OVERCOMING PRODUCTION CHALLENGES IN OILFIELDS: A NEXT-GENERATION ARTIFICIAL LIFT SOLUTION FOR COMPLEX WELL ENVIRONMENTS

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ABSTRACT

As the global oil industry increasingly relies on unconventional and marginal assets, operators face a complex array of production challenges. These include high viscosity fluids, significant solid content, gas interference, and the need for deployment in deviated wellbores. Traditional lift methods, such as beam pumping and conventional rotary electric submersible pumps (ESPs), often reach their mechanical or economic limits under these conditions. This paper introduces a next-generation Linear Electric Submersible Pump (LESP) system that integrates advanced permanent magnet linear motor technology with intelligent control algorithms to address these specific downhole complexities.

The discussion focuses on the system's unique mechanical architecture, including a modular motor design and a plug-in power cable connection that significantly reduces rig time and maintenance complexity. Furthermore, the paper details specific proprietary software algorithms designed to manage "stuck" conditions and gas slugs autonomously. These include "Jogging" and "Swing" modes for freeing wedged pumps and gas plug removal logic that prevents underload faults. By combining robust hardware options—such as magnetic flow cleaners for paraffin control—with smart surface control, this technology offers a comprehensive solution for extending run life and optimizing production in challenging well environments.

INTRODUCTION

The economic viability of mature and unconventional oilfields depends heavily on the reliability of artificial lift systems. Operators are often forced to choose between the volumetric efficiency of positive displacement pumps (like sucker rod pumps) and the deployment flexibility of submersible systems. However, deviated wellbores cause rod-tubing wear in beam pumps, while solids and gas lock frequently compromise rotary ESPs.

To bridge this gap, a rod-less Linear Electric Submersible Pump (LESP) technology has been developed. This system places the reciprocating power source directly downhole, eliminating surface moving parts and rod strings. While previous iterations of linear lift technology showed promise, next-generation systems have evolved to address maintenance speed, sensor accuracy, and autonomous fault recovery. This paper outlines the mechanical innovations and software control strategies that allow this system to overcome production challenges where legacy methods fail.

MECHANICAL ARCHITECTURE AND MODULARITY

The core of the system is a Linear Permanent Magnet Motor (LPMM) coupled to a double-acting plunger pump. Unlike conventional ESPs, which require rotary-to-linear conversion or high-speed rotation, the LPMM generates direct reciprocating motion.

Modular Motor Construction

A significant advancement in this generation of LESP is the modular sectional assembly of the motor. Traditionally, a motor failure required a complete unit replacement or a full rewind. The new design allows for the assembly of separate sections. In the event of a fault, only the specific damaged section needs to be replaced. This modularity reduces repair costs and allows operators to customize motor power and length based on specific well inflow performance relationships (IPR).

Rapid Installation Features

Rig time is a critical cost factor. The system incorporates a specialized Motor Lead Extension (MLE) with a "plug-in" connection. The connector is electrically isolated from the stator oil system. This design allows field technicians to install or replace the power cable without pumping oil into or out of the motor—a process that consumes significant time with standard ESPs. Consequently, the connection of the motor, pump, and power cable can be completed in approximately 20 minutes, streamlining the deployment process.

ADVANCED CONTROL ALGORITHMS

The hardware is driven by a Variable Speed Drive (VSD) equipped with a specialized controller. Beyond basic speed regulation, the controller utilizes specific algorithms designed to handle upset conditions without stopping production or requiring manual intervention.

Stuck Pump Recovery Protocols

In wells producing high solids or heavy oil, the risk of the pump becoming stuck or "wedged" is high. The system employs a "Wedging Algorithm" with two distinct modes to recover the pump:

1. Jogging Mode: The controller applies a constant frequency set by the operator to systematically raise the output voltage. This increases the output current and, consequently, the linear force (torque) applied to the plunger, attempting to push through the obstruction.
2. Swing Mode: This mode alternates the motor direction between forward (upstroke) and reverse (downstroke) while applying increased output voltage. This reciprocating "rocking" motion is effective at dislodging solids or debris that may be jamming the plunger or valves.

Gas Handling Logic

Gas interference typically leads to "underload" faults in standard controllers, causing nuisance trips. The LESP controller features an algorithm specifically for removing gas plugs. When a drop in load indicates gas interference, the system does not trip. Instead, it automatically adjusts the stroke rate to compress and displace the gas pocket, preventing a lock and returning the installation to its nominal operating mode once the fluid load is re-established.

Virtual Dynamometer Cards

To provide operators with visibility similar to rod pumping, the surface controller generates real-time dynamometer cards. By monitoring current and position without external load cells, the system calculates pump cylinder filling for every cycle. This allows for precise diagnosis of downhole conditions, such as fluid pound or gas interference, enabling proactive optimization.

FLOW ASSURANCE AND SOLIDS MANAGEMENT

For wells with complex fluid chemistries, the mechanical configuration of the LESP can be adapted with specific ancillary modules.

Solids Handling

The pump utilizes variable plunger-barrel clearances, referred to as "fits." These range from Fit 1 (0.001" clearance) for clean fluids to Fit 5 (up to 0.007" clearance) for high-viscosity or solids-laden fluids. Additionally, a wedge wire screen filter with a 0.2 mm slot size can be integrated into the intake module to prevent large particulates from entering the pump.

Paraffin Control

In fields prone to paraffin deposition, the system supports the integration of a Magnetic Flow Cleaner. This device generates a magnetic field that alters the molecular interactions within the crude oil. The field breaks down large paraffin aggregates into smaller particles, preventing them from crystallizing and adhering to the inner walls of the tubing. This passive flow assurance method maintains stable flow and reduces the frequency of hot oiling or chemical treatments.

DOWNHOLE MONITORING PRECISION

Reliable automation requires accurate data. The system is equipped with a robust Downhole Measuring System (DMS) connected via a "dry-type" flange, allowing for replacement without depressurizing the motor.

The sensor package provides high-fidelity data essential for the control algorithms:

• Pressure: Intake and discharge pressure monitoring with a resolution of 0.001 psi and accuracy of 0.1% Full Scale.

• Vibration: 3-axis (X, Y, Z) vibration monitoring up to 5g (50 m/s^2). This is critical for detecting mechanical wear or the onset of solids slugging before catastrophic failure occurs.

• Temperature: Monitoring of intake, tubing, and motor winding temperatures up to 150°C (302°F), enabling the VSD to derate performance to prevent overheating without tripping the system.

CONCLUSION

The next-generation Linear Electric Submersible Pump offers a sophisticated solution for wells that challenge the limits of conventional lift technologies. By combining a rod-less mechanical design with modular maintainability and intelligent recovery algorithms, the system addresses the root causes of downtime in complex environments.

The ability to autonomously recover from gas locks and stuck conditions via "Swing" and "Jogging" modes, combined with rapid installation features and precise downhole telemetry, positions this technology as a vital tool for operators seeking to maximize recovery from deviated, gassy, and sandy wellbores.

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