Comparison of Permanent Magnetic Motor and Induction Motor on power efficiency in Electric Submersible Pump

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Abstract. Artificial Lift is utilized to produce oil from a well with no natural flow or to increase the oil production of naturally flow well. One method for artificial lift is the installation of Electric Submersible Pump or ESP. ESP is the most common method and widely used to lift oil from a well. The downhole equipment of the ESP, from bottom, consists of motor, protector, gas separator if needed, and the pump itself. Designing ESP includes selecting the right motor to be installed which is suitable for the pump. Presently, there is more efficient motor technology invented and available in the market. The motor is called Permanent Magnetic Motor or PMM. The conventional motor; Induction Motor or IM; the rotor of the motor consists of electrified copper bar, to induce magnet; while in the PMM motor, the rotor consists of permanent magnet.

In this study, the PMM has higher power efficiency, higher and stable power factor, and wider and stable operating speed than IM. The power efficiency of PMM motors is up to 90%, while for IM is only up to 85%.

1. Introduction

Nowadays, the use of Artificial Lift becomes important in producing oil; one of them is Electric Submersible Pump or ESP. ESP runs on electricity, and since the electricity needed to operate an ESP is very large; reducing electricity usage will also reduce the operating cost.

The components of the ESP pump that most power use, are pumps and motors. The selection of appropriate and efficient pump and motor is an important factor in reducing power consumption. Pump selection must be in accordance with the required flow rate, which has to be the best efficiency rate for the pump. The motor selection has to match the ESP, including motor series, outside diameter, motor power, and the right combination of motor voltage and electric current. Selecting motor criteria has to be in accordance with the power capacity requirement or Brake Horse Power of system or BHP system; which is needed for pump, protector and separator power [1,2]. There are two motor types; conventional motor of Induction Motor or IM and Permanent Magnet Motor or PMM. The working principle of an IM is by giving current electricity to the stator which will produce a magnetic field, then inducing the rotor, and creating the second magnetic field with different direction of stator magnetic field; this will rotate the rotor. IM never works at synchronous speeds but at lower speeds. The difference between the two speeds causes the slip or friction; which increases with increasing load. PMM has almost the same working principle as an IM, but the PMM motor works at the same speed or synchronous so that it does not cause any slip or friction. This is because the rotor designed for PMM uses very strong magnet; while for IM, magnetic field is generated from electricity. The PMM advantages compared to IM are
more efficiency, power factor efficient, and higher motor speed. Electrical energy losses are only due to surface and subsurface equipment [3-10].

Energy losses are from hydraulics losses and electric losses. Hydraulic losses consist of energy loss at the pump, backpressure prevention energy loss, tubing energy loss, and separator energy loss. The electric losses consist of loss of energy in motor, cables and surface electric equipment. From these losses, the efficiency of each pump and motor will be evaluated [2].

2. Methodology
The first thing to be calculated is the performance of existing pump, and then compare the result if the subject well is installed with different type of pumps and motors. The comparison is based on the efficiency.

The load is calculated by using:

\[
\text{Load} = \frac{\text{BHP}_{\text{sistem}}}{\text{BHP}_{\text{np}}}
\]

While the energy, calculated for each pump is obtained from:

\[
\text{P}_{\text{hdyr}} = 1.7 \times 10^{-5} \times Q_f \times (0.433 \times \text{SG} \times \text{PSD(TVD)} - \text{PIP})
\]

The next step is to run sensitivity of the expected production rate, which will also affect the type of pump to be installed, based on the pump flow rate ability to lift fluid reservoir.

The equation used to calculate the energy loss due to hydraulics, are as follows:

**Tubing Losses**

\[
\text{P}_{\text{hdyr}} = 1.7 \times 10^{-5} \times Q_f \times (0.433 \times \text{SG} \times \text{PSD(TVD)} - \text{PIP})
\]

\[
\eta_{fr} = \frac{\text{P}_{\text{hydr}}}{\text{P}_{\text{hydr}} + \Delta P_{fr}} \times 100
\]

**Backpressure Losses**

\[
\Delta P_{bp} = 1.7 \times 10^{-5} \times Q_l \times \text{WHP}
\]

\[
\eta_{bp} = \frac{\text{P}_{\text{hyd}} + \Delta P_{fr}}{\text{P}_{\text{hydr}} + \Delta P_{fr} + \Delta P_{bp}} \times 100
\]

**Pump Losses**

\[
\Delta P_{pump} = \text{BHP}_{\text{pump}} \times \left(1 - \frac{\eta_{\text{pump}}}{100}\right)
\]

Pump efficiency or \((\eta_{\text{pump}})\)is obtained from Pump Performance Curve.

Meanwhile for energy loss due to electricity, would be as follows:

**Motor Losses**

\[
\Delta P_{\text{motor}} = \text{BHP}_{\text{motor}} \times \left(1 - \frac{\eta_{\text{motor}}}{100}\right)
\]

Motor Efficiency or \((\eta_{\text{motor}})\)is obtained from Motor Performance Curve.

\[
\Delta P_c = \frac{3 \times I^2 \times R_T}{1000}
\]


\[ P_{\text{motor}} = 0.746 \times \frac{\text{BHP}_{\text{motor}}}{\eta_{\text{motor}}} \]  

(10)

\[ \eta_c = \frac{P_{\text{motor}}}{P_{\text{motor}} + \Delta P_c} \times 100 \]  

(11)

Separator Losses

\[ \eta_{\text{sep}} = \frac{\text{BHP}_{\text{pump}}}{\text{BHP}_{\text{motor}}} \times 100 \]  

(12)

Surface Losses

\[ \Delta P_{\text{surf}} = P \times \left(1 - \eta_{\text{surf}}\right) \text{ / } \eta_{\text{surf}} \]  

(13)

3. Results and discussion

The primary well data used in this study are reservoir fluid data, production data, and well profile data. Reservoir fluid data includes SG oil, SG gas and SG water. Production data include fluid flow rate, reservoir pressure, saturation pressure and wellbore flow pressure. For well profile data includes wellhead pressure, tubing size, casing size, formation depth. These data are used to evaluate the existing pump and designed pumps to be installed. In evaluating and designing ESP, the common methodology of ESP design is used.

In this study, the subject well is already on production on ESP QN70ARC pump [11], and will be optimized by designing a new pump where there are 3 selected pumps namely D5800N pump, S6000N pump and G5200N pump [12]. There are 2 types of motors, namely IM and PMM motors. The results of the calculation of energy efficiency after evaluating existing pump and designing new pump, can be seen in table 1.

| Parameter | QN70ARC IM | D5800N PMM | D5800N IM | S6000N PMM | S6000N IM | G5200N PMM | G5200N IM |
|-----------|------------|------------|-----------|------------|-----------|------------|-----------|
| \( P_{\text{dry}, \text{HP}} \) | 82.52 | 82.52 | 82.52 | 82.52 | 82.52 | 82.52 | 82.52 |
| Efisiensi Sistem, % | 28.07 | 31.71 | 28.08 | 31.98 | 28.31 | 29.94 | 26.7 |
| \( P_e, \text{kWh} \) | 219.31 | 194.12 | 219.23 | 192.48 | 217.38 | 205.59 | 230.54 |

Table 1 shows that the most efficient energy use pump design is the S6000N pump by using PMM225.3 motor. The table also shows that the S6000N pump using the PMM225.3 motor is also far more efficient compared to the currently installed pump; where the difference in power used is quite large at 25.19 kWh. This is because the S6000N pump has a greater pump efficiency compared to other types of pumps and PMM motors have higher motor efficiency than IM type motors. The use of PMM motor reduces energy usage by 25 kWh or 10%.

3.1. Pump flow rate sensitivity

At this stage of pump design is carried out on the subject well with various types of pumps and 2 types of motors at various flow rates. The target flow rate is divided into 3 groups: low flow rate, medium flow rate and high flow rate.
3.1.1. Low flow rate. In this plan the designed rate starts from 300 to 1600 BFPD. At this Low flow rate, there will be 3 types of pumps and 2 types of motors. The pumps are D1050N, D1150N and D1400N, while the motors are IM type and PMM type motors. The results of the energy calculation can be seen in Figure 1. Figure 1 shows that at the design flow rates of 300 to 1200 BFPD, the most efficient pump design in energy use is the D1050N pump design with a PMM motor, while at the design flow rates 1200 to 1600 BFPD the pump design the most efficient in the use of energy is the D1400N pump design. In Figure 1, different types of pumps have an influence on energy use; where pumps that have high pump efficiency will be more efficient in energy use; in addition, the same pump using PMM motors gives an increase in energy efficiency compared to IM type motors, but the increase in efficiency is not significant in low flow rate conditions. The use of PMM motors will also have no effect if the pumps used are already inefficient, this can be seen in the flow rate of more than 1400 BFPD indicating that the design of the D1400N Pump with IM type motor is more efficient compared to the design of the D1050N Pump and D1150N Pump that use PMM motors.

![Figure 1. Energy sensitivity at low flow rates.](image)

3.1.2. Medium flow rate. In this range of flow rate, the designed rate starts from 1200-2500 BFPD. At this medium flow rate, there are 3 types of pumps used, namely D1750N pump, D1800N pump and G2100N pump and 2 types of motors namely IM type motor and PMM type motor. Energy calculations can be seen in figure 2.
Figure 2. Energy sensitivity at medium flow rate.

Figure 2 shows that at flow rates of 1200 to 2200 BFPD, the most efficient pump design in energy use is the design of D1800N pump with a PMM motor; while at flow rates of 2200 to 2400 BFPD, the most efficient pump design in energy use is the G2100N pump design with PMM motor. However, when it is at a design flow rate of more than 2400 BFPD, the D1800N pump is not very efficient because it is outside its optimum range and can cause pump up-thrust. In addition, the same pump using PMM motor provides a significant increase in energy efficiency compared to IM type motors at this medium flow rate.

3.1.3. High flow rate. At high flow rates, the designed rate starts from 3500 to 5500 BFPD. At this high flow rate, three types of pumps will be used, namely D5800N pump, S6000N pump and G5200N pump and 2 types of motors namely IM type motor and PMM type motor. Energy calculation results can be seen in Figure 3.
In Figure 3 above, it can be seen that at flow rates between 3500 and 4675 BFPD the most efficient pump design in energy use is the D5800N pump design with a PMM motor, while at flow rates of 4675 to 5500 BFPD the most efficient pump design in energy use is the S6000N pump design with PMM motor. For the pump design that has the least energy efficiency is the G5200N pump design. At the most optimum flow rate of the G5200N pump the energy efficiency is still smaller than the D5800N pump and S6000N Pump where the most optimum flow rate at the D5800N pump is around 5800 BFPD while the most optimum flow rate at the S6000N pump is around 6000 BFPD. In addition, at this high flow rate the use of PMM motors provides a relatively high increase in energy efficiency compared to IM motors.

4. Conclusion
Based on the analysis of the pump for the influence of motor types on subject well, a conclusion can be drawn as follows:

- The electrical energy usage of existing installed ESP on the subject well, will be reduced by 10% for replacing the pump with more suitable pump and PMM.
- The usage of PMM will reduce the electrical energy requirement as compare to use conventional IM.
- Improvement of PMM motor energy efficiency in low flow rate conditions is not significant, whereas for medium flow rate it is quite significant, and at high flow rate is very significant.
- Pumps that have high efficiency will increase energy efficiency, while inefficient pumps will reduce energy efficiency.

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