A DMAIC-Based Analysis of ESP Operational Performances and Their Influence on Production Stability

POLYTECHNIC UNIVERSITY PUERTO RICO

Author: Manuel A. Echevarría De Jesús

Advisor: Rafael A. Nieves-Castro, PharmD.

Master in Manufacturing Competitiveness

Abstract

This project applied the Define, Measure, Analyze, Improve, and Control methodology to evaluate how electrical, mechanical, and pressure-related operational variables influence the six-hour moving averages of oil, gas, and water production in a well equipped with an electric submersible pump. The analysis examined the relationships between operational conditions and production behavior to determine the extent to which these variables contribute to performance changes. Results showed low to moderate correlations, with gas production demonstrating the strongest association, while oil and water production were influenced primarily by reservoir conditions. These findings indicate that operational adjustments have a limited predictive impact but contribute meaningfully to production stability. The project identified improvement opportunities focused on stabilizing pump frequency, optimizing pressure conditions, and strengthening monitoring practices. A long-term control strategy was developed using standardized procedures, performance indicators, and continuous observation to sustain improvements in well performance.

Keywords – Control strategy, Electric submersible pump performance, Production analysis, Quality improvement

Problem Statement

Electric submersible pumps are widely used to sustain production in wells with declining reservoir pressure, yet their performance is often affected by variations in electrical, mechanical, and pressure-related operating conditions. in mature reservoirs, production behavior is strongly influenced by reservoir dynamics, making it difficult to determine how much operational parameters truly contribute to changes in oil, gas, and water rates. this uncertainty limits the ability of operators to optimize performance, reduce variability, and implement effective control strategies. the problem addressed in this project is the lack of clarity regarding the influence of key operational variables on production behavior in an electric submersible pump well and the need for a structured methodology to evaluate and improve performance.

Methodology

A quantitative research design was used to evaluate the relationships between operational variables and production behavior. The Define, Measure, Analyze, Improve, and Control methodology structured the investigation and ensured systematic evaluation of performance. Historical operational and production data were collected from an Electric Submersible Pump well, and six-hour moving averages were used to reduce noise and highlight operational trends. Operational variables included pump frequency, motor current, intake pressure, discharge pressure, and tubing head pressure. Production variables included oil, gas, and water rates. Summary statistics, correlation analysis, and multiple linear regression models were used to quantify relationships between operational conditions and production behavior

Results and Discussion

The results and discussion section presents the findings of the Define, Measure, Analyze, Improve, and Control methodology applied to evaluate Electric Submersible Pump well performance. The phases build on one another, moving from problem clarification to data exploration, statistical interpretation, improvement development, and long-term control. The following subsections summarize the outcomes of each phase and demonstrate how the DMAIC framework guided the investigation

DEFINE PHASE

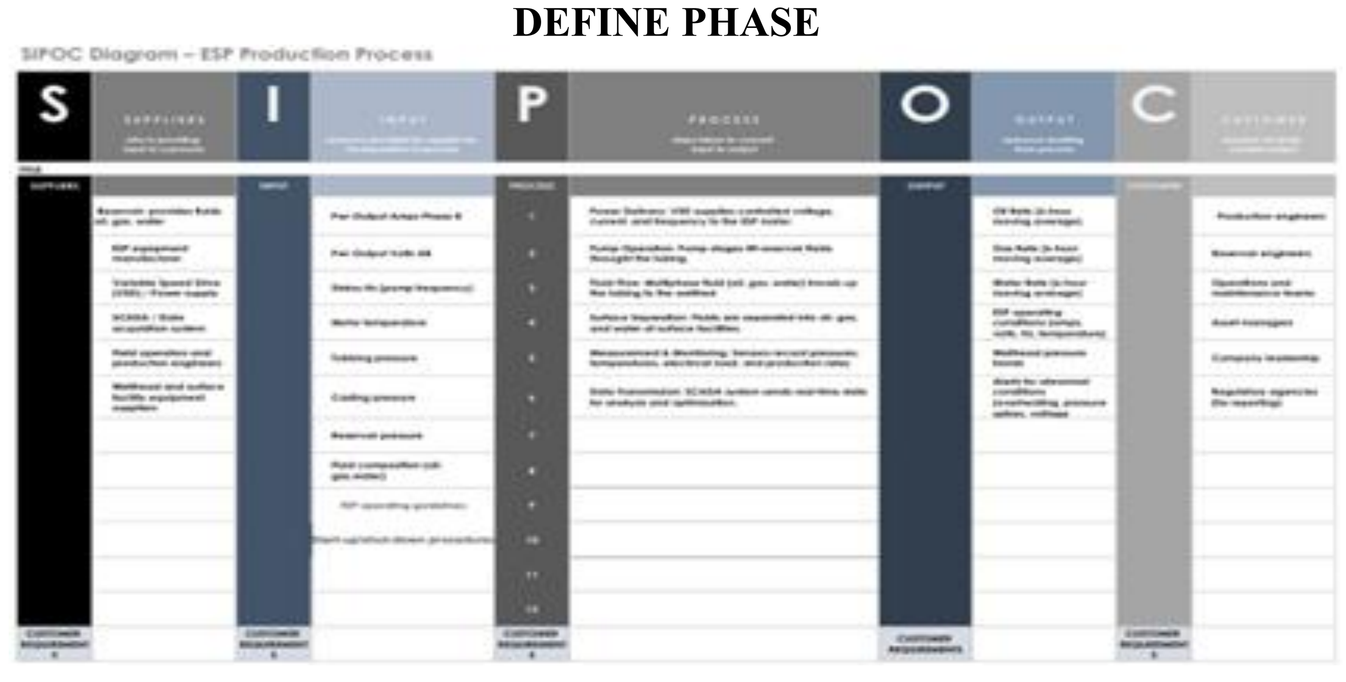

Figure 1: SIPOC Diagram

MEASURE PHASE

TABLE 1 Descriptive Statistics

	Pwr-Output Amps Ph B	Temp-Moto	Status-Hz	Tubing Pressure	Pwr-Output Volts AB	Casing Pressure	Oil Rate 6Hr MAvg	Gas Rate 6Hr Mavg	Water Rate 6Hr MAvg
Mean	284.99	235.13	54.73	174.27	265.39	178.56	82.23	1304.45	532.96
Std. Deviation	1.31	0.52	0.19	1.34	185.94	1.35	48.98	420.88	99.38
Minimum	274	233	54.1	169.37	0	173.44	0	294.6	0.31
Maximum	292	237	55.7	179.06	480	183.44	223.35	5258.58	677.63
Range	18	4	1.6	9.69	480	10	223.35	4963.98	677.32
Quartile 1	284	235	54.6	173.44	50.64	177.81	55.21	1166.37	533.27
Quartile 3	286	235	54.9	175.31	426	179.38	109.83	1335.71	571.93

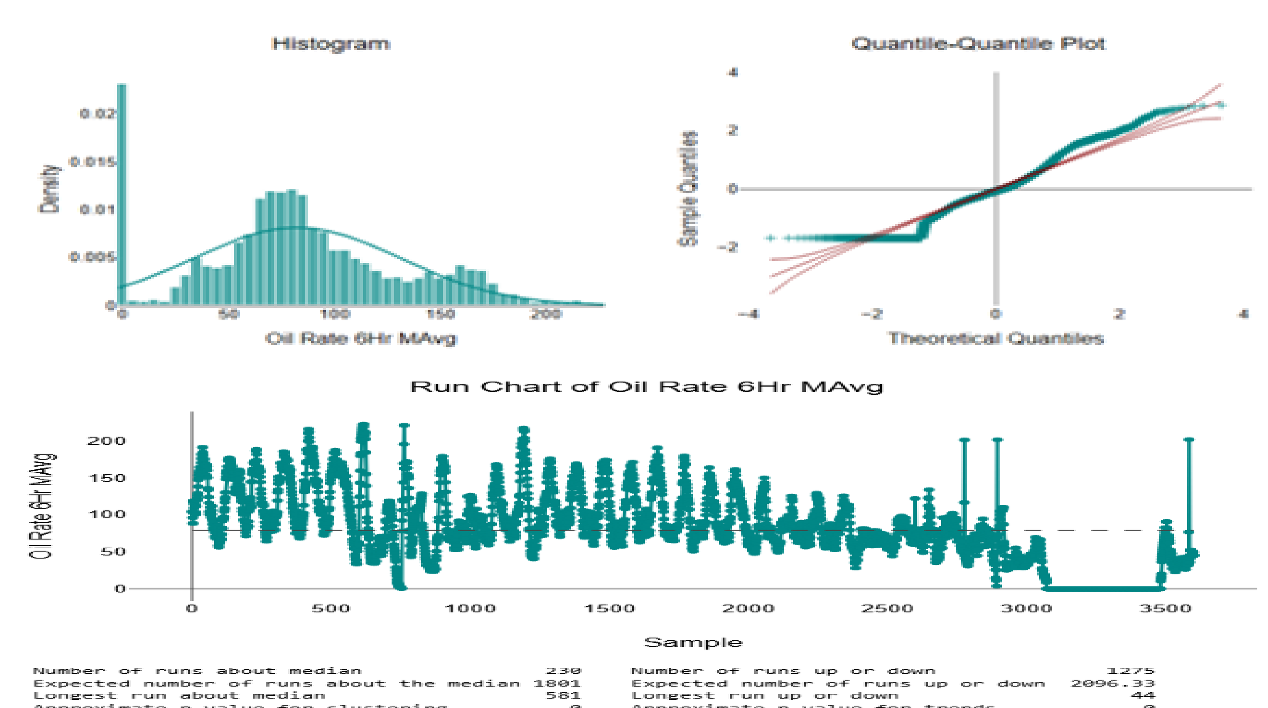

Figure 2: Histogram, Quantile-Quantile Plot, and Run charts for Oil rate 6Hr Mavg

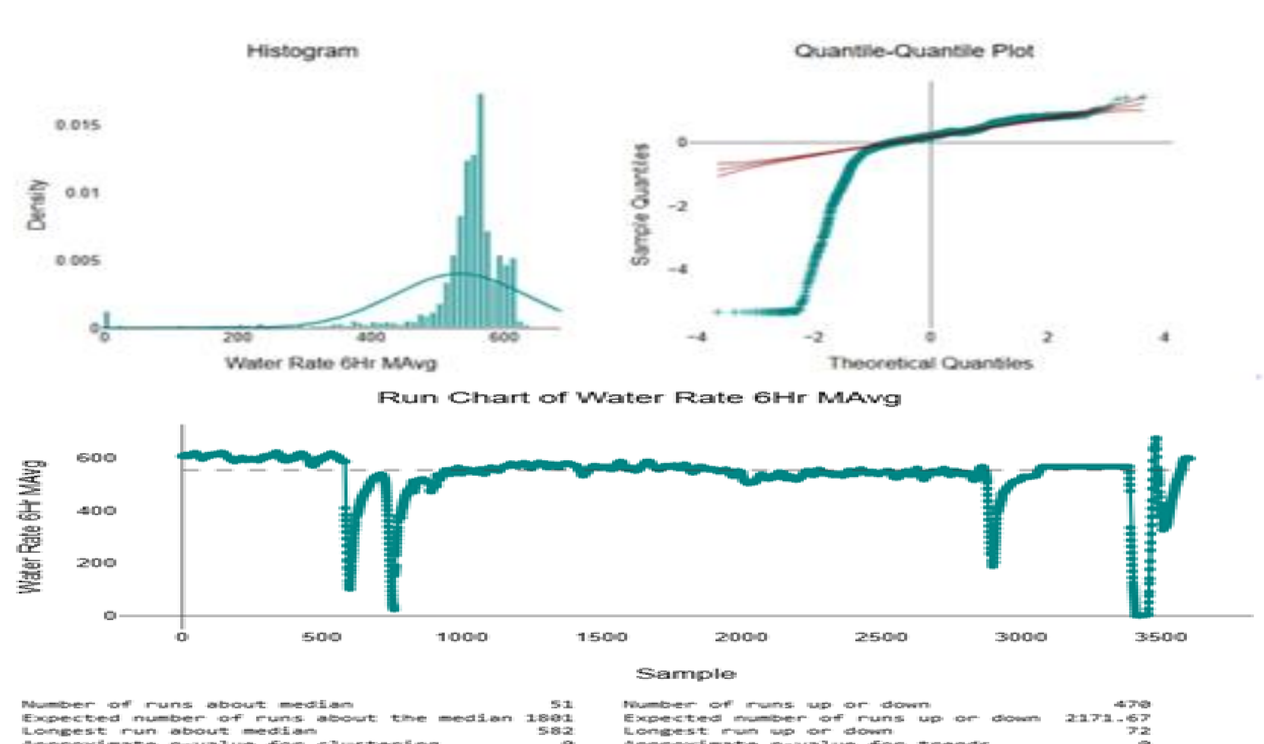

Figure 3: Histogram, Quantile-Quantile Plot, and Run charts for Water Rate 6Hr Mavg

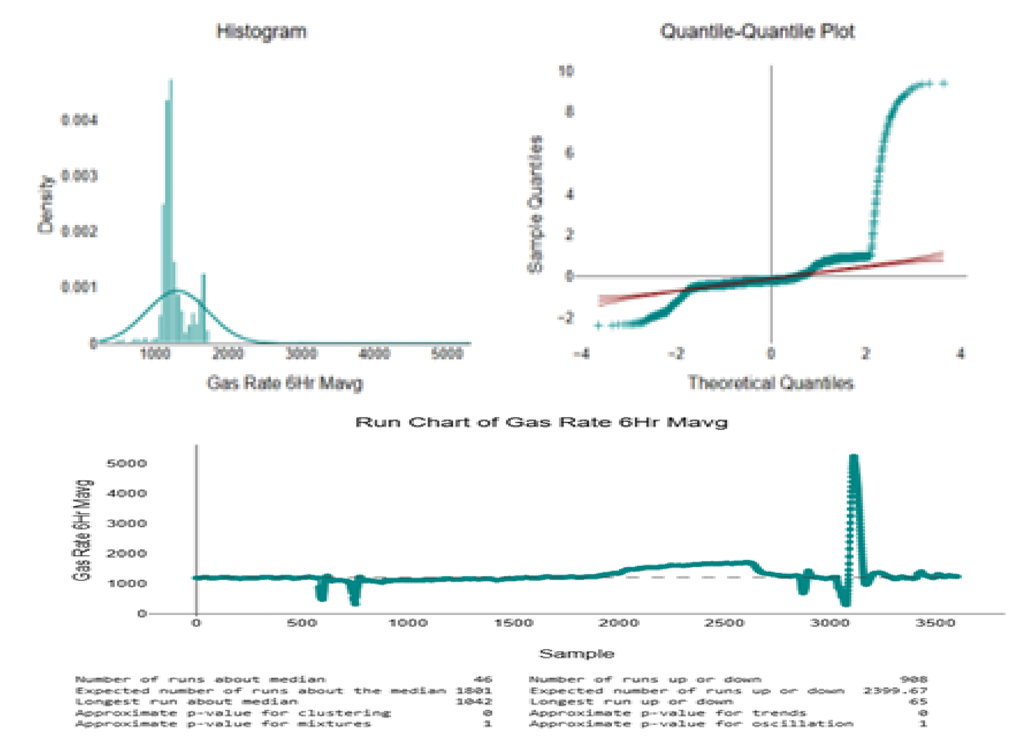

Figure 4: ***Histogram, Quantile-Quantile Plot, and Run charts for Gas Rate 6Hr Mavg***

ANALYZE PHASE

Table 2 Gas Rate 6Hr MAvg / Regression Statistics Summary (R, R², and Standard Error)

Metric	Value
R	0.36
R^2	0.13
Adjusted R^2	0.13
Standard Error of the Estimate	134.09

Table 3 Water Rate 6Hr MAvg Regression Statistics Summary (R, R², and Standard Error)

Metric	Value
R	0.21
R^2	0.05
Adjusted R^2	0.05
Standard Error of the Estimate	75.38

Table 4 Oil Rate 6Hr MAvg Regression Statistics Summary (R, R², and Standard Error)

Metric	Value
R	0.19
R^2	0.03
Adjusted R^2	0.03
Standard Error of the Estimate	40.72

IMPROVE PHASE

The Improve phase focused on developing recommendations to enhance production stability. Key opportunities included stabilizing pump frequency, optimizing intake and discharge pressures, and strengthening monitoring practices to minimize fluctuations.

CONTROL PHASE

The Control phase implemented long-term strategies to maintain operational stability, including standardized procedures, performance indicators, and continuous monitoring tools. These controls help ensure that improvements remain effective and that deviations can be detected and corrected promptly.

The Control Phase ensures that improvements implemented during the Improve Phase are sustained over time. Continuous monitoring, early warning indicators, and updated operational procedures are essential to maintaining stable ESP performance.

Conclusions

The project demonstrated that operational variables influence production stability but have limited predictive impact on oil and water production due to reservoir-dominated behavior. Gas production showed the strongest operational sensitivity. The Define, Measure, Analyze, Improve, and Control methodology provided a structured and effective framework for analyzing performance, identifying improvement opportunities, and developing long-term controls. The findings support the use of quality management principles in artificial lift optimization and highlight the importance of monitoring and stabilizing key operational parameters to enhance Electric Submersible Pump well performance.

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