Permanent Magnet Motor Safety

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Introduction

In electrical submersible pump (ESP) systems, two motor technologies provide power to the pump: the AC induction motor (IM) and the permanent magnet motor (PMM). The IM has been the industry standard since 1916. It evolved over time with many improvements and is a mature technology in 2021. PMM, a younger technology originating in the 1990s, also evolved in the early 2000s and has gained global commercial acceptance since 2010. PMM requires more precautions due to the construction and physics of the motor and how it generates voltage. Figure 1 provides a brief comparison of the two motor technologies.

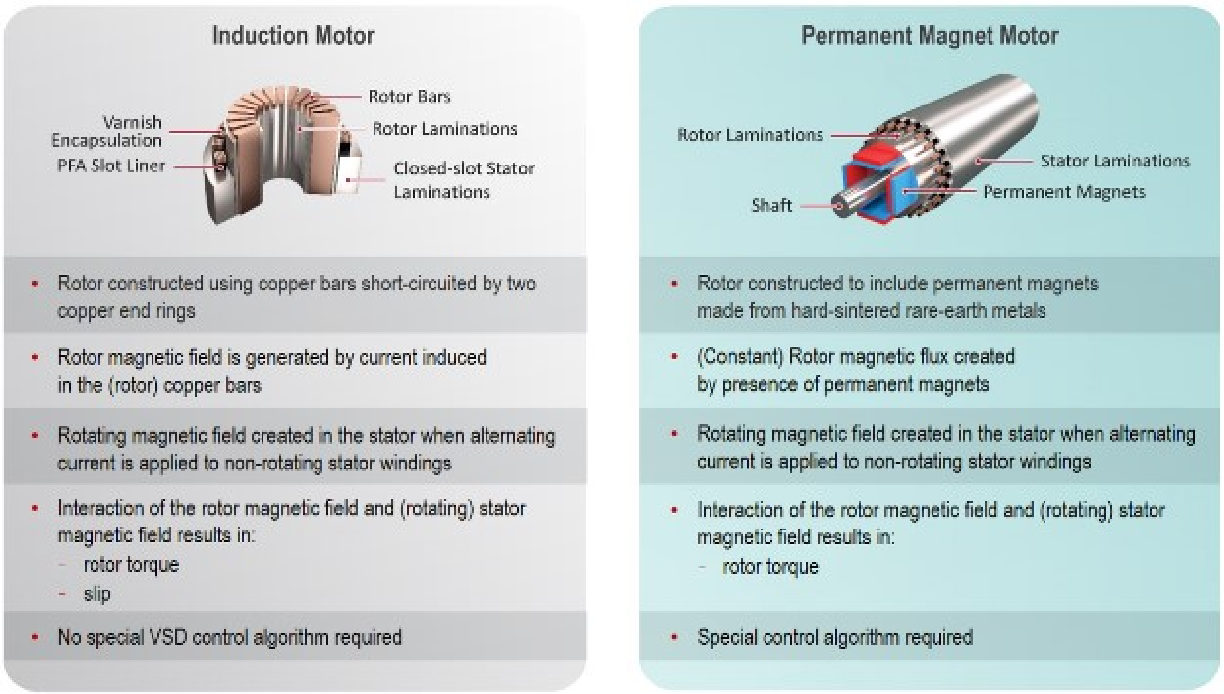

Figure 1—Comparison of Induction and Permanent Magnet Motors

In both IM and PMM, the ability to perform work arises from the torque produced by a rotating shaft resulting from the attraction of rotating electromagnetic poles in the stator to corresponding opposite magnetic poles in the rotating rotor. It is the sequence of three-phase currents flowing through the stator windings, which creates the rotating stator magnetic poles, although the physical stator itself is stationary. The poles on the rotor are created in fundamentally different ways.

— In the case of the IM, the stator magnetic field rotating relative to the rotor induces an opposing current in the rotor, which in effect acts like secondary windings, much like a transformer. This rotor current creates electromagnetic poles on the rotor. This current consumes a significant amount of energy and is a major source of the IM efficiency losses.

— Although the PMM has many of the same contributors to loss of efficiency (such as windage and stator core losses), the rotors do not require additional magnetization as they are already magnetized per the specifics of their design and the use of permanent magnets. Due to this elimination of a large source of waste power consumption, the PMM can run much more efficiently than the IM.

One of the implications of this is that the PMM will typically have a much lower idle current than the IM. Whereas an IM may have an idle current of around 35–45 % of the nameplate rating when operating at nameplate voltage, the PMM may have only around 5–10 % of the nameplate current. Exact details of PMM design will vary between suppliers.

In both IM and PMM, the poles on the rotating rotor cause an internal voltage to be generated in the stator winding, known as the electromotive force (EMF). In an IM, if the shaft rotates while the motor is disconnected from any external power source, only the residual magnetic field in the steel laminations is available to generate EMF. In most applications, this residual magnetism will be negligible such that there is no hazardous level of EMF generated, although it is known for back-spinning IMs to generate hazardous voltage. However, EMF will be generated in a PMM any time that the shaft is rotated as the rotor poles, which are magnetically strong, are always present. This EMF will be proportional to the shaft rotational speed regardless of the direction of rotation.

In a conventional well application (oil, gas, water, utility), well fluids moving up the casing-tubing annulus (kick or annular injection) or down the tubing (draining or injection through the production tubing) and then through the pump can cause the shaft to rotate, and thus the PMM to generate EMF. The faster the rotation, the higher the generated voltage that can lead to various electrical hazards, shock, burns, or arc flash.

Despite the EMF associated with PMM technology, their benefits in energy and CO_2 savings and higher power density cannot be ignored. With proper organizational capability and operational excellence, the technology can be used safely on a routine basis. The purpose of this document is to provide recommendations and information to assist with this task.

Permanent Magnet Motor Safety

1 Scope

This document serves to emphasize safety aspects and recommended practices concerning the handling, installation, trouble shooting, operation, and pulling of permanent magnet motors (PMMs) used in subsurface and surface artificial lift pumping systems.

This document does not replace any other specific safety documentation; national and/or local electrical regulations take precedence.

Subsurface systems entail the motor located downhole with the pump. Centrifugal pumps are historically called an electrical submersible pump (ESP). A progressing cavity pump (PCP) mated with a downhole motor with or without a gear reduction unit is typically called an electrical submersible PCP.

For this recommended practice, Figure 2 will be used as reference for a high-voltage conventional ESP system. The submersible system may have a pump that is centrifugal (default), co-helical axial, progressing cavity, gear, vane, or other type of rotational pump. The motor will be of rotational nature to drive the aforementioned pumps and of permanent magnet design.

There are many types of equipment configurations available for PMM operations. Configurations included in this document are listed in Table 1.

Table 1—Deployment Types

Deployment	RIH	POOH	Informative
Conventional	8.4	9.12	F.2
Cable unit	8.5	9.13	F.3
Through tubing: threaded or coupled tubing	8.6	9.15	F.4
Through tubing: coiled tubing with external cable	8.7	9.16	F.5
Through tubing: coiled tubing with internal cable	8.8	9.17	F.6
Docking station	8.9	9.18	F.7
Surface PMM	8.10	9.19	F.8
Downhole driven PCPs			Annex G

Each of these system configurations will have various considerations that shall be made to ensure personnel safety. Some are common to all PMM operations, whereas others will be unique to the given configuration.

— Surface pumping deployments have limited exposure to electrical hazards because the motor is at surface and its shaft or linkage to the pump system can be locked.

— Some deployments install the pump after the motor, and so unplanned motor rotation does not occur when tripping the motor.

In the case of linear submersible pumps, the pump is reciprocating (vertical motion) and is driven by a linear PMM comprising an armature and permanent magnet translator. The armature is the equivalent to the stator, and the translator is the equivalent to the rotor of a conventional ESP. Downhole linear PMM systems are not expressly included in this document as the force required from the fluid to lift the motor and pump is unlikely to result in motor voltage. However, the supplier should be consulted and the principles in this document applied.