Prediction and Optimization of ESP Run Life: A Data-Driven Framework Based on Field Applications in Vietnam

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ABSTRACT

Electrical Submersible Pump (ESP) performance is a critical factor in maximizing production from mature fields, yet predicting and ensuring long-term reliability remains a significant challenge due to highly variable operating conditions. Traditional approaches often rely on isolated case studies, lacking a systematic framework for decision-making. This study proposes a novel, data-driven framework for ESP analysis and optimization, leveraging readily available historical operational data. The framework is built upon a comparative analysis of contrasting ESP application scenarios in Vietnam's Cuu Long Basin—from a highly successful, long-run-life case in a beginning environment (X field) to a challenging, high-temperature case that evolved from initial failure to success (Y field). A systematic methodology was employed, involving the quantification of Key Performance Indicators (KPIs) such as Run Life and Failure Mode analysis from historical production data and DIFA reports. A custom-developed screening software, the "ESP Quicklook Tool," was integrated into the initial assessment phase. The analysis revealed that while ESPs consistently deliver production uplift (1.3 to 7.5 times), electrical system integrity is the primary failure point (50-67% of incidents). The successful turnaround at X, which increased average run life from 45 to over 730 days, was directly attributed to a DIFA-driven iterative design process. Based on these findings, a standardized three-phase workflow is presented for optimizing ESP projects. This framework, validated against diverse field data, proves to be a viable and robust approach for enhancing ESP reliability, mitigating risks, and improving economic outcomes.

KEYWORDS: *Electrical Submersible Pump (ESP); run life optimization; data-driven framework; failure analysis; Vietnam oilfields*

1 INTRODUCTION

Electrical Submersible Pumps (ESPs) are a cornerstone of artificial lift technology, essent

ial for enhancing recovery from mature and marginal oilfields worldwide (Barree et al., 2009). An ESP system's ability to provide high-volume lift makes it a preferred choice for sustaining production as reservoir pressure declines. However, the operational success and economic viability of ESPs are heavily dependent on their long-term reliability, or "run life"(Michael C. Romer,2012). Failures can be costly, requiring expensive workover operations and resulting in significant production deferment. The primary challenge lies in the high variability of ESP performance across different geological and operational environments, from benign clastic reservoirs to harsh, high-temperature, and corrosive conditions (Al-Ballam, 2022; **Abdelaziz, 2017**).

Traditionally, ESP design and selection rely on vendor software and established guidelines, but these approaches may not fully capture the complex interplay of factors in a specific field. Post-mortem failure analysis is common, but lessons learned are often confined to a single asset or team, lacking a systematic framework to guide future projects. This leads to a reactive, rather than proactive, approach to reliability management.

The oilfields in the Cuu Long Basin, Vietnam, provide a compelling case study of this challenge. ESPs have been deployed in environments ranging from moderate-temperature Miocene reservoirs with scaling risks (X field) to high-temperature (140-170°C) fractured granite basement reservoirs with complex fluid dynamics (Y fields). This diversity has resulted in a wide spectrum of outcomes, with run lives varying from less than two months to over eleven years. This disparity highlights the need for a more structured, data-driven methodology to analyze performance and derive actionable insights. This paper aims to address this need by developing and presenting a systematic framework for ESP performance analysis and optimization, using historical data from these contrasting fields to build and validate a standardized workflow.

2 RESEARCH METHODOLOGY

2.1 Data Acquisition and Description

The data used in this study was compiled from a comprehensive internal technical report summarizing over a decade of ESP operations in Vietnam (Do, N. V., et al., 2025). The dataset encompasses two key fields with diverse characteristics: X, Y (Tuan, 2016). The data includes:

Reservoir and Fluid Data: Reservoir characteristics (Table 1) and fluid properties (Table 2), including temperature, pressure, GOR, viscosity, and water chemistry.

Operational Data: Historical production rates, pump operating parameters (frequency, intake pressure), and run life statistics for each ESP installation.

Failure Analysis Data: Detailed Dismantle, Inspection, and Failure Analysis (DIFA) reports, which categorize the root cause of each failure.

Table 1. Summary of Reservoir Characteristics for Fields

Field	Reservoir	Depth (TVDSS, m)	Reservoir Temp (°C)	Porosity (%)	Permeability (mD)	Key ESP Challenges
X	Miocene	1140 - 1456	77 - 84	~21 - 26	100	Good IPR, but risk of scale/paraffin.
Y	Basement	~2700 - 2800	117 - 156	3 - 5	7.42	High temp, high heterogeneity, risk of solids.

Table 2. Summary of Fluid Characteristics and Associated Risks

Field	API Gravity	GOR	Oil Viscosity	H_2S Risk	Scale Risk	Paraffin

	(°)	(scf/stb)	@Pb (cP)			Risk
X	21 - 28.6	4.9 - 7	3.2 – 26.7	Present	High (Observed)	High
Y	36.5 - 37.2	156 - 233	0.77 – 0.96	Low	None	Medium

2.2 Analytical Framework

A systematic analytical framework was developed to process the data and derive meaningful conclusions. The framework consists of two main components:

- **Performance Quantification:** Key Performance Indicators (KPIs) were defined and calculated to provide an objective measure of success (Parida, 2006; Carl-Fredrik, 2015). These include:
  - **Run Life (Days):** The primary metric for reliability.
  - **Production Uplift (Times):** Ratio of liquid rate after ESP installation to the rate before (Gaslift or natural flow), quantifying the effectiveness.
  - **Failure Mode Categorization (%):** Percentage of failures attributed to the main subsystems (Electrical, Pump/Mechanical, Other) to identify systemic weaknesses.

- **Comparative Analysis:** A comparative methodology was used, contrasting the "best-case" scenario (X field) with the "worst-to-best" scenario (Y field) to isolate the critical success factors and failure mechanisms.

2.3 ESP Quicklook Screening Tool

As part of the proposed workflow, a proprietary software tool, the "ESP & Gas Lift Quicklook Tool," (Do, N. V., et al., 2025) was developed for the initial screening phase. This tool uses fundamental reservoir and well data as inputs to rapidly perform hydraulic calculations. It determines key parameters such as Total Dynamic Head (TDH), Pump Intake Pressure (PIP), and required power, providing a first-pass assessment of ESP feasibility and flagging potential risks like cavitation. The tool's interface and typical output are shown in Fig. 1.

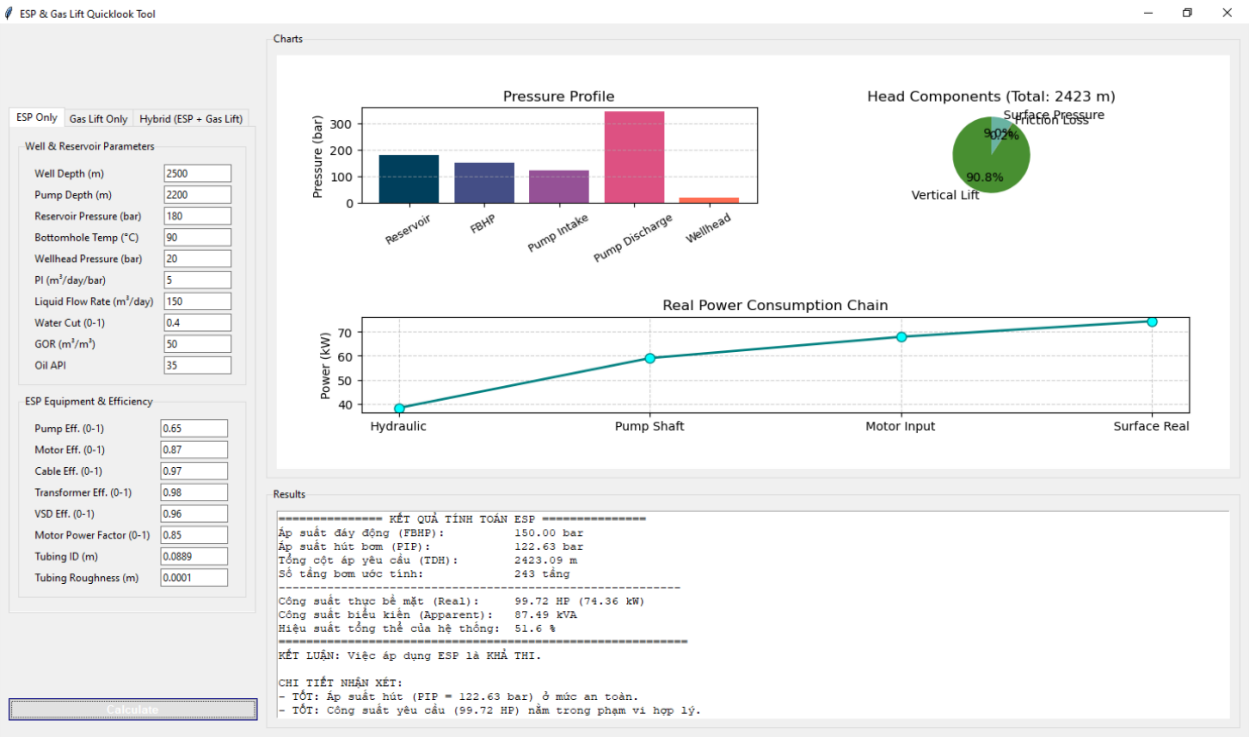

Fig. 1. User interface and results from the ESP Quicklook Tool for initial candidate screening.

3 RESULTS AND DISCUSSION

3.1 Performance Baseline and Failure Mode Analysis

Analysis of the entire dataset reveals that ESPs are highly effective at increasing production, with uplift ratios ranging from 1.3 to 7.5 times compared to previous production methods. However, this effectiveness is undermined by reliability issues. A systematic categorization of failures across all fields (Table 3) consistently identifies the electrical system as the primary weak link, accounting for 50-67% of all recorded failures (Alhanati, 2001). This category includes failures of the downhole cable, motor, sensors, and surface equipment (Heninger, 2019. This finding indicates that improving electrical system integrity is the most critical area for enhancing overall ESP reliability.

Table 3. Summary of Common ESP Failure Modes in Vietnam

Field	Main Failure Group	Estimated Failure % (Avg)	Details of Main Failure Incidents
X	Electrical	60%	Primarily Downhole Sensor (DHS) signal failures.
	Pump	20%	Stoppage due to Scaling: 1 incident.
	Other	20%	Operational issues.
Y	Electrical	50%	Cable/Connector/Penetrator failure; Stator winding/DHS failure.
	Pump	30%	Motor bearing failure/Torque Lock (Root cause); Abrasion issues.
	Other	20%	Operational issues.

3.2 Comparative Analysis of Field Scenarios

3.2.1 Scenario A: Proactive Management in a Benign Environment (X Field)

The X field represents a benchmark for success, with multiple ESP systems achieving run lives exceeding 10 years. This success is attributed to two factors: a favorable operating environment (moderate temperature, good IPR) and, crucially, **proactive operational management**. The systems were consistently operated within their optimal hydraulic window (48-50 Hz, PIP > 1690 psia), minimizing stress. Furthermore, a known scale risk was actively mitigated with an acid stimulation program, which prevented pump damage and extended run life.

Figure 2. XP well ESP Pump

3.2.2 Scenario B: Reactive Improvement in a Harsh Environment (Y Field)

The Y field provides a powerful lesson in iterative, data-driven improvement. The initial 2013 deployment in the high-temperature (140-170°C) reservoir resulted in catastrophic failures within 45 days.

- **Root Cause Analysis:** DIFA reports identified the root cause as a mechanical failure of the low-specification motor thrust bearing, which could not handle the extreme thermal stress, leading to a "Torque Lock" event.
- **Iterative Design Improvement:** This failure analysis directly informed a design upgrade in 2014. The key change was the replacement of the standard bearing with a **High-Load (HL) Thrust Bearing** and the use of high-temperature Aflas elastomers in the seal section (Fig. 3,4), reflecting improvements in motor technology (Del Pino, 2015). This single, data-driven change dramatically increased the average run life to over 730 days (2 years), demonstrating the power of a rigorous problem-solving cycle.

Figure 3. Example of a catastrophic ESP failure at the X field

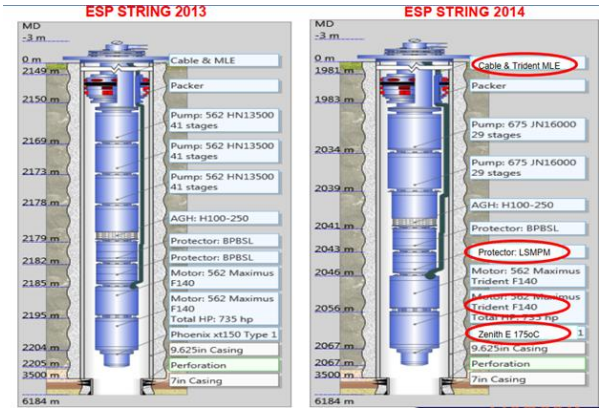

Figure 4. An example of the data-driven design evolution at the K field, comparing the original 2013 ESP string design with the upgraded 2014 design featuring a high-load bearing Protector (LSMPM) and enhanced motor

4 A STANDARDIZED WORKFLOW FOR ESP OPTIMIZATION

Based on the synthesis of these results, a standardized three-phase workflow is proposed to institutionalize best practices and guide future ESP projects.

Phase 1: Screening & Design (Foundation):

- Rigorous Data Collection: Mandate complete and recent PVT, water analysis, and DLS data.
- Initial Screening: Utilize the "ESP Quicklook Tool" to perform a rapid feasibility check.
- Risk-Based Design: Classify the well (low/high risk) and select materials and components accordingly. For high-risk environments, specify high-tier components (e.g., HL bearings, Aflas seals) from the start, avoiding the initial failures seen at Y.

Phase 2: Installation & Commissioning (Execution):

- Stringent QA/QC: Mandate third-party inspection and a detailed checklist for all equipment.

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- Flawless Installation Protocol: Require 100% specialist supervision, with strict adherence to procedures for cable handling and makeup torque, incorporating industry best practices for safety and project management (Alghamdi, 2024).
- RIH Simulation: For complex wellbores, a simulation of the Run-In-Hole process is mandatory to pre-emptively identify and mitigate mechanical clashes.

Phase 3: Operation & Improvement (Lifecycle Management):
- Proactive Monitoring: Use VSDs and downhole sensors to maintain the ESP within its optimal operating envelope (BEP, safe PIP).
- Mandatory RCFA/DIFA: Institute a mandatory and detailed Root Cause Failure Analysis for 100% of failures.
- Shared Knowledge Base: Establish a "Lessons Learned" database and conduct regular workshops between operators to prevent repeat failures.

5 CONCLUSION

The traditional, often fragmented approach to ESP management contributes significantly to performance variability. This study has demonstrated that by systematically analyzing historical data through a structured framework, critical success factors and failure mechanisms can be clearly identified. The key findings are:

- The electrical system is the most significant point of failure in ESP operations in the studied fields, requiring the highest priority for investment in robust technology.
- A rigorous, data-driven, iterative design cycle, guided by detailed failure analysis (DIFA), is capable of overcoming even the harshest operating environments, as proven by the turnaround at the Y field.
- Proactive operational management, including maintaining an optimal operating window and mitigating known risks like scale, is fundamental to achieving exceptional, long-term run life.

The proposed three-phase workflow provides a standardized, practical, and scientifically-grounded framework for operators to move from a reactive to a proactive ESP management strategy. Implementing this framework can significantly improve prediction accuracy, enhance reliability, and maximize the economic return of ESP technology in Vietnam and other regions facing similar operational challenges.

Contribution
- Conceptualization: Nguyen Khac Long, Nguyen Van Do
- Data Collection: Nguyen Van Do, Nguyen Van Thanh, Truong Van Tu, Nguyen Van Bien
- Data Analysis, Model Development: Nguyen Van Do
- Original Draft Writing: Nguyen Khac Long, Nguyen Van Do, Nguyen Van Thanh, Truong Van Tu, Nguyen Van Bien
- Draft Editing: Nguyen Khac Long, Nguyen Van Do

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