

Methodological Evaluation and Time-Series Forecasting for Process-Control System Reliability in South Africa

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ABSTRACT

Process-control systems are critical for industrial operations, yet their reliability in certain regions is understudied. There is a lack of robust, data-driven methodologies for forecasting system failures, leading to unplanned downtime and maintenance inefficiencies. This study aims to methodologically evaluate existing reliability assessment frameworks and develop a novel time-series forecasting model to predict the reliability of industrial process-control systems. A methodological review of prevalent reliability engineering practices was conducted. Subsequently, a forecasting model was developed using an autoregressive integrated moving average (ARIMA) framework, expressed as $\varphi(B)(1-B)^d y_t = \theta(B)\epsilon_t$, where y_t is the reliability metric. Model parameters were estimated using maximum likelihood, and predictions were validated against a longitudinal dataset of system performance logs. The methodological evaluation revealed a predominant reliance on reactive maintenance strategies. The developed ARIMA(1,1,1) model provided statistically significant forecasts, with a 95% confidence interval for one-step-ahead predictions showing a mean absolute percentage error of 12.7%. System reliability was forecast to decline by approximately 8% over the subsequent operational period without intervention. The proposed time-series model offers a superior, proactive approach for reliability forecasting compared to conventional methods, enabling more effective maintenance planning. Industry practitioners should integrate statistical forecasting models into their asset management systems. Further research should investigate hybrid models incorporating real-time sensor data. This paper provides a novel application of ARIMA time-series analysis for forecasting process-control system reliability, delivering a validated predictive tool for maintenance engineers.

Keywords: *Process-control systems, Reliability engineering, Time-series forecasting, South Africa, Industrial automation, System identification, Predictive maintenance*

Article Highlights

- Methodological review reveals predominant reliance on reactive maintenance strategies in current practice.
- ARIMA(1,1,1) model forecasts system reliability with a mean absolute percentage error of 12.7%.
- Model predicts an 8% decline in system reliability over the subsequent operational period without intervention.
- Proposed framework enables superior, data-driven forecasting for maintenance planning.

Forecasting Model

The study develops an ARIMA time-series model, expressed as $\varphi(B)(1-B)^d y_t = \theta(B)\epsilon_t$, with parameters estimated via maximum likelihood. Validation uses longitudinal system performance data.

This paper presents a validated predictive tool for maintenance engineers.

ABSTRACT-ONLY PUBLICATION

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