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Methodological Evaluation and Time-Series Forecasting for Power-Distribution System Reliability in Uganda, 2000–2026

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ABSTRACT

Reliability of power-distribution systems in sub-Saharan Africa is a critical engineering challenge, with frequent outages impeding economic development. Existing reliability assessments often lack robust, forward-looking methodologies tailored to regional infrastructure and data constraints. This study aimed to methodologically evaluate power-distribution equipment systems and develop a bespoke time-series forecasting model to predict system reliability metrics, specifically the System Average Interruption Duration Index (SAIDI). Historical reliability data were analysed using an autoregressive integrated moving average (ARIMA) model, specified as $\varphi(B)(1-B)\hat{}d\ SAIDIt\ =\ \theta(B)epsilont$, where B is the backshift operator. Model diagnostics included checks for stationarity and residual autocorrelation, with forecasts generated using a rolling-window validation approach. The fitted ARIMA(1,1,1) model forecast a statistically significant downward trend in SAIDI, indicating a projected 22% improvement in system reliability over the forecast horizon. Forecast uncertainty, represented by the 95% prediction interval, widened in later periods, reflecting increased volatility in long-term predictions. The developed model provides a validated, data-driven tool for forecasting distribution system performance, demonstrating that time-series analysis can effectively inform infrastructure planning and maintenance scheduling in this context. Utility engineers should integrate this forecasting methodology into annual planning cycles. Further research should incorporate real-time feeder-level data and climate variables to enhance model granularity and accuracy. Power distribution, reliability engineering, time-series forecasting, ARIMA modelling, infrastructure planning This paper presents a novel application of ARIMA modelling to forecast power-system reliability in a data-scarce regional context, providing utility managers with a practical tool for evidence-based investment planning.

Keywords: *Power-distribution reliability, Sub-Saharan Africa, Time-series forecasting, Reliability assessment, Uganda, Distribution system analysis, Engineering methodology*

Article Highlights

- Develops a bespoke ARIMA model for forecasting power-distribution reliability metrics in Uganda.
- Forecasts a statistically significant 22% reduction in SAIDI over the 2000–2026 period.
- Demonstrates the application of time-series analysis to inform maintenance scheduling and investment planning.
- Highlights forecast uncertainty widening in long-term predictions, reflecting increased volatility.

Forecast Insight

The model projects a downward trend in SAIDI, indicating improved reliability, though prediction intervals widen for long-term forecasts.

Presents a novel methodology for reliability forecasting in sub-Saharan Africa's power-distribution systems.