DEPLOYMENT OF PMMS FOR ESP WELLS IN THE PERMIAN BASIN: REDUCING POWER CONSUMPTION AND CARBON FOOTPRINT – LESSONS LEARNED

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ABSTRACT

Environmental performance plays a crucial role in energy production today and providing effective solutions to reduce carbon footprint of oil field operations is a top priority. Extensive research has been conducted to develop energy efficient technologies aimed at reducing power consumption, particularly in the artificial lift segment. Permanent Magnet Motors (PMM) have gained increasing attention from operators in the Permian, leading to the installation of hundreds of PMMs. This paper presents an evaluation of PMM performance in the field, evaluates a case study, and highlights lessons learned.

The approach involved evaluating over 170 PMMs installed in the Permian Basin using statistical analysis and operation performance. A holistic field analysis of the average lifting cost per barrel for PMMs versus Induction Motors (IMs) was considered and the average carbon footprint reduction was calculated.

A complete comparison between PMM and conventional induction motors was carried out to assess application selection including single vs tandem motors, energy saving, lifting cost, and environmental impact in gassy wells that experienced frequent shutdowns due to high operating temperatures. In most of the cases, wells were equipped with an induction motor, which was later replaced by a PMM. Therefore, a like to like comparison will show more reliable and precise data. Well models' software's were created to analyze power consumption, operating temperature, and motor efficiency. Additionally, CAPEX, OPEX, were estimated and reported.

The results of the study reveal that PMMs offer significant improvements in both efficiency and sustainability compared to IMs. A pilot project demonstrated that switching to PMM reduced power consumption by 20-32%, saving greater than $10,000 annually in electrical cost per well. Additionally, average uptime was 97.5% which contributing to the production of thousands more barrels of oil annually.

PMM also achieved a higher efficiency (92% compared to 77% for IM) and generated less heat (operating temperatures of 174°F compared to 205°F for IM) than the IM. Furthermore, the carbon footprint was reduced by 23%, equating to 63 tons of CO_2 per well per year, and 10k tons annually for 170 wells.

Operators across the Permian are actively searching for new technologies to reduce their carbon footprint. The results of this effort suggest that PMMs offer both economic and environmental benefits for ESP operations, particularly during the mid-to-late stages of well life when gas-liquid ratios rise.

INTRODUCTION

Concerns over global warming and environmental sustainability have increasingly driven the search for innovative solutions to reduce power consumption and minimize ecological impact. In this context, advancements in industrial technologies have emerged as key contributors to energy efficiency. One such innovation is the incorporation of Permanent Magnet Motors (PMM) into artificial lift systems (Johnson, 2021). PMM technology is proving effective at lowering operational power costs and reducing emissions—a combination that is attracting significant interest from major operators within the industry (Smith ET AL, 2022). This shift not only enhances economic performance but also aligns with the broader push toward sustainable practices in the energy sector.

Aiming to reduce the company's energy intensity index, a pilot project was conducted to deploy PMMs for reducing the power consumption of the field's ESPs. The results were evaluated by Al Hashar et al. (2024), who reported that for high-flow-rate wells (4,000–9,000 BPD), replacing IM with PMM reduced power consumption by 14%. Meanwhile, a 7% reduction in power consumption was achieved for low-producing wells. Likewise, Chaudhari et al (2022) analyzed the results of a pilot project conducted in a field utilizing polymer flooding. Polymer deposition on the IM leads to increased heat generation, causing operating temperatures to rise rapidly to 180°C. This temperature-induced deposition necessitates frequent back-flush interventions to sustain target production and may results in motor failures. In contrast, PMMs operate at temperatures 15–20% lower due to reduced frictional, mechanical, and hydraulic losses, achieving efficiencies of up to 93%. The implementation of PMM systems also minimized the need for back-flushing operations, thereby reducing CAPEX and lowering intervention costs.

This paper outlines the key advantages of PMMs. It involved analyzing the performance of over 249 PMMs installed in the Permian Basin using statistical methods. Additionally, a comparative assessment was conducted between a PMM and a conventional induction motor to quantify energy savings and evaluate the environmental impact in a gassy well prone to frequent shutdowns due to elevated operating temperatures

PERMANENT MAGNET MOTOR BENEFITS

A PMM is an AC motor that uses magnets embedded into or attached to the surface of the rotor. These magnets generate a constant motor flux, eliminating the need for the stator field to induce flux in the rotor, as required in an induction motor. This results in a more efficient motor with a better power factor and higher horsepower per unit length, making PMMs significantly shorter than conventional induction motors.

Figure 1 illustrates a comparison between 300 and 400 series induction motors and PMMs. For slimline motors, a PMM can generate up to 200 HP with a length of 27 feet. In contrast, achieving the same horsepower with an induction motor requires a tandem configuration, extending the total length to 50 feet. Similarly, in the 400 series, a single PMM can generate 425+ HP, whereas a tandem induction motor is needed to reach the same output. A shorter ESP string can be particularly beneficial when the pump setting depth window is limited, as it allows for a more compact motor rather than fewer pumps, helping to avoid zones with high dogleg severity (DLS) and meet production objectives.

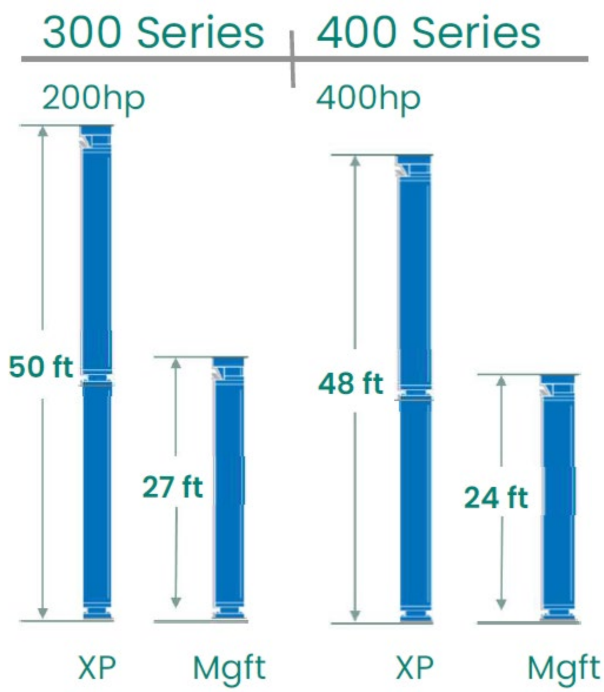

Figure 1. Length comparison between IMs and PMMs.

Some of the key advantages of PMMs as discussed in the literature include:

- Eliminates induction losses:
    - As discussed, the stator does not have to make the rotors become an electromagnet. Through the use of the permanent magnets, the losses associated with inducing the rotor to become a magnet are eliminated.
- Decreases system power consumption by up to 20%:
    - The following example shows the impact of a typical system efficiency improvement for a 400 series system. For purposes of the comparison, 300 HP of hydraulic work by the pump was selected as this is representative of many Permian wells.
    - The system efficiency is improved by 19.7% as the total input power to the motor decreases from 484 HP to 404 HP. This assumes both the IM and PMM are operating at peak performance. The efficiency and power factor improvements of the PMM not only help the motor, but they also cause the cable, transformer, and drive to also have lower losses. This is a benefit of the lower current and lower motor power required if using the same voltage winding as the comparable IM (see Figure 2).

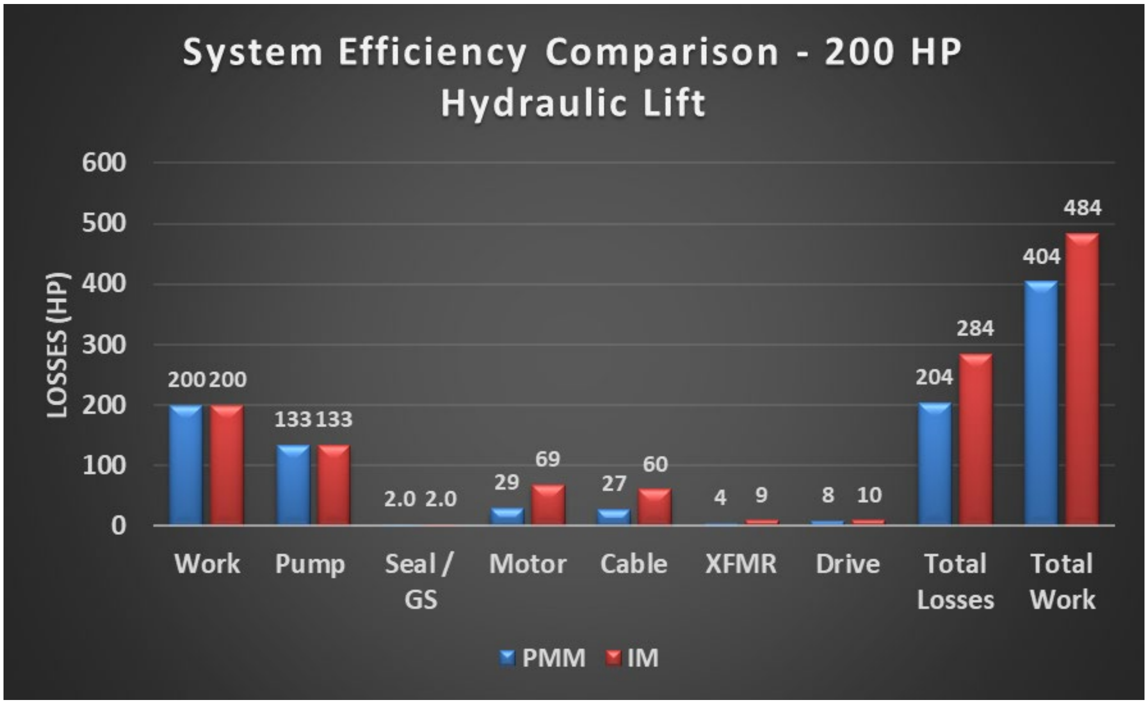

Figure 2. System efficiency comparison.

- Reduces motor power loss by up to 67%:
  - In the 300 series motors, it is common to see efficiency improvements from 76% to 92%. When evaluating the losses, this is a 67% reduction (8% vs 24% losses). In some cases, this may actually be more than a 67% reduction of power loss due to the PMM having a very flat efficiency curve compared to the IM. This is specifically comparing the best operating points.
- Lowers idle amps, enabling better control at lower loads:
  - The idle (no load) amps of the PMMs are much lower than conventional IMs. Conventional IMs have idle amp values around 35-50% of the nameplate amp value. In contrast, PMMs can have idle amps of 5% or less than the nameplate amp value. This can aid with dealing with high gas situations. With a conventional IM, the high idle amps will cause the motor to heat up unless it is slowed down significantly. In the case of the PMM, it does not have to necessarily be slowed down for it to stay cool. This enables more control options to deal with high gas situations without changing the step-up transformer tabs.
- Offers higher power density:
  - Achieving higher horsepower with the same motor length enables setting the ESP closer to the producing zone in deviated wellbores.
  - Lowers the weight requirements for unconventional type deployments such as wireline deployed ESPs.
  - Eliminates the need for most tandem motor connections which in turn increases the system reliability by removing components from the

system and decreasing the amount of service required for the equipment.
  - The following is a representation to illustrate the typical differences in the motor lengths when comparing the PMM to the equivalent IM.

- Keeps power factor and efficiency at optimal levels over entire load range (Figure 3):
  - Having flatter efficiency and power factor curves allow the motor to be applied in wider load applications while still maintaining peak performance.
- Delivers higher power factor:
  - Higher power factor reduces the current required for a motor to operate provided that the same voltage winding is selected.
  - This in turn helps reduce cable power losses by up to 25% and can also reduce the overall power system size requirements.

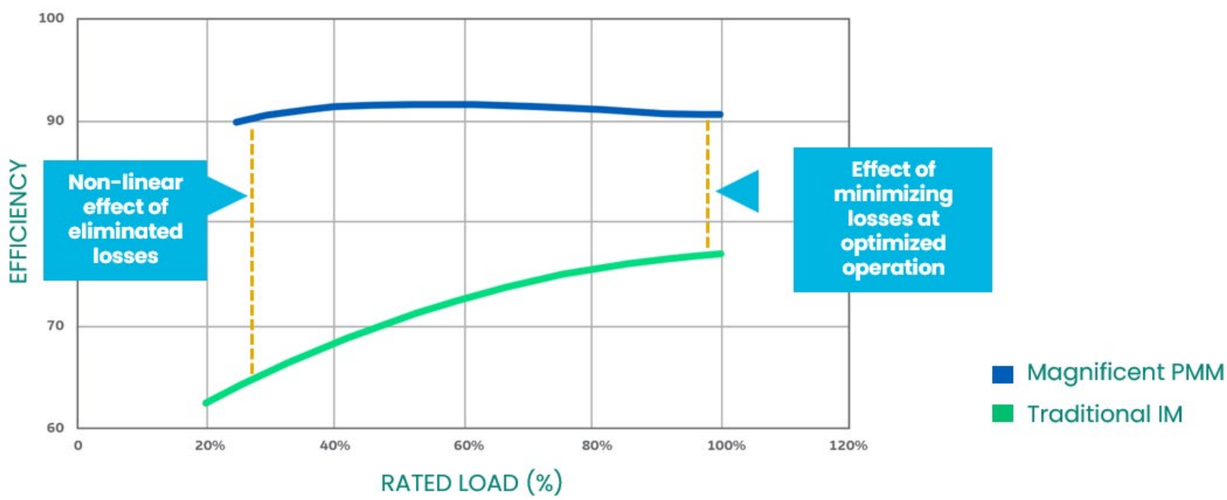

Figure 3. Efficiency comparison.

PMM RELIABILITY

The reliability of the PMM technology is an important consideration of whether or not it is appropriate to utilize the PMM in a given well. To date, there have been more than 170 of the 400 series PMM installations in the Permian. The reliability of these units has been compared to similar system IMs. In addition, the reliability of more than 500 additional 400 series installations in North America and almost 600 installations of 300 series PMMs have also been evaluated.

To date in these approximately 1000 PMM installations, the reliability of the PMMs has proven to be equivalent or better than the comparable IMs. In the case of the 300 series, the PMMs have actually demonstrated significantly improved reliability of 20%+ improvement to run life. While the 400 series has shown only marginal difference to the equivalent IM series, this appears to be due to the already significant reliability of the 400 series IMs (generally above 98% survival at one year depending on the specific well environments). However, there does appear to be some improvement in the 400 series reliability (.5-1% improvement to 1 year survival).

There are several reasons attributed to the run life improvements of using the PMMs. Some of these include:

- Reduction of motor components:
  - With significantly less components in the system, it reduces the overall potential for component failures.
- Elimination of tandem motors:
  - By eliminating the need for tandem motors, this reduces both potential for field service errors as well as eliminates connection points that may allow for well fluid ingress into the motors.
- Better temperature profile:
  - While PMMs often have the same heat rise as the IMs at 100% load, the heat rise at lower loads is typically much less in the PMMs.
  - Due to the lower idle current of the PMM, low load situations such as during a high gas event will have less tendency to overheat the motor.
  - The temperature profile often enables the 400 series PMMs to be utilized in 7 inch casing. This improves the system natural gas separation due to the increased equipment to casing clearance. This in turn lowers the potential for the pump to gas lock / interference which reduces system mechanical stress and heat.

CASE STUDY RESULTS

1st case study

Aiming to lower the operating cost and improve energy efficiency, an operator in the Permian Basin considered installing PMMs. The company was operating 50 wells and was facing high electricity costs and gas-related shutdowns. The high produced GLR limited well drawdown and gas slugging events caused frequent ESP shutdown due to overheating. Most of the wells were slim hole applications, making it challenging for traditional ESP systems with IM to reach the needed 200 horsepower. This required tandem motor connections, connecting two to three motors in each system. Due to the high motor temperatures, often above 250 °F, the operator had to regularly de-rate the motors to avoid temperature related failures. This practice tended to increase instability which resulted in higher power consumption and lower production per well than predicted. The IM was replaced with a PMM to evaluate the technical and economic viability and to address the challenge of operating an ESP in a deep well with high GLR.

The table below summarizes the ESP string in both cases. As it can be seen, the main component that was replaced was the motor from a Tandem slimline IM to a single slimline PMM. The ESP string included a gas handler pump, a multiphase pump, and an extended flow range pump (FlexER series).

Table 1. IM vs PMM ESP String Comparison.

Equipment	Install 1	Install 2
Pump	402 Stages - FlexER	402 Stages - FlexER
Multiphase	69 Stages - MVPER	104 Stages - MVPER
Gas Handler	15 Stages - GH1400	16 Stages – GH2500
Motor	Slim IM -Tandem 230HP	Slim PMM – Single 205HP

The operating trends of the ESP with IM is depicted in Figure 4. The system was operating in Proportional Integral Derivative controller mode (PID). Frequency oscillated from 47 to 60 hz and motor current fluctuated from 20 to 30 amps. The severe fluctuations were mainly attributed to gas interference. Frequent shutdowns due to high motor temperature caused by these fluctuations occurred throughout the run. The numerous system shutdowns resulted in a downtime of 12%. This downtime prevented from an efficient operation and led to suboptimal liquid production.

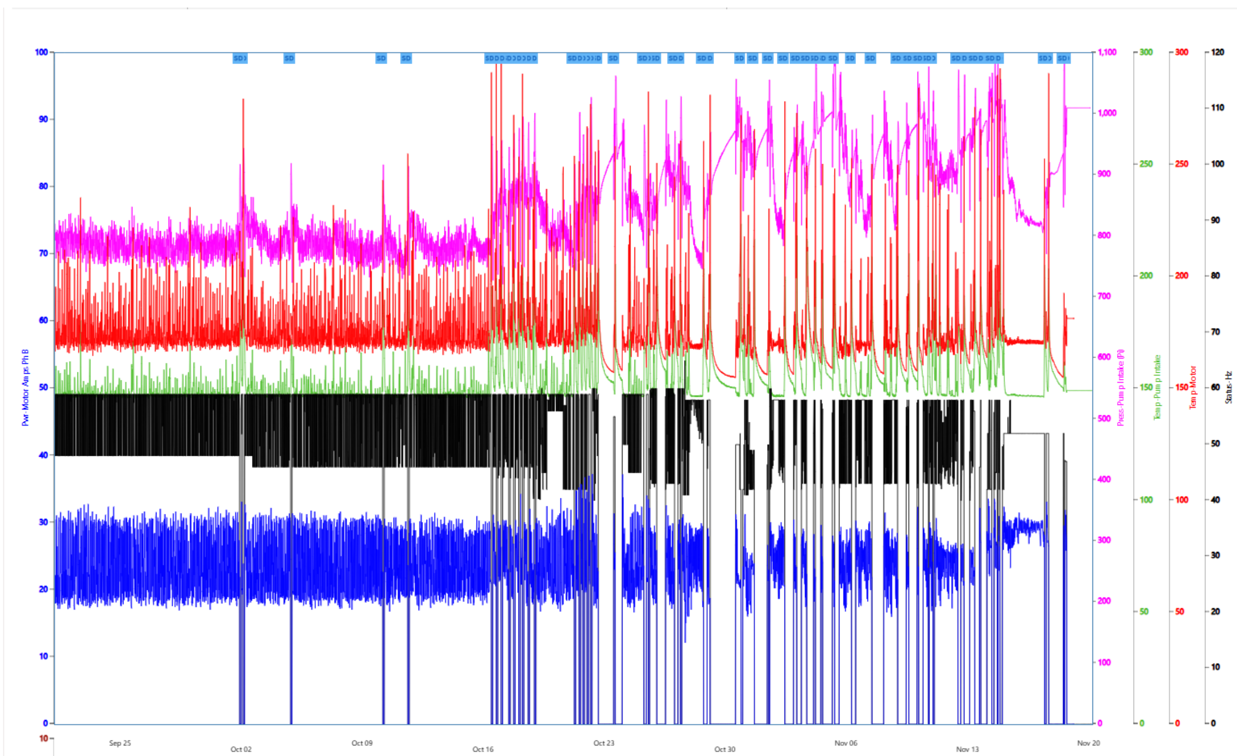

Figure 4. Well’s operating parameters with 375-series IM.

Figure 5 illustrates the ESP system with the PMM installed. Due to the severe gas interference, motor current and frequency oscillated in this case as well. However, system shutdown was reduced considerably due to the better operating temperature profile of the PMM. This allowed the unit to run more efficiently and decreased the intake pressure by approximately 100 psi leading to higher drawdown and thus higher production rates. The total downtime was 2.5%, which also led to increased overall (both liquid and gas) production.

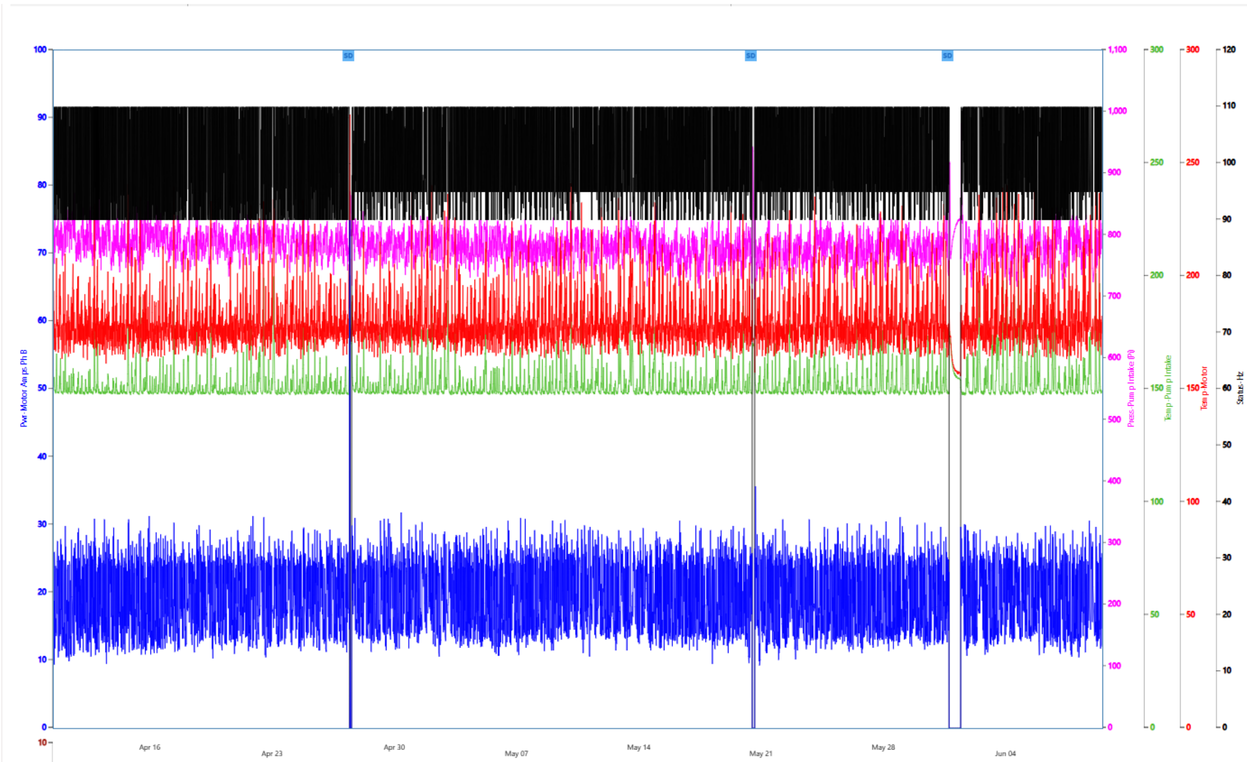

Figure 5. Well’s operating parameters with 375-series PMM.

The chart in Figure 6 presents the power consumption and cost comparison between the system using IM and a PMM. On average, power consumption was reduced by 25–32% with PMM, resulting in cost savings of approximately $1,000 per month.

The table 2 highlights key operating parameters, showing that PMM outperformed IM with a power factor of 96% and a motor efficiency of 91%, compared to only 77% and 74% for IM, respectively. Additionally, the average motor temperature with PMM was 30°F lower, and the power voltage drop was reduced by 23% compared to IM.

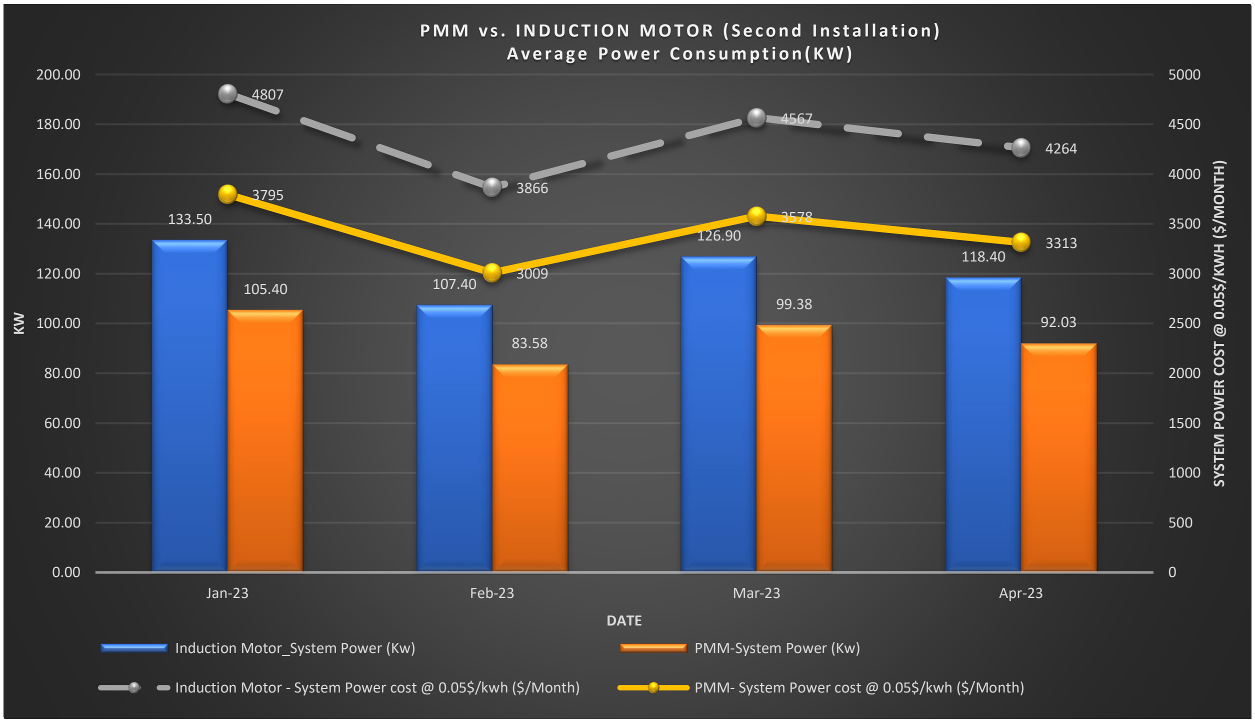

Figure 6. PMM vs. IM average power consumption (KW)

Table 2. Operating parameters comparison.

System	Average Power Factor %	Motor Eff %	Average Motor Temp F	Average Cable Voltage Drop (v/Kft)
PMM	96.5	91.3	174.1	13.5
IM 375 Tandem	77	74	204.7	17.5

With the increasing awareness of global warming, operators in the Permian are looking to reduce their operation's footprint. Power saving offered by PMMs can substantially contribute to that cause.

The average annual savings is roughly 150,000 kWh/year. The carbon intensity of electricity generation in the US is about 0.386 kg CO_2 (EIA).

CO_2 Saving (metric tons/year) = 150,000 x 0.386 /1000 = 57.9 metric tons or 63.8 U.S tons of CO_2/year.

2nd case study

Similarly, an operator in the Permian considered replacing a 450 IM with a 440 PMM. The main challenges were the high gas interference and the frequent overheating shutdowns which caused a significant non-production time. The ESP string installed included a 440 PMM, tandem gas separator, gas handler pump, multiphase pump, and wide operating rang pumps to accommodate to the potential production decline.

Figure 7 depicts the system operating parameters with the PMM. As it can be seen, despite the increasing GLR, the motor temperature was kept below 180 ℉. The ESP has fewer shutdowns hence increasing the well's uptime.

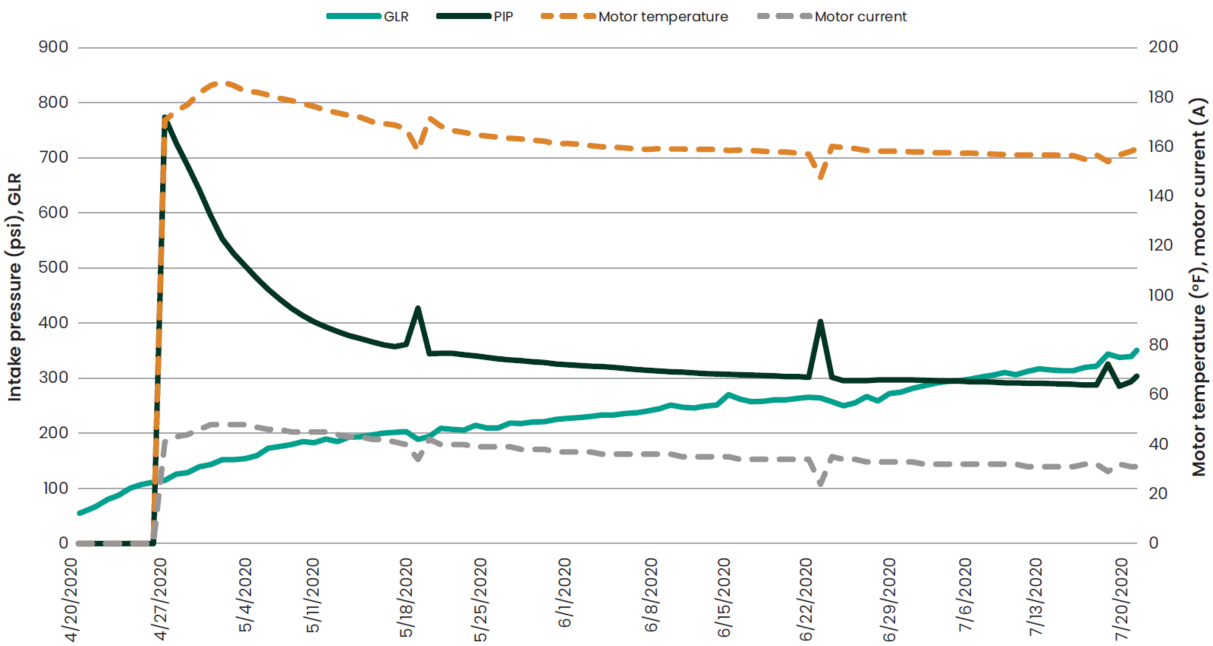

Figure 7. Well's operating trends with 440 PMM.

The operator was able to reduce the electric bill by 32%, roughly $19,000 annually.

CONCLUSIONS

In the harsh Permian Basin oil fields, PMM's have earned a roll in the continual progress of improved energy efficiency and increased production for ESP Systems. Not only can they contribute to the direct reduction of the carbon footprint, but in some challenging applications, they may allow for improved system stability and even increased oil production. Reliability has been shown to be the same or better than equivalent induction motor systems. The value proposition of the PMM reveals that it is going to be a key technology moving forward. In many cases, it may even displace the induction motor market.

Extensive data from over 1,000 PMM installations revealed that 300-series PMMs, on average, have 20% greater reliability compared to 300-series IMs. The data also showed that the run life of 400-series PMMs is comparable to that of 400-series IMs, with a 98% survival rate in the first year.

The case study comparing the Slim PMM to the Slim IM demonstrated that the PMM outperformed the IM with a higher power factor, greater motor efficiency, and lower power consumption. Additionally, the system reduced high-temperature shutdowns, increasing uptime to 97.5%. The estimated carbon emission reduction was 63 tons of CO_2 per year.

Replacing a 450-series IM with a 440-series PMM reduced power consumption by 32%, saving thousands of dollars annually on electricity costs. Additionally, it improved the overall system performance, increasing the unit uptime.

ACKNOWLEDGMENT

The authors would like to thank Baker Hughes for the support and the permission to publish the paper.

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