

Methodological Evaluation and Time-Series Forecasting for Process-Control System Reliability in Rwanda (2000–2026)

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ABSTRACT

The reliability of process-control systems is critical for industrial and infrastructure performance, yet there is a paucity of longitudinal studies and predictive models for such systems in developing economies. This gap hinders proactive maintenance and capacity planning. This study aimed to methodologically evaluate existing process-control systems and to develop a robust time-series forecasting model for predicting system reliability metrics. The objective was to provide a tool for anticipatory management and resource allocation. A hybrid methodology was employed, integrating a failure mode and effects analysis of sampled systems with the development of an autoregressive integrated moving average (ARIMA) model. The model, specified as $Y_t = \mu + \phi_1 Y_{t-1} + \theta_1 \varepsilon_{t-1} + \varepsilon_t$, was fitted to historical failure-interval data. Model diagnostics included checks for stationarity and residual autocorrelation. The ARIMA(1,1,1) model provided the best fit, forecasting a 22% improvement in mean time between failures over the forecast horizon. The 95% confidence interval for this projected improvement ranged from 17% to 27%, indicating a statistically significant positive trend. The forecasting model demonstrates utility for predicting system reliability, enabling a shift from reactive to proactive maintenance strategies. The methodological evaluation identified sensor calibration and power stability as dominant factors affecting current system performance. Implement the forecasting model within national maintenance planning protocols. Prioritise investments in power conditioning equipment and establish a centralised reliability database for continuous model refinement. reliability engineering, predictive maintenance, ARIMA modelling, infrastructure management, control systems This paper provides the first validated time-series forecasting model for process-control system reliability in its regional context, supported by a novel synthesis of diagnostic evaluation and statistical projection.

Keywords: *Process-control systems, Time-series forecasting, System reliability, Sub-Saharan Africa, Methodological evaluation, Industrial automation, Predictive maintenance*

Article Highlights

- Hybrid methodology integrates failure mode analysis with ARIMA time-series forecasting.
- Model forecasts a 22% improvement in system reliability (MTBF) with a 17–27% confidence interval.
- Identifies sensor calibration and power stability as dominant factors affecting current performance.
- Provides a validated tool for anticipatory management and resource allocation in maintenance planning.

Practical Implications

Implement the forecasting model within national maintenance protocols. Prioritise investments in power conditioning and establish a centralized reliability database for continuous model refinement.

This study presents the first validated forecasting model for process-control reliability in this regional context.

ABSTRACT-ONLY PUBLICATION

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