MAXIMIZING WELL PRODUCTION ON TIGHT CASING ESP APPLICATIONS IN THE PERMIAN BASIN

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ABSTRACT

Electric Submersible Pumps (ESPs) are commonly known in Artificial Lift Systems for high flowrates capabilities; however, this has been limited on tight casing application due to HP constraints, clearance for chemical treatment lines all the way down to the bottom of the equipment, and reliability concern on tandem motor applications. Three different oil operating companies in the Permian Basin were experiencing production constraints on their wells due to these common limitations. For the first case, the horsepower limitation of the 420 series motor, constrained them to set the intake at desired 7,700 ft in a 5.5x17# casing, and meet the target production of 7,400 BFPD. After proposal was presented, the operator successfully installed the 510 HP Permanent Magnet 399 Series Motor, which ended up producing +7,800 BFPD, drawing down 22 psi/day in 20 days and then lowering the PIP to ~1,600psi. In a second case, the operator had HP limitations to set the intake at 9,000 ft deep and target 4,500 BFPD in a 5.5x20# casing, also needing clearance to set CT line below the sensor. The proposal included retrofitting the Drive and selecting the 510 HP Reynolds Permanent Magnet 399 Series Motor, meeting the clearance and set depth criteria, and exceeding the target production to +5,000 BFPD, drawing down 45 psi/day in 20 days and then lowering the PIP to ~1,150psi. The third, is a case of horsepower limitation on an unusual completion with 5”x18# production casing where a conventional slimline ESP was originally installed with 375 series tandem IM. The system described could not draw the well down, minimum pump intake pressure was above 2,000 psi, with the unit running at high motor loads and total fluid rates averaging only ~720BPD. After proposal was presented, the operator proactively pulled the system and successfully installed the Permanent Magnet 399 Series Motor. New HP capability allowed to upsize the ESP which resulted in increased production 4 times in oil, 8 times in gas and over 2 times in total fluid to ~1,850BFPD, with a drawdown of ~60psi/day for the first 2 weeks taking the pump intake pressure down to ~1100psi after just 20 days of startup. These scenarios demand significantly higher HP levels that are not achievable with conventional induction motors, further highlighting the performance advantages and broader applicability of Permanent Magnet Motor technology in modern high-demand ESP environments.

INTRODUCTION

ESPs remain one of the most effective artificial lift methods for achieving high production rates in unconventional reservoirs. As well's configurations evolve toward longer laterals and tighter casing programs, ESP systems are increasingly required to deliver higher horsepower within restricted outer diameters. In these scenarios, conventional induction motor's technology often reaches its practical limits, leaving less options in pump sizes, and compromising the system reliability, and operating efficiency.

Permanent Magnet Motor technology offers a step change in power density and efficiency, allowing higher horsepower delivery without increasing motor diameter or resorting to tandem configurations. This paper documents field-proven applications that depict how PMM technology can successfully overcome ESP constraints in tight casing environment while significantly improving the well performance.

LIMITATIONS OF INDUCTION MOTOR ESPS IN TIGHT CASING WELLS

Horsepower and System Length Constraints

In 5-in. casing applications, the maximum deployable horsepower using induction motors is frequently limited by motor OD restrictions, heat dissipation capability and the need for tandem motors to achieve target HP. Tandem configurations increase overall ESP length, complicating installation, compromising reliability and chemical injection strategies.

Reliability and Risk Considerations

Operational risks associated with tandem induction motors include:

- Increased mechanical connections
- Elevated torsional stress
- Higher probability of fishing operations in case of failure

These risks are amplified in unconventional wells where intervention costs are high.

PERMANENT MAGNET MOTOR TECHNOLOGY

Permanent Magnet Motors utilize high-energy magnets in the rotor, eliminating rotor current and associated losses. Compared to induction motors, PMMs provide:

- Higher HP per unit length

- Improved electrical efficiency
- Lower operating temperatures
- Higher torque capability at comparable OD

These characteristics enable ESP system designs that were previously impractical in tight casing environments.

CASES OF STUDY

Permian Basin unconventional reservoirs are challenging environments for ESP system performance. In order to improve ESP system reliability and enhance production, Permanent Magnet Motors provide the required HP in tight casing application to maximize production and returns. The following case studies confirm Permanent Magnet Motors can achieve the newest targets of longer laterals.

Completion Data

Table 1—Well Configuration Summary

	Case 1	Case 2	Case 3
Production Casing	5.5 in, 17 lb/ft	5.5 in, 20 lb/ft	5.0 in, 18 lb/ft

Original ESP System Scenarios

Case 1. The initial ESP system design consisted of a 400 Series pump driven by a 420 Series induction motor with a nameplate rating of 416 HP. Two potential intake setting depths were evaluated, approximately 5,100 ft and 7,700 ft, to determine the most suitable operating point for achieving the target production rate. However, under both scenarios, the induction motor demonstrated insufficient horsepower capacity to sustain the required operating conditions. As summarized in Table 2, the system was projected to operate beyond the motor’s allowable load limits while attempting to deliver approximately 7,400 BPD.

Table 2—Insufficient HP for ESP System Case 1

Parameter	Initial ESP System Designed
Motor Type	400 Series IM
Operational Rated / Nameplate HP	430 / 416
Motor Load	Exceed Limit
Total Fluid Rate	~7,400 BPD

Parameter	Initial ESP System Designed
Pump Intake Pressure	~2,900 psi (Not feasible by PI)
Drawdown Capability	Limited
Intake depth	5,111 ft (Limited)

At the proposed intake depth of 5,111 ft, the design predicted a pump intake pressure (PIP) of approximately 2,900 psi, which was not feasible based on the well's productivity index (PI). Subsequent updates to the well test data further indicated that, at the target flow rate, the expected PIP would be closer to ~1,700 psi. This discrepancy confirmed that the original design was fundamentally horsepower-limited and unable to meet the required drawdown conditions. As a result, the induction motor configuration was deemed unfeasible for this application, necessitating the evaluation of alternative motor technologies. Permanent Magnet Motor (PMM) technology was identified as a viable solution to overcome these limitations.

Case 2. Following hydraulic fracturing of the well, completed with 5.5-in., 20 lb/ft production casing, the operator anticipated achieving the target production rate at a significantly deeper ESP intake setting, estimated at approximately 9,000 ft. The expected operating conditions are summarized in Table 3. To enable rapid recovery of post-fracture production volumes, the ESP system would be required to operate at elevated motor loads while delivering substantial drawdown, with a target pump intake pressure of approximately 1,000 psi and an overall drawdown requirement of ~3,000 psi.

Table 3—Baseline Performance Case 2

Parameter	Stimulation
Motor Type	To be determined
Total Rated / Nameplate HP	To be determined
Motor Load	To be determined
Target Fluid Rate	4,500 BFPD
Target Pump Intake Pressure	~1,000 psi
Drawdown Capability	~3000 psi
Target Intake depth	~9,000 ft

Under these conditions, conventional induction motor technology presents significant limitations, particularly in tight casing environments where outer diameter restrictions constrain available horsepower. Additionally, this application required sufficient clearance within the completion to allow for the installation of a chemical treatment (CT) line below the downhole sensor, further restricting equipment selection and configuration. These combined constraints—high horsepower demand, deep setting depth, and completion clearance requirements—rendered the use of an induction motor impractical. Permanent Magnet Motor technology was therefore selected as the optimal solution, as it provides the necessary power density and reduced system footprint to meet both operational and mechanical constraints.

Case 3. The original ESP system installed in this well consisted of a slimline pump driven by tandem 375 Series induction motors with a combined nameplate rating of 108 HP. At the time of evaluation, the system was already in operation, producing approximately 724 BPD, as detailed in Table 4. Despite operating at high motor loads approaching the upper limit of the equipment, the system was unable to achieve sufficient drawdown, with pump intake pressure remaining above 2,000 psi.

Table 4—Baseline ESP Performance Case 3

Parameter	Original System
Motor Type	375 Series IM
Total Rated / Nameplate HP	98 / 108
Motor Load	High / Near Limit
Total Fluid Rate	724 BPD
Pump Intake Pressure	>2,000 psi
Drawdown Capability	Limited
Intake depth	5,700 ft

This performance indicated a clear horsepower-limited condition, where the available motor power was insufficient to effectively lift the produced fluids and reduce bottomhole pressure. The use of tandem induction motors increased system complexity while still failing to provide the required performance. By transitioning to a Permanent Magnet Motor configuration, the system was able to deliver higher available horsepower within the same geometric constraints. This enabled the upsize of the slimline pump, resulting in a significant improvement in well performance, including increased drawdown capability and more than doubling of production rates.

System Redesign Using Permanent Magnet Motor

The redesigned ESP systems replaced the induction motors with a single Reynolds PMM 399 Series Motor, enabling higher available horsepower for running larger capacity pumps without exceeding casing constraints (See table 5).

Table 5—Motor Technology Comparison

Parameter	Induction Motor	Permanent Magnet Motor
Power Density	Low–Moderate	High
Efficiency	Moderate	High

Parameter	Induction Motor	Permanent Magnet Motor
Tandem Requirement	Yes	No
System Length	Longer	Shorter
Thermal Losses	Higher	Lower
Operational Risk	Elevated	Reduced

Equipment Selection and Performance Analysis

Case 1. Designing the ESP system for this case scenario, included replacing the 420 Series induction motor 416 HP with a Reynolds PMM 399 Series Motor 510 HP, having higher available horsepower and enabling us to use the operator's owned pump, exceeding production expectations despite the casing constraints.

The increased horsepower capability allowed us to take advantage of the 400 series ESP pump owned by the operator to this application, which can lift 6000 BFPD at BEP. With the PMM available HP, we exceeded the expected production of 7,400 BFPD by maximizing the operating point at the high-end fringe of the ROR. The original IM offer never passed the designing stage due to insufficient HP even at max load, what could have compromised the reliability of the system. Two intake set depths options were proposed by the operator, ~5,100 ft and ~7700 ft, maximizing production under the more stringent scenario. Table 6 summarizes the advantage of PMM over IM in tight casing application for Case -1.

Table 6—Motor Available HP Comparison Case 1

Parameter	IM-Driven ESP	PMM-Driven ESP
Motor Size	420 Series	399 Series
HP required. Depths 5111ft/ 7742 ft	483/491	483/491
HP available	416 - Insufficient	510
Operating Load	Over 100%	97%/ 98%
Submergence	Not applicable	4044 ft/ 6676 ft

Case 2. The challenge for IM in this scenario goes beyond the flow rate, but the capability to deliver the required HP in a deep setting and a tight casing application. 510HP PMM was selected due to its power density in smaller OD, that provides the HP required and clearance to set CT line below the sensor. The increased horsepower capability allowed the ESP pump to operate exceeding the expected production and match the operating point closer to the pump's Best Efficiency Point (BEP), even at the early stage of production after frac stimulation, see summary on table 7. Table 8 below summarizes the motor selection.

Table 7—Pump Performance Case 2

Pump Size	400 Series
Pump Capacity	5,800 BPD at BEP
Target Rate/Actual Rate	~4,500 BPD/ +5000 BPD
Intake depth (ft)	9,000
PIP (psi)	~1,000
Relative BEP Position	Near BEP
Hydraulic Efficiency	Good
Available Head	Good

Table 8—Motor Selection Case 2

Parameter	PMM-Driven ESP
Motor Size	399 Series
Target Rate (BPD)	4,500
HP required. Depths 9,000 ft	494
HP available	510
Operating Load	90%
Submergence	~2,200 ft

Case 3. For this well, completed with a 5.0-in., 18 lb/ft production casing, the primary limitation to achieving maximum production was the available horsepower, even when using a slimline induction motor configuration. The original ESP system, equipped with a tandem 375 Series induction motor with a nameplate rating of 108 HP, was constrained by both the motor's power output and the geometric limitations imposed by the casing size. Operating under these conditions, the ESP pump was unable to reach an optimal operating point, resulting in suboptimal fluid rates, limited drawdown, and reduced hydraulic efficiency.

Table 9—Pump Performance Comparison Case 3

Parameter	Original ESP	PMM-Driven ESP
Pump Size	Slimline	Slimline Upsized
Motor HP Nameplate	108	200
Operating Rate	~720 BPD	~1850 BPD
Relative BEP Position	Far Right of BEP	Near BEP
Hydraulic Efficiency	Low	Improved
Available Head	Limited	Increased

The implementation of a Permanent Magnet Motor (PMM) with a significantly higher available horsepower—200 HP in this scenario—enabled a comprehensive system redesign. This increase in available power allowed the operator to upsize the existing slimline pump, thereby increasing the pump capacity and shifting the operating point closer to the pump's Best Efficiency Point (BEP). As summarized in Table 9, this modification resulted in a near tripling of the total fluid rate from approximately 720 BPD to 1,850 BPD. Additionally, the relative position on the pump curve moved from the far right of the BEP, where efficiency is low, to a position near the BEP, substantially improving hydraulic efficiency and available head.

The adoption of PMM technology not only provided sufficient horsepower to overcome the previous operational limitations but also allowed the operator to leverage the slimline pumps already available in their inventory. This solution minimized intervention and capital expenditure while maximizing production performance, demonstrating the clear advantage of high-power-density PMM-driven ESP systems in tight casing applications.

Pump Curve Discussion

Case 1. Figure 1 illustrates the pump performance curves for the Case 1 configuration. The operator-owned 400 Series pump was initially operating at the high-end fringe of the Recommended Operating Range (ROR), a region where hydraulic efficiency is reduced and the risk of motor overload increases. With the increased available horsepower provided by the Permanent Magnet Motor (PMM), it was possible to modulate the operating point gradually, lowering both the productivity index (PI) and the surface flow rate over time. This gradual adjustment allowed the pump to move toward the Best Efficiency Point (BEP), optimizing energy utilization while maintaining sustainable drawdown rates. As a result, the system demonstrated:

- Prolonged efficient operation across varying production conditions
- Optimized motor load, reducing thermal and mechanical stress
- Sustained drawdown without compromising pump or motor integrity
- Reliable, low-intervention operation over extended production periods

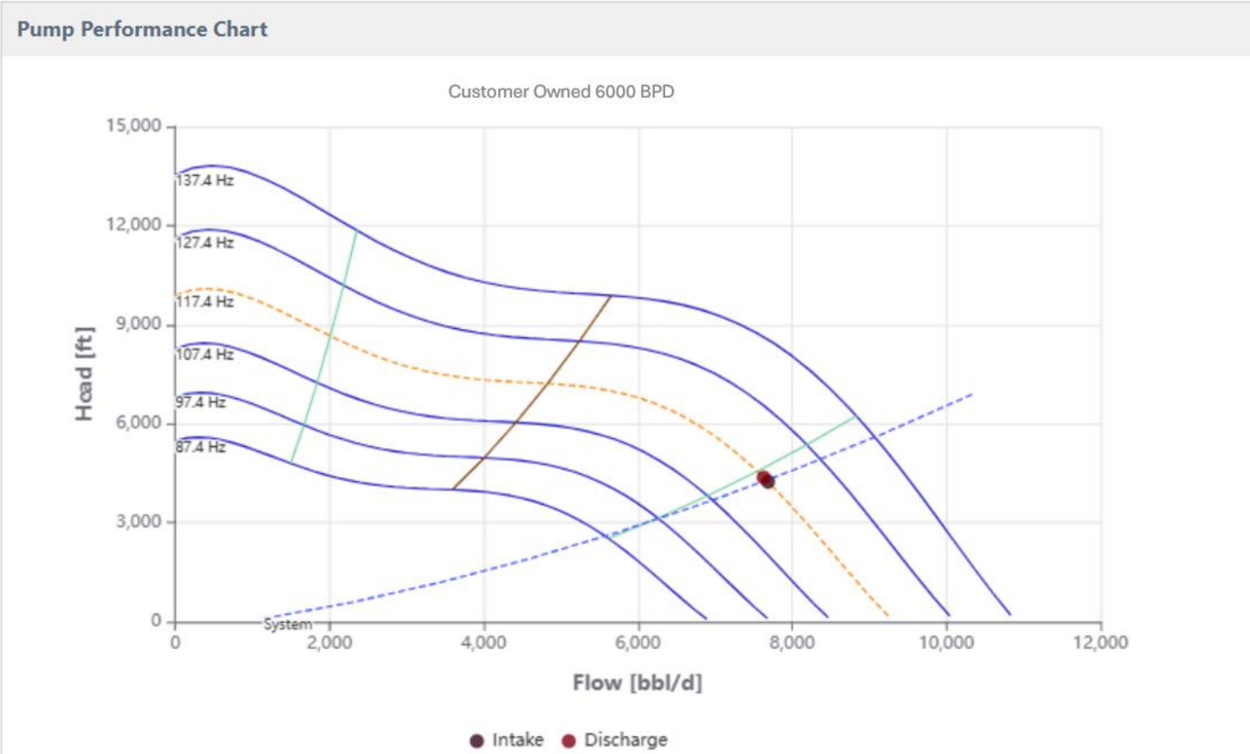

Figure 1. Pump Curve with PPM (Surface flow rate 7,400 BFPD, Intake 7,740 ft)

Case 2. Figure 2 depicts the pump operating point for Case 2. In this scenario, the ESP system was configured for a deeper intake depth (approximately 9,000 ft) within a restricted 5.5-in. casing. The selection of a PMM with higher power density enabled the pump to operate near its Best Efficiency Point (BEP) from the outset, significantly improving hydraulic efficiency compared to an induction motor configuration. Additionally, the design allowed sufficient clearance to install a chemical treatment (CT) line below the downhole sensor. Continuous chemical treatment helped reduce scale, paraffin deposition, and gas interference in the pump, further enhancing efficiency and sustaining optimal pump performance over time. By maintaining the operating point close to the BEP and combining it with active chemical treatment, the system maximized production potential while minimizing electrical and mechanical losses. Operational benefits observed included:

- Efficient hydraulic performance over the production cycle
- Optimized motor load, ensuring safe thermal limits
- Sustained drawdown, effectively lowering the bottomhole pressure
- Improved pump efficiency and reliability due to chemical treatment
- Consistent, low-intervention operation in a deep, tight-casing environment

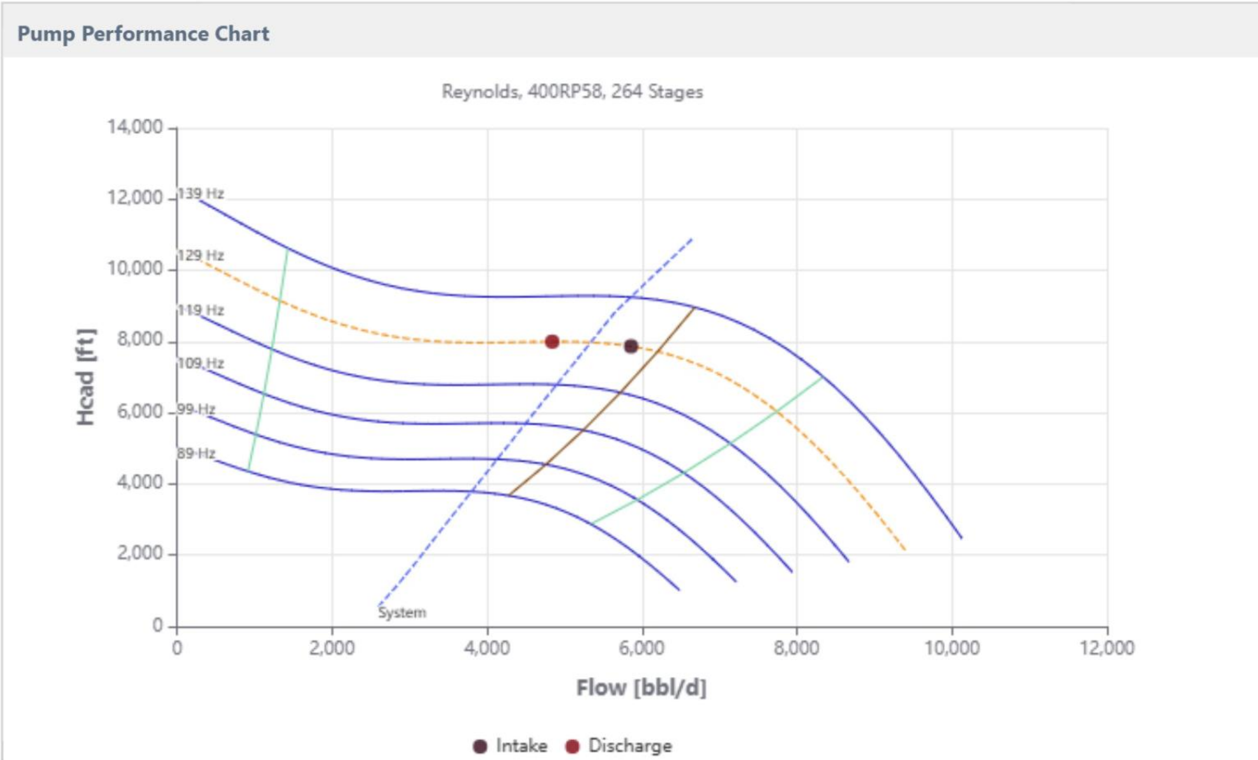

Figure 2. Pump Curve with PPM (Surface flow rate 4,500 BFPD, Intake 9,000 ft)

Case 3. Figure 3 presents the pump performance curves for Case 3. The original slimline ESP, powered by a tandem induction motor, was unable to provide sufficient drawdown due to horsepower limitations. Upgrading to a PMM allowed the use of an upsized pump, shifting the operating point firmly within the Recommended Operating Range. This adjustment resulted in more than a twofold increase in production rates, improved hydraulic efficiency, and sustained drawdown without exceeding motor load limits. The system achieved:

- Significantly improved production rates with controlled efficiency
- Optimized motor performance with reduced operational risk
- Sustained drawdown over the production interval
- Reliable, low-intervention operation in a constrained casing environment

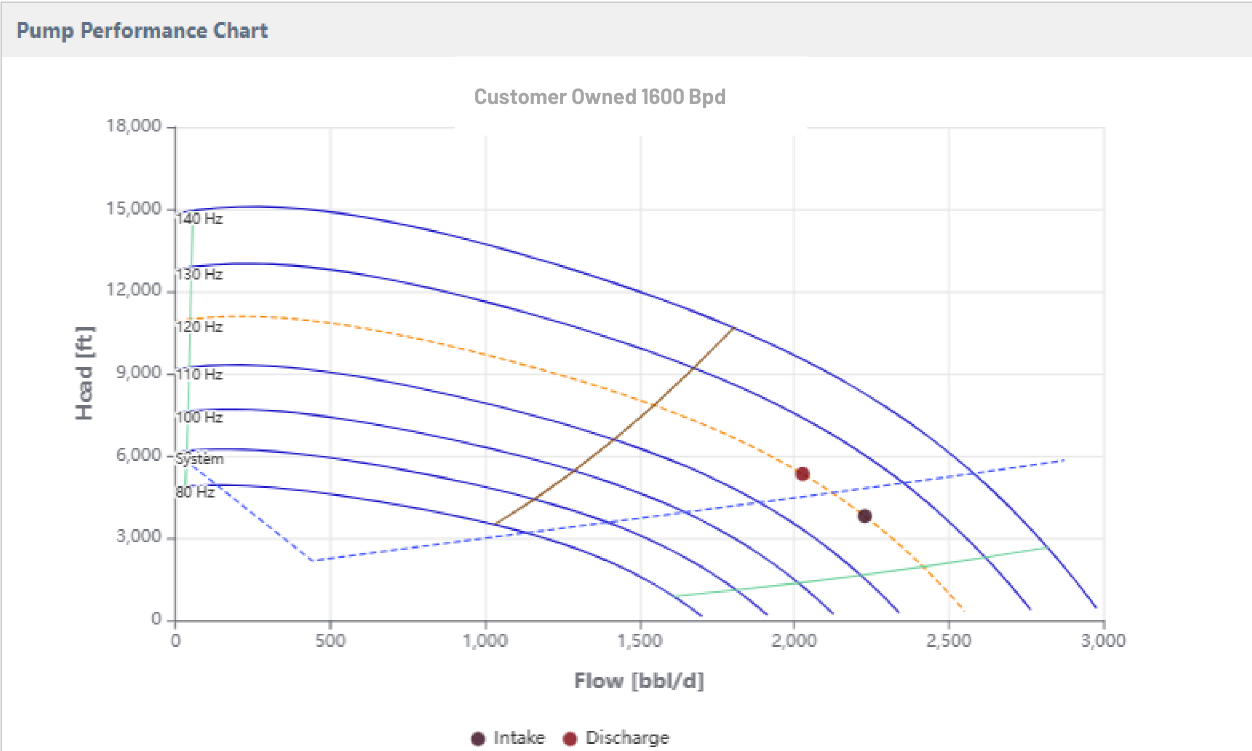

Figure 3. Pump Curve with PPM (Surface flow rate 1,630 BFPD, Intake 6,026 ft)

PERFORMANCE AND PRODUCTION RESULTS

Available HP Analysis. Case 1

Figures 4 and 5 illustrate the significant advantage of Permanent Magnet Motors (PMM) compared to conventional induction motors (IM) in tight casing applications. Figure 4 shows the comparison between the required horsepower to achieve the target production and the available horsepower for each motor type. While the induction motor struggles to meet the required HP at both proposed intake depths, the PMM consistently provides sufficient power margin, ensuring that the pump can operate at or near the desired flow rate without overloading the motor. Figure 5 complements this analysis by showing the operational motor load as a function of intake depth for both motor types. The graph clearly demonstrates that the IM operates at or above its maximum rated load in the same conditions, leaving minimal safety margin and increasing the risk of thermal or mechanical failure. In contrast, the PMM maintains a motor load well below its maximum capacity across all depths, providing a larger operational envelope, reducing mechanical and thermal stress, and allowing sustained high-flow operation.

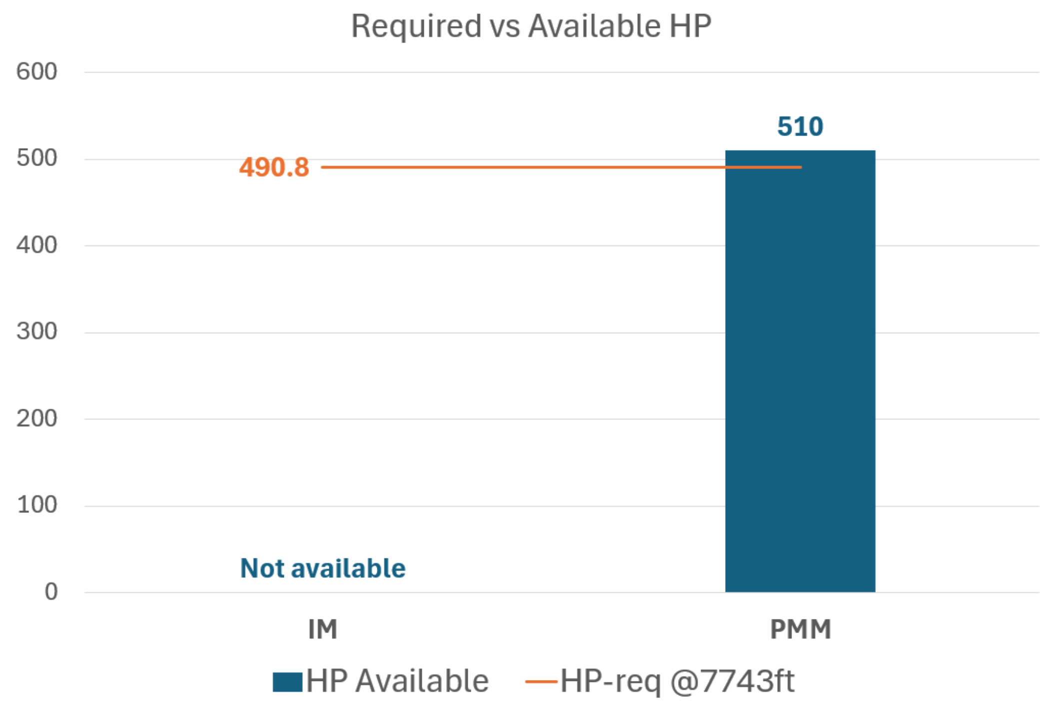

Figure 4. Required vs Available HP IM/PMM

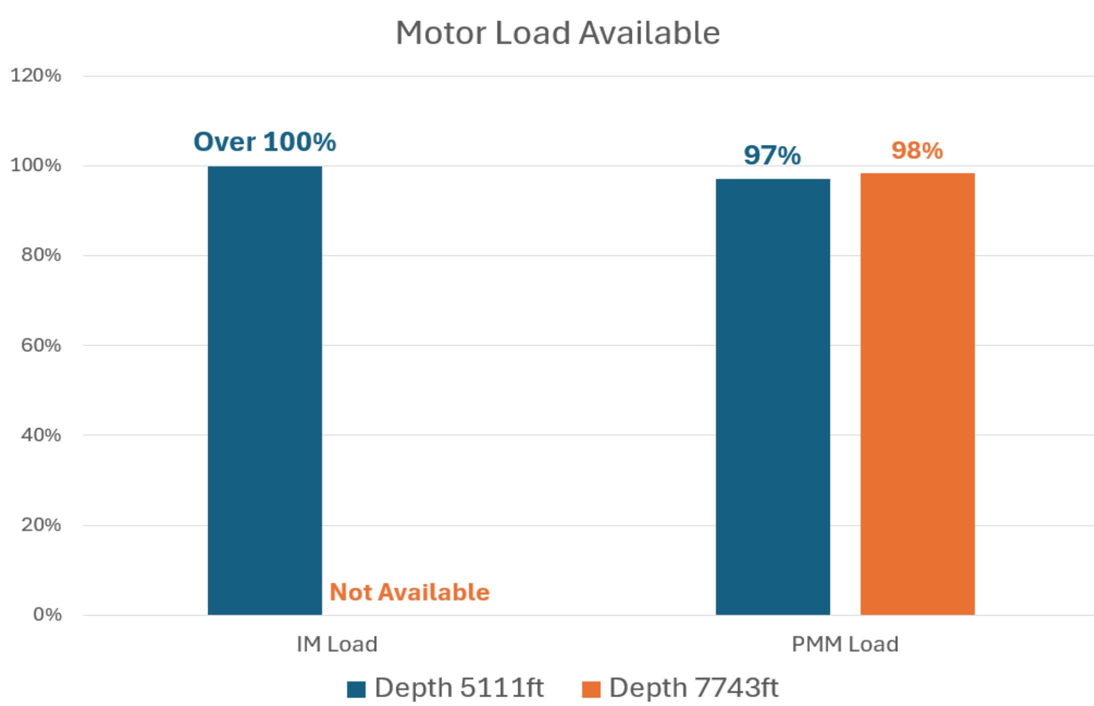

Figure 5. Motor Load Available at different depths. IM/PMM Production Exceeds. Case 1

Figure 6 depicts how after the PMM-driven ESP system was installed, it exceeded the production target at the early 20-days after starting up, gradually lowering the PIP over time along with the PI, shifting the pump operating point toward its BEP and sustaining drawdown without overloading the motor. Production results are summarized in table 10 included below.

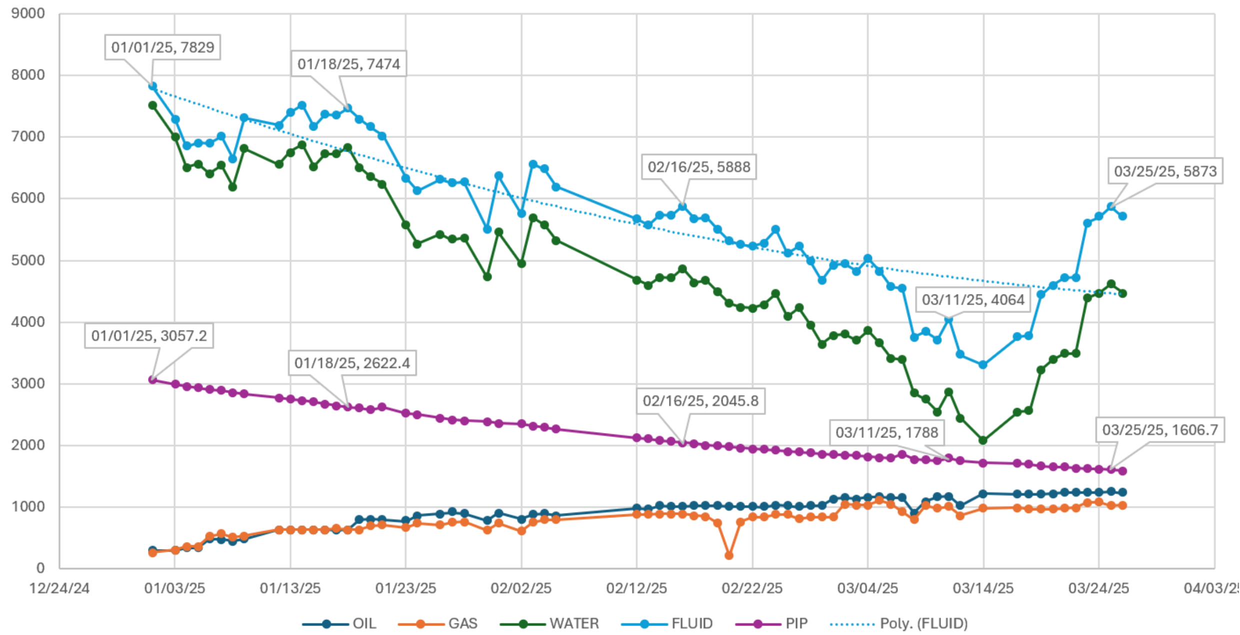

Figure 6. 90-days Production and PIP Trends more stringent scenario with PMM

Table 10—Production Results. Case - 1

Parameter	Design condition – Baseline	After PMM Installation
Oil Rate	370 BOPD	~2.1× exceed
Gas Rate	370 MSCFD	~1.7× exceed
Total Fluids	7,400 BPD	~1.1x exceed

Production Exceeds. Case 2

Figure 7 depicts how oil production was maximized and sustain over time; despite the increase in gas production (which started low), and the high total liquid rate the early 20-days after starting up, the PMM-driven ESP system displayed exceeded production trends and gradual lowering of PIP over time, sustaining drawdown without overloading the motor. Production results are summarized in table 11 included below.

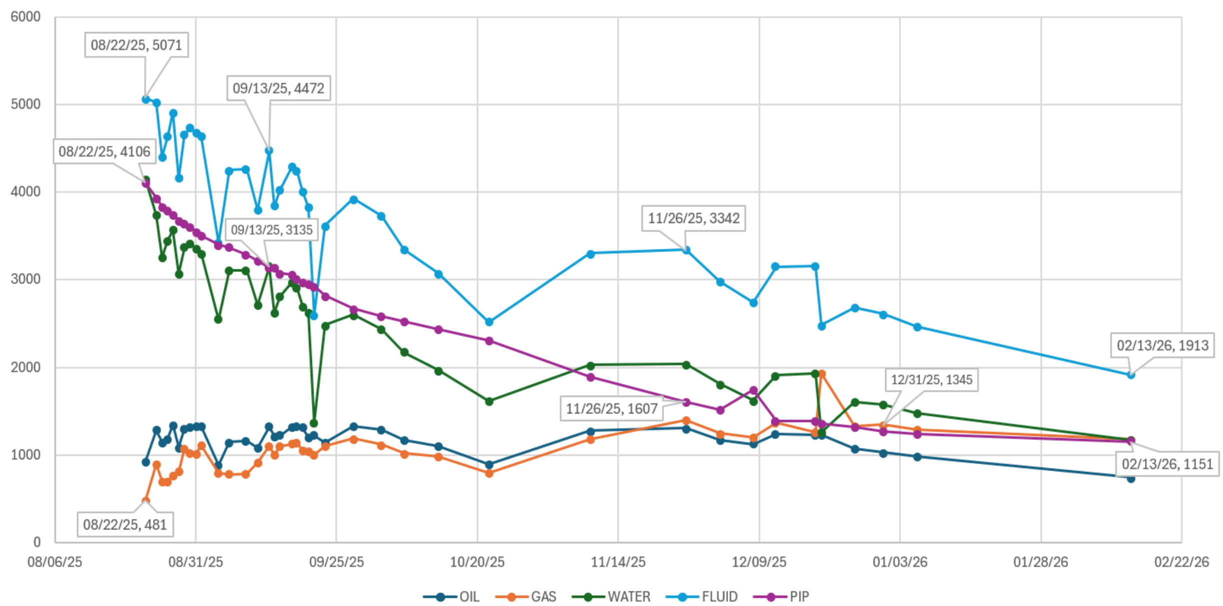

Figure 7. 90-days Production and PIP Trends more stringent scenario with PMM

Table 11—Production Results. Case - 2

Parameter	Before - Design	After PMM Installation
Oil Rate	Baseline	~2.1× exceeds
Gas Rate	Baseline	~0.2× reduction
Total Fluids	Baseline	~1.1x exceeds

Production Increase. Case 3

Figure 8 illustrates the production trends over a 60-day period following the transition from a conventional induction motor (IM) to a Permanent Magnet Motor (PMM)-driven ESP system. The increased available horsepower allowed the operator to upsize the slimline pump, resulting in a significant enhancement in overall well performance. On average, oil production increased by approximately 4×, while gas production increased by 8×. The oil cut improved by ~1.6× to approximately 11%, and the total liquid production rate increased by 2.6×, surpassing the operator's initial expectations. These improvements demonstrate that optimizing motor power availability through PMM technology not only supports pump upsizing but also ensures operation closer to the pump's Best Efficiency Point (BEP), resulting in:

- Sustained, higher production rates across oil, gas, and total fluids
- Improved oil cut and hydrocarbon recovery efficiency
- Optimized motor load with reduced risk of overloading

- Reliable, low-intervention operation over extended production periods

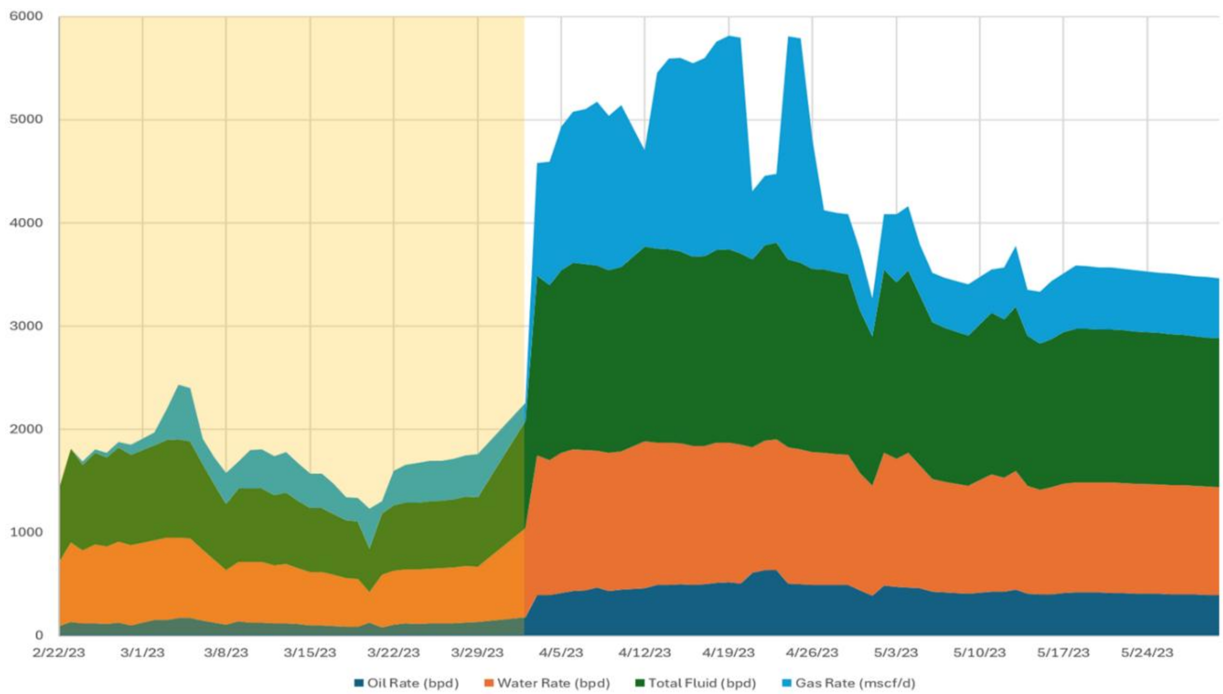

Figure 8. 60-days Production Comparison Slimline Pumps IM vs PMM

Table 12—Production Results. Case - 3

Parameter	Before - IM	After PMM Installation
Oil Rate	Baseline	~4× increase
Gas Rate	Baseline	~8× increase
Total Fluids	Baseline	~2.6x increase

Drawdown Performance

Case 1. The PMM system achieved:

- Initial drawdown rate of ~22 psi/day
- PIP reduction to ~2600 psi within 20 days
- Stabilized PIP near ~1600 psi after ~200 days
-

The system now operates at a stable motor load with improved reliability and consistent production.

Case 2. The PMM system achieved:

- Initial drawdown rate of ~45 psi/day
- PIP reduction to ~3200 psi within 20 days
- Stabilized PIP near ~1150 psi after ~180 days

The system operated at a stable motor load with improved reliability and consistent production.

Case 3. The PMM system achieved:

- Initial drawdown rate of ~60 psi/day
- PIP reduction to ~1600 psi within 20 days
- Stabilized PIP near ~850 psi after ~80 days

The system operated at a stable motor load with improved reliability and consistent production.

CONCLUSIONS

The field cases presented in this study highlight the transformative impact of Permanent Magnet Motor (PMM) technology on Electric Submersible Pump (ESP) performance in tight-casing, high-demand unconventional wells. The key conclusions are as follows:

- Horsepower, not inflow, is often the limiting factor in tight-casing ESP applications.
- Permanent Magnet Motors deliver a step-change in power density and operational efficiency.
- Pump upsizing and improved drawdown are achievable with PMM-driven ESPs.
- Elimination of tandem motors reduces system complexity and operational risk.
- Chemical treatment integration enhances pump efficiency and reliability.
- PMM technology expands the practical applicability of ESPs in modern unconventional wells.

Overall, the results from the three case studies demonstrate that integrating PMM technology into ESP systems represents a significant advancement in artificial lift design, improving production efficiency, operational reliability, and overall field economics in unconventional tight-casing applications.

REFERENCES

- Society of Petroleum Engineers. (2017). “Application of Permanent Magnet Motors in Electric Submersible Pump Systems.” SPE-187213-MS, presented at the SPE Artificial Lift Conference, The Woodlands, Texas.
- Society of Petroleum Engineers. (2016). “Optimization of ESP Systems in Unconventional Horizontal Wells.” SPE-181123-MS, presented at the SPE Annual Technical Conference and Exhibition (ATCE).

- Institute of Electrical and Electronics Engineers. (2018). "Performance Comparison of Permanent Magnet and Induction Motors in Industrial Applications." IEEE Transactions on Industry Applications, Vol. 54, No. 3.