Artificial Lift Electric Submersible Pump Design Considerations for Oilfield Operations in Iraq

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Abstract

Oil & Gas operating companies in Project Rounds 1 and 2 committed to a sum total plateau production of 11.1 million b/d oil over ten Iraqi oilfields. This compared to current production of 1.5 million b/d at time of tender.

Of this amount, sum total production commitments for Project Round 1(Rumaila, West Qurna 1, Zubair oilfields) comprise 6.4 million b/d from a current production of 1.5 million b/d. The remaining seven oilfields had under 60k b/d production at time of tender.

Achieving this approximately 725 % increase in overall Iraqi oilfield production requires significant investment in secondary recovery technologies and advanced artificial lift operational processes. Typical methods deployed in the industry are a choice of either gas lift, or the application of electric submersible pumps, rod pumps, jet pumps, or progressive cavity pumps.

By far, the secondary recovery artificial lift equipment expected to be applied most in Iraqi oilfields is the electric submersible pump (ESP). This paper details many of the ESP design criteria and considerations necessary to achieve operational goals and optimize reservoir production.

Introduction

Over the lifetime of a well, the pressure will fall. At some point, there will be insufficient downhole pressure underground to force the oil to the surface. After natural reservoir drive diminishes, secondary recovery methods and tools are applied. Engineers and geologists choose from various recovery techniques to optimize production, maintain reservoir health, and best manage operating expenses (OPEX) and equipment and facility capital expenditures (CAPEX) to achieve production goals and return on investment (ROI).

Artificial lift professionals rely on the supply of external energy through the use of pumping lift tools and into the reservoir typically in the form of injecting fluids to increase reservoir pressure, thereby replacing or increasing the natural reservoir drive with an artificial drive.

In Iraq and many other locations in the Middle East GCC operating environment, electrical submersible pumps (ESPs) are increasingly being used to bring the target fluid oil to the surface, together with associated water and gas. Other constituents such as corrosive and deadly hydrogen sulfide (H2S) i.e. sour gas, CO2, asphaltenes, and sand fines are often encountered in produced fluid.

The Rumaila oilfield, with current production of 1 million b/d at time of tender is slated to produce at least 2.85 million b/d at peak production. It was tendered in Round 1 and awarded to BP (51 %) as operator, and CNPC (49%) as investment partner.

The ESP form of artificial lift was selected as the method of choice by BP, after considering both gas lift and ESP options. BP awarded an approximately $100 million ESP equipment and services contract to two original equipment manufacturer (OEM) vendors in the summer of 2010. First delivery and commissioning of ESPs occurred 3Q2010.

At time of writing, Exxon Mobil is out to tender 3Q2010 for ESPs and related ancillaries to meet lifting requirements for the West Qurna 1 oilfield. Production commitment is slated for 2.325 million b/d from current levels of 270,000 b/d.

A complete data table of operators and partners involved in Project Rounds 1 and 2 are provided for reference, together with production commitments and general financial information.

Oil Field	Bidding Consortium[a]	Proved Reserves (Billion Barrels)	Current Production (Barrels/Day)
Project Round 1			
Rumaila	BP (51%), CNPC (49%)	17.8	1,000,000
West Qurna 1	ExxonMobil (80%), Shell (20%)	8.6	270,000
Zubair	Eni (44%), Oxy (31%), Kogas (25%)	4	205,000
Project Round 2			
Majnoon	Shell (60%), Petronas (40%)	12.6	55,000
Halfaya	CNPC (50%), Petronas (25%), Total (25%)	4.1	3,000
Qaiyarah	Sonangol (100%)	0.8	2,000
West Qurna 2	Lukoil (75%), Statoil (25%)	12.9	0
Badra	Gazprom (40%), Kogas (30%), Petronas (20%), TPAO (10%)	0.1	0
Garraf	Petronas (60%), Japex (40%)	0.9	0
Najma	Sonangol (100%)	0.9	0
Total		**62.7**	**1,535,000**

Note: Numbers affected by rounding.
[a] Key to acronyms and national affiliation: BP = Royal British Petroleum (United Kingdom), Royal Dutch Shell (United Kingdom), Eni (Italy), Oxy = Occidental Petroleum (United State (Angola), Lukoil (Russia), Statoil (Norway), Gazprom (Russia), TPAO = Turkish Petroleum C
[b] A signature bonus is a non-recoverable sum of money that the winning bidder agrees to

Design considerations and operational disciplines

An outline of design considerations pertinent to all ESP applications and operational considerations in Iraq and a detailed description for each item follows:

- ESP System Application Selection
- Fluid Properties
- Pump design criteria design
- Motor design criteria
- Seal section
- Cable design criteria
- Motor lead extension (MLE) pothead criteria
- Variable Speed Drive and Harmonics
- Commissioning methods
- Troubleshooting metrics and methods to resolve
- Training
- Remote COM telemetry and equipment securitization /Production optimization
- Security
- Personnel retention and successful environment adaptation.

ESP System Application Selection

The oil & gas operator evaluates and designs his overall system characteristic production curve and pump head capacity curves to meet production objectives.

Processes and data utilized are Productivity Index relationships in a 100% water environment, and/or Inflow Production Ratio (IPR) Vogel correlations for flow efficiency equal to 1.00 and Standings extension of Vogel's work for flow efficiencies other than 1.00(damaged wells) based on flow below the bubble point pressure for oil, gas and water, together with data such as PVT in the form of pressure, solution gas oil ratio and formation volume factor (if gas is present), percentage water cut, fluid properties such as degree API, viscosity, temperature, percent intermittent and continuous gas and other critical pertinent data. Pump system selection utilizes various software to facilitate calculation estimation and design. Pump companies either utilize third party software such as Subpump™, or proprietary software sizing programs such as the advanced Avocet™ well and surface modeller and the Autograph™ ESP sizing primer.

The operator is recommended to understand how to thoroughly work with these software tools on an independent basis or through the use of third party support in order to satisfy design due diligence. In addition, during operations and while monitoring actual operating conditions, it is essential to understand the ins and outs of the equipment design and the basis for certain operating ranges. Examples are thrust loads, minimum and maximum operating range (and why), proper start up characteristics and utilizing an ESP tornado curve to set proper voltage and frequency (Hz), free gas and gas separator criteria and limits. Operators should inquire as to the safety factor built in to each ESP element selection and in regard to industry standard API RP11 guidelines.

Plant inspections, equipment birth certificates, mil certifications and witness performance testing help ensure that the pump designed is as close to the performance of the actual pump delivered within reasonable industry standards. Anything less is at operator peril.

Other system considerations include ESP tool handling and toleration of well treatment chemicals used downhole such as scale inhibitors, acids and various solvents.

Power quality whether utilizing grid or genset is an important consideration and should be an integral part of the design process. In addition, the operator should carefully select surface controls equipment and understand the “how’s and why's” of harmonics as it relates to variable speed drive (VSD) operation of the ESP. To date, there is not a specific API standard as it applies to harmonics and VSDs for ESP operation. Each vendor has its own methodologies and claimed standards.

<u>Fluid properties</u>

It is essential to understand not only bottom hole temperature (BHT) to ensure proper cooling past the motor, but to capture as much fluid data as possible to help select the proper equipment. Examples: solids – sand fines – amount and characteristics (sharpness, angularity, etc). Scaling can be a serious game stopper such as with calcium carbonate build up and rotating equipment locking, so a complete understanding of all parameters should be documented and shared with your chemical treatment professional independently and also in collaboration with the ESP vendor. The affects of H_2S and CO_2 are well known to practitioners and further comment not provided.

With regard to thrust and solids, hardened bearings and bushings, assess whether tungsten carbide hard facing or ceramics should be considered. Case studies in similar well conditions should be documented and reviewed.

Fluid conditions form the basis for corrosion design prevention. Small details to prevent galvanic corrosion like flange bolting should be part of the design making process.

In southern Iraq, downhole temperatures are being set at the 350 F design bar. This is relatively very high to the industry, and so monitoring equipment and well conditions is essential.

<u>Pump design criteria design</u>

Besides software head / capacity (H-Q) sizings. metallurgical selection and the use of hardened bearings, the operator should understand starting torque characteristics as it relates to shaft design and actual manufactured tools (straightness, vibration) and the selection process between ceramics and tungsten carbide. It is this author’s opinion that floater versus compression pump selection criteria are overstated in this day and age.

Together with abrasion resistant materials capable of handling thrust, and advanced seal section design and thrust capabilities, the operator should be pleased to review the type of pump selected and understand why a vendor selected one versus the other, without interfering in the selection as long as thrust considerations are taken into account.

Seal section design criteria

The function of the seal is to transfer the motor torque to the pump shaft and equalize the internal unit and wellbore pressure. The seal also handles the pump shaft thrust load (thrust bearing) and isolates the well fluid from the motor oil fluid (labyrinth chamber and mechanical seal), providing volume for motor oil expansion (bags /bladder). Multiple (redundant) seals should be considered as a good investment in critical or uncertain situations.

Motor design criteria

In an ideal situation, it is the motor that will fail without any other systemic root cause, AFTER A LONG AND SUCCESSFUL RUN. Too often, vendors and operators are quick to blame an early pull on motor issues, instead of other causal factors. Rarely are power harmonics, improper applications, remedial training of commissioning personnel, or actual commissioning methods thoroughly evaluated. If in doubt, get professional independent third party support to work out troubleshooting matters with you utilizing proven root cause system processes such as Nakamichi.

An operator's understanding of the Motor Characteristic Curve (MCC) is critical for proper commissioning and a long run. But how often are operators' and commissioning personnel even aware of the MCC? Did the operator witness the actual MCC during manufacture and understand its implications? Example and case in point: When operating to the right side of the MCC a drop in voltage does not result in amperage to increase. In fact, just the opposite occurs, as the amperage actually drops, at the same time collapsing the oscillating harmonic field. It is this field turning back on a very unstable initial field that often causes many shutdowns when a compressor or other equipment causes a voltage drop. Cycling and loading effects: mechanical stresses on motor and complete rotating equipment string, thermal degradation.

Cable design criteria & MLE

There are hundreds, if not many thousands of possible cable material combinations. Basics for Iraqi oilfields: consider standardizing ESP cable to be H_2S rated. Considerations: Cable insulation, jacket and armor materials, together with standardized clamps and protectors. Given high temperatures and sour gas environment, a cable design of EPDM and Lead combination is in order. Operator should be in a position to witness quality certification process.

Variable Speed Drive & Harmonics

To which specific ESP industry standard and code are you specifying VSD selection?

What criteria are you using during inspection?

What process are you utilizing to identify and measure harmonics?

What is nameplate VSD efficiency over intended operating range (not just a claimed nameplate full load value)?

If a manufacturer is not even aware of or real time monitoring VSD efficiency over entire operating range how could this oversight affect equipment?

A list of many similar hundreds of questions with regards to frequency regulation, wiring and terminations, power and harmonics may be asked. The specific VSD industry standard and API guidelines as it applies to ESP operations would be the best place to start.

Commissioning, Troubleshooting, Training (CTT)

Pre-commissioning meetings with operating personnel to ensure their understanding of the big picture, with composite HQ curves and MCC's in hand go a long way to achieve runtime and production goals. Like driving from Nome, Alaska to Miami, Florida, without a map it is easy to get lost, waste a lot of time, and spend far too much money – not to mention the pain and turmoil alone the way. Do the right thing. Get your roadmaps and talk about how all concerned plan to get from point A to point B in plain English before the road trip.

Troubleshooting is a process to plan ahead of deploying the first ESP, instead of waiting for the first mishap before getting started. What process will you utilize? Are you on the same page as the vendor as to methodology? Have you already met the vendor's troubleshooting team to assess how you will tackle the issues at hand, and through which prior agreed process (example: Nakamichi).

Training and what it comprises is oft misunderstood, and less appreciated. It should be a program that executes to measurable operating objectives. In brief, the day after training, operators should be able to execute to a measurable specific task, with100% proficiency. These measurements are to be directly tied to OPEX and CAPEX, thereby making it a ROI business metric. As is so often the case without measurables, it was not actually training but just another seminar. In my profession, I like to tell students that training is like preparing for the final exam and making an A on the final. It's always hard work and a skill set you are proud to own. Whereas, a seminar is like showing up for the first day of class. Little individual effort, no homework and no measurables except that you attended - typically just words forgotten and rarely applied. So let's make sure we value training and see it as a worthwhile investment and not an expense.

<u>Remote COM telemetry and equipment securitization /Production optimization</u>

The topic of downhole monitoring, production optimization, remote COM telemetry and asset securitization is drawing increasing attention in the industry. Most ESP manufacturers have given a valiant effort to understand these typically out sourced technology offerings and attempt to standardize and integrate a meaningful package. The reality is that oil & gas operators are typically left with a lot to be desired. Consider utilizing a third party upfront during the tender process to help integrate technology offerings, and work towards a seamless integration of your surface well site and remote telemetry with a particular vendor's downhole monitoring sensor package. A good third party integrator can also tie in asset securitization and complete the entire package.

<u>Security, Personnel Retention, Environment</u>

In the first few instances of contract execution in Iraq, ESP vendors are utilizing third party companies to recruit and directly commission/ service their equipment. How are staff being trained? What are the standards to measure up to with regard to commissioning /operations, safety, and security?

<u>Workshop, Storage and ESP Teardown Facilities</u>

Paramount is 24/7 localized service comprising a local workshop, inventory storage, assembly and ESP teardown capabilities. Work encompassed is refurbishment, re-calibration and repair service, for both downhole and surface equipment. This is a necessity and should be an expectation. Oil & Gas operators should step up and upfront support the business case by a vendor to commit to this type of investment in Iraq, and not expect a service company to front the entire business case risk pending an award contract. For this reason, partnerships with local Iraqi enterprises with long term interests willing to facilitate with plant, equipment and Iraqi staff are critical and highly recommended to help get the ball rolling.

Conclusion and Summary

The integration of ESP technology in Iraqi oilfields is an important element to achieve target oil & gas production. As important as ESP technology is to the effort, significant focus to continual improvement in operational processes and integration with local Iraqi business enterprises are also essential.

About the author:

Mr. Davidson is the Principal Consultant and President of Artificial Lift Pro Services Inc. In affiliation with Houston based Production Associates, he serves as advisor for oil & gas operations worldwide, including Iraq and the GCC.

From 1992- 1996, he was a Business Development executive with the Bassam Group, Saudi Arabia and supported Eastern Province oilfield management for Hydril and Geophysical Research Corporation. Returning to the GCC region in 2008, he served as Vice President – Commercial & Operations for the Al Turki Group (ATCO), Saudi Arabia. From 1996-2007, Baker Hughes Centrilift management in various responsibilities, and as a Senior Technical Training Specialist. Noble Drilling – 1988-1992. Termomeccanica Italiana S.p.A. and the U.S. Patent & Trademark Office, Washington DC 1983-1988. Halliburton Brown & Root 1978-1980 as an engineering intern.

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