control systems.

Many of the producers that have experienced the common RTU issues mentioned above, as well as multi-vendor support and an aging workforce, have found an alternative that can solve these problems. The solution comes in the form of a PLC controller that is modular, scalable and capable of handling the wide variety of communications and application support required in their pursuit of the digital oil field.

Modular system design allows the PLC hardware to be configured in a number of different ways. A wide variety of modules are available from manufacturers of PLCs and also their partnerships with 3rd party vendors. This modularity allows for monitoring and control of a wide variety of field instruments. Communication support for many different network types is also supported through modular configuration. Some RTU's have support for modular hardware as well, but what we have seen in industry is that balancing the module requirements with application and control requirements in an RTU is much more difficult than with PLC's (that were built for this purpose). Also, 3rd party modules for RTU's are not typically available because RTU's are not open architectures like PLC's.

Scalability is important when one considers the way that a multi well pad is put together. Often times a single well will be installed at the multi well site. Then months, or sometimes years, later additional wells and equipment will come online. In this case manufacturers want the ability to build equipment skids off site and simply plug them in and configure them at the well pad. To save money they want to reduce the need for trenching, wire pulling, wire termination, panel and instrument installation in the field. Scalability in both programming and hardware is required in this case.

PLCs have been traditionally known as a blank canvas approach to automation and control. Only engineering firms or experienced programmers would know how to start from scratch and develop the control required in a PLC. Modern PLC's have libraries of code pre-developed and documented that can be added quickly in an almost drag and drop fashion. Alternatively some experienced PLC companies have pre-developed upstream O&G libraries that are configurable on site. This means that, to start up a PLC, or to add skid hardware into an existing system, you would only need to enable and configure the required data from the HMI. This eliminates the need for someone like a well technician to know the programming environment and write new code when hardware is added.

Programming in the PLC environment is also more focused on allowing changes to the program and configuration without needing to shut down the process (online edits). When program modifications or new IO are required this can be done online with a PLC. Traditionally RTU's cannot accept IO and program changes without being taken offline and being downloaded to. In the modern multi well pad environment this is a critical point because the shutdown of the control system results in lost production.

Scalable PLC hardware architecture is one of the major benefits to using a PLC vs an RTU on a multi well pad. Remote IO functionality is one of the key components to a PLC's scalability. Compared with an RTU, which traditionally has no native remote IO functionality, the PLC remote IO capability can save costs for installation when compared to a similar RTU architecture. Also, when equipment skids are added to a site they can come with pre-mounted and wired IO and instruments. Startup of these skids is as simple as plugging an Ethernet cable into a switch and configuring the IO at the controller.

On-line editing was mentioned as a benefit of PLC over RTU control. There are also other things that can be done with the system online that will prevent production loss. For example, hot swappable hardware modules are available with PLC systems. So, if you have an IO module fail, or need to add a module to a remote IO rack you can simply plug the module in and configure the IO for control.

These features are just some benefits that the PLC has over RTU control. PLC's have gone through their fair share of technology updates throughout their existence. They have been fine tuned in many industrial process control environments just as rugged as the upstream O&G environment and they have been designed with scalability and modularity in mind.

Well Pad Lifecycle Management in the Digital Oilfield

Well pad lifecycle management is a major headache to well pad operations teams. Wells will often times go through several flow states: Natural Flowing, Electronic Submersible Pump (ESP) or Progressive Cavity Pump (PCP), then Sucker Rod Pump. Flow type and lifecycle is different per well. Often times multiple RTU's are used just to control the various lifecycles of the well. Changing the RTU means changing communication drivers to the SCADA because the physical RTU at the well is hardware from a new vendor. Configuring the RTU to control the application and setting up that hardware at the SCADA is often a painstaking process carried out by the SCADA and Automation teams.

Well pad lifecycle management using a PLC with applications developed for specific upstream needs is a bit of a philosophy change for many producers. But the benefits can bring efficiencies and optimization abilities that operators previously never thought of.

By using the modular and scalable IO hardware architectures discussed above we are able to install IO modules in the locations of instrumentation and pull that data directly to the PLC. We can design and architect the IO in two ways: (1) build all of the IO needed for control based on maximum (worst case scenario) or (2) use the hot swappable features in the PLC to add IO as the lifecycle state of the well changes. In either scenario: hardware in the control system remains constant, communications to the SCADA system use the same drivers, and the system remains online and in control of the applications while this is done. Additionally there remains just a single PLC program to maintain. Compare and contrast this effort with RTU control and the technician would need to either shut down the controller to add additional IO or add a new RTU to the system to control the new application. The addition of a new RTU requires change management of another program and configuration.

As we discussed earlier there are many vendors that make their own application to control a variety of upstream production needs, typically each vendor uses a different type of RTU. Some typical applications include: Artificial Lift, Production Equipment Automation, and Flow Computers. Usually vendors support a few specific applications, but not all of the applications required. Those RTU vendors that have tried to cover all of the applications have managed to do so using a multiple-RTU architecture in a distributed environment. This is because RTU's often don't have the memory and IO capability required to control an entire multi well pad and all applications in a single CPU.

PLC support on multi well pad designs is growing daily with application support for equipment control, artificial lift, and flow measurement. Equipment automation is easily handled through rich programming environments and a wide variety of IO and communication modules. Flow measurement is also supported with AGA and API compliant flow measurement, calibration support and custody transfer reporting to SCADA systems. Artificial lift applications, while not as prevalent in PLCs, are being developed rapidly to support all types of artificial lifts.

In my travels to companies throughout the America's I'm finding that most producers utilize the artificial lift methods differently. Often times, the same producer at two different locations will use the same artificial lift (say RPC) in different ways. One of my goals has been to talk to these different producers and understand the many different issues they have with today's applications. One of the main issues I hear is that the applications developed in RTUs are "Black Box", meaning it is a system designed with specific inputs and to control specific outputs. The problem expressed is that this black box is ok for a certain amount of wells, but there is no flexibility to change the way the black box functions. This often leads to them needing to change vendors to support their needs. Or they just have to live with the technology they have, knowing that it is not functioning as efficiently as they require. In those same discussions, it's acknowledged that the flexibility of a PLC artificial lift function block that can be modified in the field with common industrial tools (IEC-61131) has much benefit.

Conclusion

Early on in O&G upstream production, the RTU was the best technology that could be implemented. It was ruggedized and power conservative. It also handled the lower bandwidth communication networks between the site and the SCADA. Over the years producers have demanded more and more from their RTUs. The modern day multi well pad with 30 or more wells per site has pushed the limits of RTU technology and producers are seeking a better solution to help them be more efficient and reduce costs.

The PLC was traditionally thought of as more of an engineer's tool and not the ideal solution for single well pad control. It was traditionally not built for inhospitable and harsh environments, nor was it a low-power consumption device. Today's modern day well pads are, in essence, small factories. They have environmentally-controlled buildings and utility or generator power. This makes them the ideal environment for a PLC. When we architect a multi well pad control system and utilize the modular and scalable hardware and programming capabilities we are able to reduce costs, installation time and maintenance overhead.

The gap between RTU and PLC application support is quickly reducing. PLC's have the capability for multi flow run custody transfer of liquid and gas. This has been done with a PLC for years now. Artificial lift applications, tank management and other specialty applications are being developed at a rapid rate for PLC controllers. Combining these specialty applications into one PLC controller and making these applications configurable and field customizable is the next step in control evolution for the multi well pad and the future of the digital oil field.

ABOUT THE AUTHOR

Title and place of education: Devry University, Phoenix Arizona – Bachelor of Science,
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Career development: Zachary began his career as a field service engineer with Rockwell Automation in 2005. He received training through the Rockwell Automation Engineer in Training program. In 2009, Zachary began working for Infinity Power and Controls with a sole focus on the oil and gas industry. At the company he was embedded at an enhanced oil recovery field with a large United States-based oil producer. There he was in charge of upgrading a legacy control system and SCADA for the plant and field automation. In 2014, Zachary returned to Rockwell Automation as an Oil and Gas Senior Engineer. He has since served as a lead proposal writer for several large projects and also worked on several oil and gas projects for modernization of legacy control systems, as well as installing new equipment.

Current title: Onshore Upstream Oil & Gas business development manager, Rockwell Automation