Bringing AI & IoT into Upstream Oilfield Facilities

Innovation has been slow in the oil and gas industry. A key reason is the paradigm "Because we've always done it that way." Together, we can change that!

A Technical Paper

Prepared for

Facility Engineers and Designers

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EXECUTIVE SUMMARY

Time flies! A few years ago, on December 22, 2017, E&P Magazine published article titled, *"Insight: Data-driven Energy Industry Is Ripe for Growth",* author Michael O'Connell touted the reality that the oil and gas industry stands to save billions of dollars annually by getting on the IOT and AI bandwagon.

That same month Automation World published an article titled, *"Oil and Gas Hunker Down,"* author Lauren Gibbons Paul asked, *"After weathering storms both economic and meteorological, will the industry stick to the hard-won lessons it has learned about the importance of optimization and process improvement?"* Ms. Paul's question was provocative then, and there is little doubt that Mr. O'Connell's conclusions were correct too.

So, the question is, "Are we there?" Well, in an industry traditionally mired in history of "boom-to-bust" economics where diminished oil prices and long-standing paradigms perpetuate the mindset that, "We're doing it this way **because we've always done it this way**," only time will tell.

It seems the E&P component of our industry has a really tough time of getting out of its own way, at least as regards embracing advancements automation. There are exceptions, of course, but overall, we are an industry slow to change.

And even now, faced with a panacea of affordable automation, too little consideration is given to the use of the Internet of Things and Artificial Intelligence in the upstream sector where all fluids are processed and oil and gas are sent to market … essentially the same way they were 100 years ago! This creates a potentially game-changing opportunity!

I take pride in the fact that I have designed and walked through thousands of your tank batteries. These are places where oil and gas are separated and shipped off to market, the literal cash register of all E&P companies. Yet, I have NEVER been in even one such facility, simple as most are, that has not had crude oil spilled onto the ground!

Wading through a pool of crude oil sticks in your mind! It is not hard to imagine the waste an oil spill represents … and chilling to realize the dangers as you walk through it … if, for instance, it were to suddenly ignite! After so many decades, shouldn't we now ask, "Could this oil spill have been avoided?" After all, six decades ago we put a man on the moon with less AI than your smart phone has built into it! There is simply no excuse for not using today's automation tools to avoid the next oil spill. So, why are we?

SCADA AND INFORMATION OVERLOAD

We now live in a marvelous age where nearly anything we can conceive can be affordably realized! We can measure anything, sense anything, communicate anything … all in the twinkling of an eye. Accurately too, if we do it right! And we do it with SCADA (supervisory control and data acquisition). But when we do, we find ourselves engulfed in a wave of information overload!

What we are struggling with now is how to properly collect and then to manage all of this information! Instrumentation has taken a quantum leap forward, becoming accurate and affordable, but we are slow to replace the antiquated electronics we installed a decade or two ago. What falls behind is our ability to use today's technology today, to use available information in real time, to make intelligent decisions with it today, to let our upstream facilities manage themselves, all via AI. We could use today's smart controls and AI supervisory software to achieve a level of performance, efficiency, optimization, and increased profits never before possible.

We can do this on the more obvious levels in upstream operations; with ultrasonic level transmitters to control tank levels, and variable speed controls to manage pumping rates. Is instrumenting and automating a tank battery so it manages itself really too "out there"! And if so, why? Perhaps it's because too few of us have the disjointed skill sets necessary to do it right. The code author has never walked through a tank battery after a tank runs over, through a pool of spilled crude oil. And perhaps the lease operator who does this daily is afraid that if he or she speaks up, automation just might replace him, or her.

Then there is the reality that every time the price of crude drops $10/barrel the industry lays off its lower tier people … robbing the industry of those hands-on skill sets. We do tend to handcuff our field operations this way, and it is costly!

Today the domestic oil and gas industry enjoys production from over 1,700,000 wells! Imagine, if each one spilled only ten barrels per year, the industry would lose nearly 17 million barrels of oil annually worth over half-a-trillion dollars. It happens … year after year!!

So why don't we take better advantage of our IOT and develop our own AI?

One big reason is that we tend to be short sighted. It is the Wall Street mentality that has been a big part of our history. We budget for the short term and adjust rapidly when oil prices change. Our morning meetings focus on the activities of the last 24 hours. There is no time for a long-term approach! Budgets stay focused on the micro level rather than the long-term macro level. We make bad decisions, like installing a $300 pressure transmitter on the bottom of an oil storage tank to transmit the tank liquid level to us remotely. As BS&W accumulates on the tank bottom this device is trapped in the muck. It fails, and the tank runs over! We might have upped our game and spent $1,400 for a state-of-the art tank roof mounted level transmitter. It is accurate to 1/16". Muck will not ever defeat it. But if we don't an oil spill is inevitable! Yet, look at all the money we saved! We spent $300 for the transmitter instead of $1400 on an electronic level transmitter and saved $1100! Then we had an oil spill that cost us over $5,000 to clean up!

Short-term decisions like this only look good on paper. They get raises for the project manager who saved $1100 per tank by installing the pressure transmitters. And by the time the muck accumulates, and the tank overflows, he's spent his raise and is long gone, or he's been laid off …

leaving the next facility operator to try to figure out how to placate his supervisor who is really upset because he ran his tanks over again!

The biggest reason we make the decisions we make is that we are stuck in the past. Our paradigms force us to accept things the way they are because "we've always done it this way."
We simply must overcome both!

What is clearly needed here is innovation, a meeting of the minds! A commitment to break the constraints of the past, and a mind meld between the best of our code writers and our best lease operators and their supervisors.

In reality few code authors have any idea what should happen in a tank battery, so they are handcuffed when asked to write an AI program that completely automates a tank battery. On the other hand, most lease operators and their supervisors have some idea what should happen if something goes wrong, and what to do about it, but they have no idea what instruments to select to sense it or how to write the code needed to detect it and make the right moves automatically to correct it, or to divert it, or to stop it completely. But as a team, they do!

We often use this approach as we practice HAZOP/PSM, gathering our most knowledgeable field and professional folks together to play the "what if" game … but usually only after the facility design is on the drawing board. We almost never ask them to take this approach in the design phase of a new production facility, so it has the possibility of managing itself!

But the time has come!!

GETTING IT DONE

Let's see how this might take place!

Imagine a facility design where the production is from a long lateral shale formation completed with a multi-stage frac job using 150,000 pounds of proppant. The new well makes 8,500 BWPD, 1500 BOPD 3.5 MMSCFD and about 100#/day of frac sand during IP. The oil is 48°API, the water is 1.065 specific gravity, and the gas is 1350 BTU.

With light oil like this it is unlikely that we'll have any difficulty separating the water and BS from it, so the only reasons we'd design the facility to include a new heater treater is 1) because we've always done it that way (a reason showing how locked in the paradigms of the past we are), and 2) because we might accumulate tank bottoms over time and it would be good to be able to process them as they accumulate.

But to properly implement AI based on the IOT we choose, we need the analytics only presently available from the operations staff and interpreted through our code authors.

It might go something like this …

OIL-WATER-GAS-SAND SEPARATION

First, we need a properly sized FWKO to do the job of separating the majority of the water, if not all of the water, from the oil. Using the rule of thumb for light oil (100B/D per square foot of interface area) we can see that the FWKO needs to have about 100 square feet of interface area. Using the standard length to diameter ratio of 2-4 L/D, and sticking to standard nominal diameters, the FWKO could be a 6' x 16'-8" or a 5' x 20'. Too small and it will carry over. Too large and it will have poor hydraulics and the flows with short-circuit reducing retention time and separation. The smaller diameter vessel will cost less, so we pick it. Being almost 2-1/2 times as heavy as the produced water and 3.3 times heavier than the oil, we know the sand will separate so we have the FWKO designed with sand pans.

In the past, we'd probably stop there, but today we can install a sand sensing probe to alert us electronically when and as the sand accumulates. We do, but rather than simply alarming a sand build-up so the operator can drain it out, we trigger quick open valves under the sand pans to remove the sand automatically. We operate the FWKO at 100 PSIG and route the sandy water through hydro-cyclones which dump the sand with less than 20% water into hopper bags or roll-off boxes for disposal or re-use. We cycle the sand dumps in short bursts to minimize the effect of rapid vessel draining on the overall separation process, so the water and oil actually separate. If the sand sensor senses more sand accumulating than is being removed the new operating software (AI) adjusts the dump valves (IOT) cycle intervals and durations until an equilibrium is reached. The hopper bag or roll-off box are monitored with load cells so as they approach about one day's holding capacity the operator or designated contractor is alerted to change them out for new ones. And finally, we protect the FWO with a normally closed automatic ESD valve, help open by a signal from the AI when operations are normal and closed during periods of power outrages or in critical alarm conditions.

With the sand removed the produced water and oil volumes can be accurately measured using lesser expensive turbine flow meters (about $1/5^{th}$ the cost of Coriolis meters). Flows are monitored in real time. A 10% deviation in oil or water flow from one eight-hour period to the next triggers a text message to the operator so he knows a well is down, or a line is leaking somewhere. A 20% deviation alerts remote staff to check the tank battery security cameras looking for leaks (more AI). Sump pumps, installed within containment confines to move spills and rainwater to storage, are monitored for run time and duration. If a production deviation and an extended sump pump event occur at the same time the AI starts an event timer. If the event timer signals (more AI) a sequential repeat of the same event an ESD is triggered and all wells feeding the battery are shut in until the operator remedies the issue.

Our new FWKO is fitted with a pressure transmitter and a high and low-level transmitter. Each can trigger a shutdown event.

Produced gas is efficiently separated from entrained liquids by a serpentine vane demister located near the outlet end of the FWKO and leaves the vessel to flow first through a conventional orifice plate meter run, a back-pressure valve, and on to its gas sales line.

Produced water is sent from the FWKO to a HWSB® Skim Tank, described in more detail below, for final oil-water separation. Oil from the Skim Tank flows to a dedicated oil treating tank. This tank is fitted with a side-wall mixer (Jensen Int'l, Tulsa) and three Chromalox LTFX totally enclosed electric immersion heaters. A density compensated ultra-sonic liquid level transmitter (LT) monitors the tank level and feeds the AI with this data. When the tank is 80% full the tank heaters are switched on and the sidewall mixer and a demulsifier feed pump are started. The demulsifier is added through a sidewall dip tube feeding the emulsion breaking chemical into the impeller intake of the mixer to assure thorough mixing. The oil temperature is monitored by a sidewall temperature element installed in a 24" long thermowell so it monitors a representative sample of the moving oil. As the oil temperature reaches its preset set point the heaters cycle on and off, but the mixer continues to run for a pre-set time. When that time elapses the mixer and chemical feed pump are shut off, and the heaters remain active. This heated oil is left static for at least eight hours to allow all of the water of emulsion to settle out. After eight hours a bottom circulating gear pump is started and the tank bottoms are recycled into the inlet of the FWKO.

The oil leaving the FWKO is sent to additional oil storage tanks, each fitted with a normally closed automatic inlet valve, held open by a signal from the AI when operations are normal, a bottom circulating pump, and a pair of density compensated ultrasonic LT. As each tank reaches 80% of its capacity the LTs signal the bottom circulating pump to start, comparing level measurements, and left it stay on until the tank reaches 95% full, assuming the output from the two transmitters is within preset tight tolerances. If not, a text message is sent to the instrument tech alerting him of the drift so he can recalibrate or replace the faulty sensor. If the drift exceeds a wider tolerance, the AI switches all inflow to the next tank to avoid the possibility of a tank overflow. When the LTs are in agreement the bottom circulating pump continues to pump until the tank level is down to 90% full, at which point the AI shut it down. This shutdown alerts the operator and/or the oil purchaser to move this tank load of oil to sales. The LTs monitor the tank level changes over time during the transfer, and the AI records the number of barrels of oil transferred out of the heated tank and each of the other oil storage tanks. The duration of level change is recorded. The time of each nominal volumetric increment a cross-check against custody transfer, giving the owner an accounting of oil sales in real time.

Where oil is sold via a LACT Unit the tank level AI monitoring serves as a cross-check against the LACT meter to confirm accurate and proper oil sales, thereby avoiding inaccuracies or potential oil thefts (for instance, if the LACT Unit is not active but the oil tank levels are falling something is wrong! In this event the AI can trigger an alarm horn, focus all battery cameras on the oil tank area, start a recording, and trigger a remote alarm to owner headquarters, turn all battery lights on high, close the electric gate leading from the highway to the tank battery, etc.). If the LACT Unit rejects oil it is directed into the heated tank for emulsion resolution as previously described.

All water leaving the FWKO is first sent to a DFSD® tank to remove all entrained gas and fine suspended solids. The DFSD® then divides the flow evenly to dedicated Skim Tanks immediately downstream. These are often the patented KBK HWSB® Skim Tanks. These tanks are specifically designed to remove small amounts of oil from large volumes of water, clarifying the water for reuse. The HWSB® design has replaced most conventional oilfield "gunbarrel" tanks which were designed over one hundred years ago for the low water cut applications of those days, but which were never intended for use in today's high water cut applications.

Since the early 1990s, KBK's HWSB® has become the standard of the industry for today's high water cut water clarification applications. The HWSB® tank is always taller than downstream water storage tanks and the oil tanks to allow for gravity flow, simplifying the facility design and eliminating the need for water and oil transfer pumps.

The HWSB® is fitted with one high level ESD level transmitter identical to those used in the oil tanks. A guided wave radar interface level detector is added to display the oil-water interface on a display screen for a user-friendly operation. As the interface lowers, the automation software can automatically drain off the rag layer just below the clean oil or alert the operator to do so manually.

The design of the HWSB® precludes overflowing conditions in nearly all cases. The rare exceptions are when an outlet valve is accidentally closed or in the unlikely event that an outlet line plugs, so high level ESDs are rare. The ESD is recommended to prevent costly oil spills and tank battery oil spill cleanups.

Water leaves KBK's HWSB® Skim Tank through a KBK engineered large diameter concentric pipe adjustable water leg. This industry standard patented design is made with a 30" OD vertical outside pipe with a 20" concentric and adjustable inside overflow pipe. Water flows into the annulus between the 30" outside pipe and the inside 20" pipe. When it reaches the top of the 20" pipe inside it overflows down into the 20" inside pipe and exits near its bottom. The top section of the 20" pipe O-ring sealed to the lower portion and is adjustable using a geared jack screw. The spillover elevation of the adjustable pipe determines the elevation of the oil-water interface inside the Skim Tank and adjusts so the operator can manage the depth of the oil layer inside the Skim Tank. Operators in cold weather areas often raise it in winter to allow for more oil retention time in the colder winter months and to minimize tank bottoms accumulating in the receiving oil tank. The water overflowing the 20" inside vertical pipe in the water leg flows on to the next water storage or water transfer tank.

This water storage/transfer tank is always shorter than the HWSB® Skim Tank, usually by about 8', to allow for gravity flow. It is also fitted with a pair of LTs identical to the others. One is dedicated to managing the outflow of water, often to an offsite water disposal plant. It does this by feeding levels via AI to the transfer pump's VFD (variable frequency drive) which increases or decreases the pump's motor-driver speed, thereby maintaining the water level in the storage/transfer tank. As in the oil tanks, the LTs check each other for consistency, and report any/all discrepancies to the Instrument Technician via text AI generated messages. The secondary LT is dedicated to a high/low level detection condition which can trigger a system ESD.

The water transfer pump is backed up by a stand-by pump, both feeding a mass-flow meter which is monitored by the AI. Any deviation above or below preset high and low flow rate conditions triggers an alarm which, in the case of high level starts the second transfer pump, or in the case of a low-low level results in an AI triggered ESD of the entire system should it exceed the low-level or high-level tank limits, and/or persist for more than a few minutes. In the event of a low-low level condition, the AI monitors the sump pump operations which could indicate a water leak inside the containment, and if so detected, triggers a full system ESD and sends out an automated cell phone call to the lease operator directing him/her to return the facility ASAP.

WHAT IS THE IoT CAP-EX COST AND THEIR OP-EX ROI?

Once we realize that all of this is possible, it becomes obvious that it is not so far-fetched after all. While the traditional question may be, "Can we afford it?" the operative question really is, "Can we afford not to use IOT and AI related technologies in the 21st century?!"

In the past many of us have focused on a micro view, from the perspective of minimizing CAPEX. The answer in former times, from the project manager in charge of building the new facility, was almost always an emphatic, "NO!" However, in the 21st century where prolific production is the norm and downtime is the costliest of all operations concerns, we tend to have a longer-term view of overall operational economics. Today, the answer is always a resounding, "YES!" The reality of very high downtime costs compared to the capital cost of the necessary equipment needed to avoid downtime paints a clear picture of both short and long-term economics favoring IoT and AI from the bottom to the top of most organizations today. So, let's look at the added costs of IoT and AI in more detail to see what it costs, and what it saves.

CAPEX COSTS – FWKO IoT & AI

Let's take a typical facility designed for 5,000 BOPD and 50,000 BWPD. This facility will consist of a FWKO, a heater treater, a VRT, one DFSD desanding degassing, flow-splitting tank, three HWSB® skim tanks, oil, and water storage tanks, a LACT unit, a VRU, an LP flare, and a large emergency flare.

The FWKO will be fitted with the following AI/IOT friendly instruments, valves, and controls which are over and above the traditional controls:

1. 6" x Class 600 88A-T40-xx Apollo SS Inlet ESD ball valve with electric actuator @ $5,784 + $1,376 = $7,160
2. Invalco ISM780 oil-water interface probe in lieu of pneumatic LLC @ $4,340 - $926 = $3414
3. Three sand pans, 2" x Class 100 full port ball valves with electric actuators @ 3 x $866/ea. = $2,598
4. One Ashcroft Model A2XBM0242C010000#G#high/low pressure transmitter @ $529
5. Two Rosemount #5081 high-low level transmitters @ $780/ea. = $1,560
6. Labor, conduit, wiring @ $15,000
7. AI software @ $15,000

FWKO IoT Added Cost Over and Above Normal = $44,732

CAPEX COSTS – TANK BATTERY

The tank battery will have one DSFD®, three HWSB®s, four 1500-barrel oil storage/sales tanks, one 1500-barrel reject/slop oil processing tank, and four 1500-barrel water storage tanks each fitted with LTs and one of them fitted with heating and mixing components:

1. Thirteen density compensated ultrasonic level transmitters @ $1,160/ea. = $15,080
2. Four 2" Valworx SS 2" electrically actuated ball valves #565352 @ $505.44/ea. = $2,022
3. One Jensen Int'l tank mixer @ $3,150
4. Three Chromalox 15 Kw LTFX shrouded electric immersion heaters @ $8,600/ea. = $34,400

5. One spare Goulds 3196 standby water transfer pump with VFD @ $13,850
6. Five oil/tank bottoms recycle gear pumps @ $1,880/ea. = $9,400
7. Labor, conduit, and wiring @ $125,000
8. AI software @ $125,000

Tank Battery Total Costs Over and Above Normal = $327,902
Total AI/IOT adder for FWKO and Tank Battery = $327,902 plus a $25,000 contingency.
Short Term AI/IOT Grand Total Adder = $352,902

Adding $350,000 to any tank battery construction for automation may seem extravagant on the surface. This is the main reason it is rarely proposed or seriously considered.

THE LONG-TERM APPROACH

When management considers the cost of operating a single oilfield tank battery facility all factors must be considered. The costliest of these factors is downtime. The cost of lost production from unnecessary downtime and unforeseen upsets like tank overflow events far outweighs the cost of AI and IoT components.

In a 5,000 BOPD facility the oil alone is worth $350,000 each day. The loss of oil production from only one day roughly equals the CAPEX cost of all added components needed to minimize it.

In addition, there are upsets and normal operational errors that add even more costs and further justify expenditures in the IoT and AI that help avoid these costs. Some of the likely costs follow:

1. Assume three tank overflows for an average of 7 hours each = 21 hours of lost production. At 5,000 BOPD normal production we will lose 21/24th of 5000 barrels or 4,375 barrels. Today each barrel is worth about $70, so our annual loss from three seven-hour tank overflow events $306,250.

2. Assume this facility has four ESD's that shut it down for a total of 32 hours per year. The cost of this is clearly 32/24th x 5,000 BOPD x $70 or $467,000.
   a. The AI controlled self-managed system should reduce this downtime by at least 50%, cutting the cost to about $233,000 if the system were fully automated and self-managed.
3. When a tank battery is self-managed the operations staff is freed up from the daily visits normally necessary, so they can do more important chores like providing the maintenance necessary on other less automated facilities. If we reduce the overhead expense of operating this facility by 75% of the annual cost of the operators, we save at least $60,000 in direct costs plus another 22% G&A costs per employee or $13,200 for a total of $73,200 per year.

When we add these probable costs together, we see that operating as we have in the past is likely to cost us $846,250 as compared with an automated facility built with state-of-the art IoT and AI. In ten years, AI and IoT would save this facility owner nearly $8.5 million!

This is hard to overlook!

CONCLUSIONS

Interest in artificial intelligence (AI), and in the internet of things (IOT), has been slow to gain popularity in the upstream sector of the oil and gas industry. While they seem to hold great promise, they are also in serious competition with other, higher profile technologies such as long lateral completions and multi-stage fracking, and rightly so! The higher profile technologies are inarguably the lowest hanging fruit of today's E&P sector.

Nevertheless, the application of today's AI and IOT technologies to existing and new upstream facilities has the opportunity of propelling those upstream process operations into the 21st century, streamlining operations, reducing wastes and inefficiencies, and adding significant profitability … all at a time when it's seriously needed.

ABOUT THE AUTHORS

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