Maintaining deep well submersibles

Maintenance of submersible pumps is complex due to the depth at which they are installed, which makes access difficult. Correct facility design to extend the time between failures and the monitoring of several parameters to determine the pumps’ performance during operation are therefore vital factors, as Miguel Ortiz and Alejandro Palomo report.

Generally, maintenance performed on submersible pumps is mostly corrective due to, among other reasons, the fact that these pumps are installed at depths ranging from a few metres to several hundred metres (Figure 1). So, unlike pumps used on the surface, once they are installed they become inaccessible for maintenance or for any kind of diagnostic measurement that might be taken directly on them. The installation depth also makes the cost of assembly and disassembly quite high in most cases, so maintenance aside from corrective maintenance may be uneconomical. In this situation, proper design of the facilities involving submersible pumps is especially important in order to try to extend the hours of operation until the pump or any other element fails.

It is important to note that submersible pumps (Figure 2) are billed as ‘maintenance free’ equipment, with manufacturers stating in their manuals that they do not require regular maintenance. Professionals who are dedicated to the maintenance of such equipment must achieve the following objectives:

1. Ensure the service; that is, ensure that the machines are available when needed.
2. Extend the time between interventions, thereby reducing maintenance costs.
3. Optimize performance, especially with respect to energy consumption, to
achieve the optimal price per cubic metre of water extracted.

In most cases, a submersible group is not disassembled and revised until a malfunction prevents proper operation. Therefore, the appearance of a fault provides the opportunity not only to repair the pump in the time required to guarantee the service (point 1 above) but also to make appropriate improvements to extend the operation until the next fault (point 2) and to review the efficiency of the system to see if it is possible to optimize (point 3).

**Design of facilities**

It is important to choose correctly not only the submersible pump but also all the elements of the installation to ensure the desired service. Common examples of errors at the design stage are:

- **Assuming that more water is better.** Installation of a pump that is too large can lead to problems of various kinds (turbidity, excessive start/stop manoeuvres, increasing the electrical power needed, greater investment in the purchase of equipment, etc.) without any practical benefit to the user. In addition, with regard to the well itself, it can cause clogging of filters, casing collapse, worsening water quality (e.g. saltwater intrusion), and so on.
- **Sizing the equipment only for the worst operating point (usually the highest flow and head).** Keep in mind the possible existence of other operating points and consider if it is possible to size for the most common one (which should be the most efficient).
- **Undersizing the electrical components (cables and switchgear).** This generally produces high heat losses, inductances and voltage drops ("brownouts") that damage the equipment.
- **Failing to take motor cooling into account.** Submersible motors are cooled by the pumped water flow that circulates outside before entering the water pump. This flow is recommended to have a speed higher than 0.5 m/s and lower than 2.5 m/s. To achieve this you can vary the diameter of the motor, install a refrigeration jacket to increase this rate or alter the depth of installation to a point with a different well casing diameter.
- **Installation of an undersized riser pipe often leads to high pressure losses that increase the overall head and move the operating point. This can result in a failure to reach the required flow for the application.**
- **Failure to provide the necessary elements to control the recommended operating parameters: flow, static and dynamic level, consumption, voltage, turbidity, operating hours, starts, motor and water temperature, etc.**
- **Improper choice of the location of the pump in the well.** The installation of the equipment at an incorrect depth can result in an insufficient water level above the pump and therefore a decrease in the available NPSH, with the possibility of cavitation or dry running at a decreased level in the well. In addition, installing the pump in front of the water inlet screens of the well casing can cause turbidity and sand drag. Another possible problem is poor motor cooling due to either an inappropriate relationship between motor and casing diameters at the selected point, which results in unacceptable cooling rates, or direct water input to the hydraulic element (not cooling the motor) because of the position of the pump below the well screens (Figures 3 and 4).

**Condition-based maintenance**

In order to go beyond merely corrective maintenance and prevent failure before it occurs, it is important to monitor regularly a number of parameters that may be appropriate to warn of an imminent failure, thereby implementing a system of condition-based maintenance (CBM). CBM does not avoid the repair or the costs associated with the fault, but it allows anticipation, thus reducing the impact and costs associated with an unscheduled stoppage. Furthermore, early intervention can lead to a more precise determination of the source of the problem (not hidden by more severe damage) and help to draw conclusions and take measures to improve future operations.

Vibration analysis is widespread in CBM for rotating machines but it is not possible...
to apply this technique for submersible pumps. Among the recommended parameters to monitor for this type of maintenance on submersible pumps are:

- Motor insulation
- Motor temperature
- The turbidity of the extracted water
- Water flow
- Dynamic water level
- Energy consumption
- Specific consumption (this parameter encompasses the above three)
- Other electrical parameters: current, power, etc.

Moreover, as in any machine, it is important to control the number of operating hours and the number of starts they perform.

Motor insulation

Due to the subsurface installation of a submersible pump, the available point for measuring motor insulation is the end of the power cables at ground level. As a result, the measurement obtained corresponds to the combined insulation of the wires and the electric motor.

Two possible ways of tracking this parameter are:

- Carry out periodic measurements of insulation resistance with a megohmmeter
- Install a device to measure the leakage current continuously to indirectly determine the state of insulation.

Monitoring this parameter can lead to detection of early electric faults, both in the electric motor and in the power cables. Monitoring is possible without the need for special equipment at the time of the pump’s installation, so it can be applied to equipment that is already installed.

Motor temperature

In order to track the motor temperature, it is necessary to mount a Pt-100 platinum resistance temperature sensor in the pump motor before installation, with the wiring brought to the surface along with the power cables.

The temperature of a motor depends on several factors, including water temperature, water velocity outside the motor and motor speed, so it is not possible to define a generic temperature cut-off for all motors, although the usual working range varies between 40°C and 60°C (Figure 5).

Variations in the normal operating temperature of the motor allow early detection of, among others: mechanical failure of the equipment (e.g. axial bearings); a change in motor cooling conditions; a change in the operating point of the pump; and variation in the power supply (low voltage, etc.). One of the consequences of an increased motor temperature is usually burnt stator windings; for this reason, monitoring this parameter can prevent a motor rewind.

Turbidity

There are two possible ways of tracking turbidity in the water flow: by periodic measurements or by the installation of a continuous measurement device. High levels of turbidity normally occur simultaneously with a change in water levels. The main scenarios that may occur are:

1) A rise in both static and dynamic levels. Turbidity, usually sudden onset, will be associated with heavy rainfall in the area. The cloudy water enters the aquifer due to numerous surface runoffs. This phenomenon usually ceases within days of the end of the rain.

2) A lowering of static and dynamic levels. There is a reduction in water reserves due to lack of rain, and turbidity appears progressively. Turbidity appears because the surface water intake is reduced as a result of the lower levels, which causes an increase in water entry speed. This increase in speed draws in fine particulate material from the aquifer.

3) A decreased dynamic water level with a similar static level. In this case there are two possible situations. If it is associated with an increased extraction rate, the turbidity would be generated by increased water intake velocity, which would exert a drag on particles larger than those previously mobilized. If there is no increase in extraction rate, this would indicate the existence of additional head losses due to problems in the well casing, facilitating the entry of particles from the circumferential space outside the casing or from the aquifer itself. It is recommended to interrupt the operation, disassemble the pumping equipment and perform a video inspection of the inside of the casing to locate the problem.

Follow-up is possible without special equipment at the time of installation of the pump, so it can be applied to equipment that is already in place. With respect

Figure 5. Temperature evolution in a submersible pump motor in ‘normal’ operation, with two starts and two stops in 24 hours.
to submersible pumps, the influx of sand is one of the ‘classical’ problems. Submersible pumps are designed to extract clean water but permit a sand content of about 25–50 mg/litre. This amount is very high; for example, with a sand content of 50 mg/litre, an electric pump that lifts 150 m$^3$/h working 24 hours a day would draw in about 180 kg of sand in one day, 5.4 tonnes in one month and nearly 65 tonnes in a year.

Besides, this amount of solids flowing inside the pump can also damage the structure of the well. Before choosing systems that are resistant to the influx of sand, the first step is to try to avoid this happening. Very often it is as simple as adjusting the flow to a rate at which the turbidity and the drag are reduced below certain limits. Sometimes this effect is achieved by changing the position of the pump in the well.

Specific consumption

The specific consumption, which has units of Wh/m$^3$/m, represents the energy consumed by the pump to raise 1 m$^3$ of water to a height of 1 m. Height here means the total elevation; that is, the dynamic level of the water in the well plus the height from ground level.

A range of equipment is necessary to monitor this multicomponent parameter. With respect to monitoring the dynamic water level, this should be considered during the design stage, since disassembling the pump once in situ to install a system to measure the water level is uneconomical in most cases. To obtain the height from ground level, a pressure gauge or pressure transducer will be required. To measure the energy consumed, the power meter from the distributor can be used, provided that it is a facility with just one submersible pump. In the event that there is more than one submersible pump, power analysers for each pump would be needed in order to obtain the energy consumed independently. To monitor the volume, a flowmeter (electromagnetic, ultrasonic, Woltmann type, etc.) is needed at the wellhead.

The monitoring of specific consumption over time allows early detection of a number of problems. These include: loss of flow due to leaks in the riser pipe or the flanges; an increase in the gaps between the hydraulic elements; abrasive wear on the blades; and sitting up of the impellers due to the continuous drawing in of clay or silt (adhesions in hydraulic channels).

To demonstrate the usefulness of monitoring specific consumption, let’s consider the data from two facilities. The first example (Figure 6) shows the improvement of specific consumption associated with the rise in dynamic level due to the displacement of the operating point of the monitored pump to a new position that provides a better performance.

In the second case, the specific consumption at a facility worsens over time until the poorly functioning pump is disassembled (September) and replaced with a spare pump. As a result, from October on the specific consumption is noticeably improved (Figure 7).

Experience gained in managing a fleet of more than 200 submersible pumps in recent years suggests that the optimal reference value for the specific consumption is around 5 Wh/m$^3$/m.

Contact

Miguel Ortiz Gomez
Maintenance manager
FACSA
Castellon, Spain
Tel: +34 964 221008
Email: mortiz@facsa.com
www.facsa.com

Alejandro Palomo Nortes
Technical and commercial director
Salinas y Perez
Murcia, Spain
Tel: +34 968 253833
Email: alejandropalomo@salinasyperez.com
www.salinasyperez.com

www.worldpumps.com