

Predictive Maintenance in SMT Machines Using Electrical Multiparameter Sensors and Hybrid Machine Learning Models

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INTRODUCTION & AIM

Surface-Mount Technology (SMT) manufacturing demands high operational reliability. Predictive maintenance based on continuous sensor monitoring has emerged as a promising approach, but its effectiveness depends on robust anomaly detection systems.

CHALLENGE:

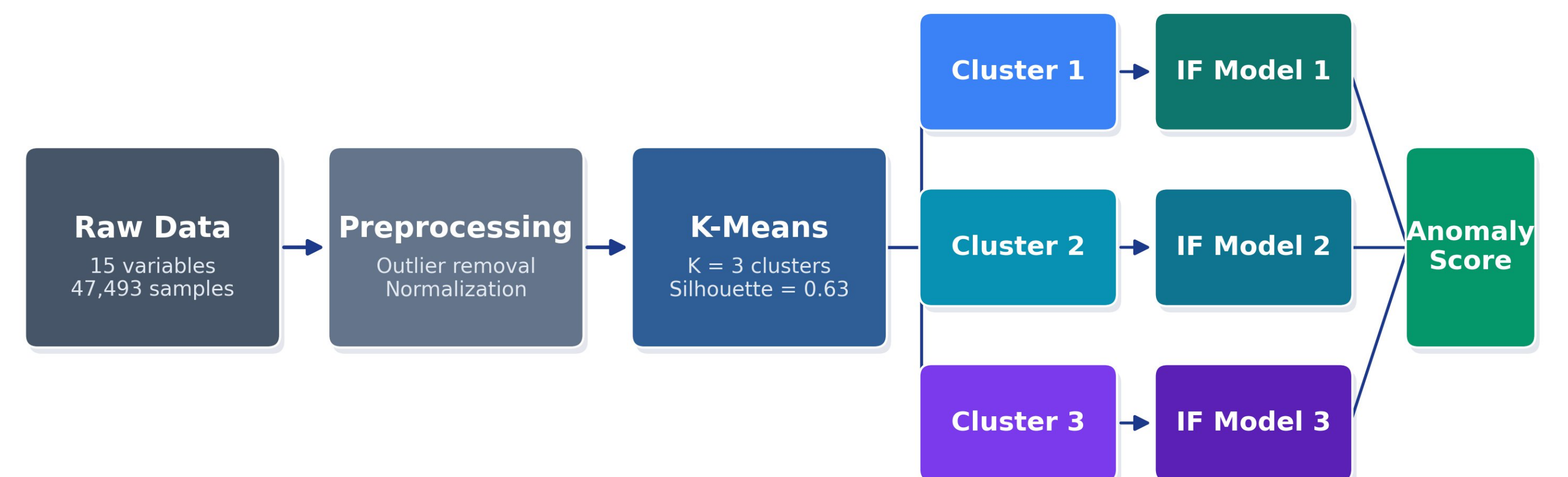
Traditional global methods (Isolation Forest, One-Class SVM, Local Outlier Factor) assume a single operational context, failing to adapt detection behavior across different regimes and often producing unstable alarms.

AIM:

Develop a context-aware hybrid approach combining K-Means clustering for automatic regime segmentation (K=3 selected via silhouette-score grid search over K=2–10) with cluster-specific Isolation Forest models for anomaly detection.

METHOD

Proposed Hybrid K-Means + Isolation Forest Pipeline



RESULTS & DISCUSSION

+53%

Regime Separability

Silhouette 0.63 vs 0.41
→ Operational regimes are machine-learnable

+37%

Temporal Stability

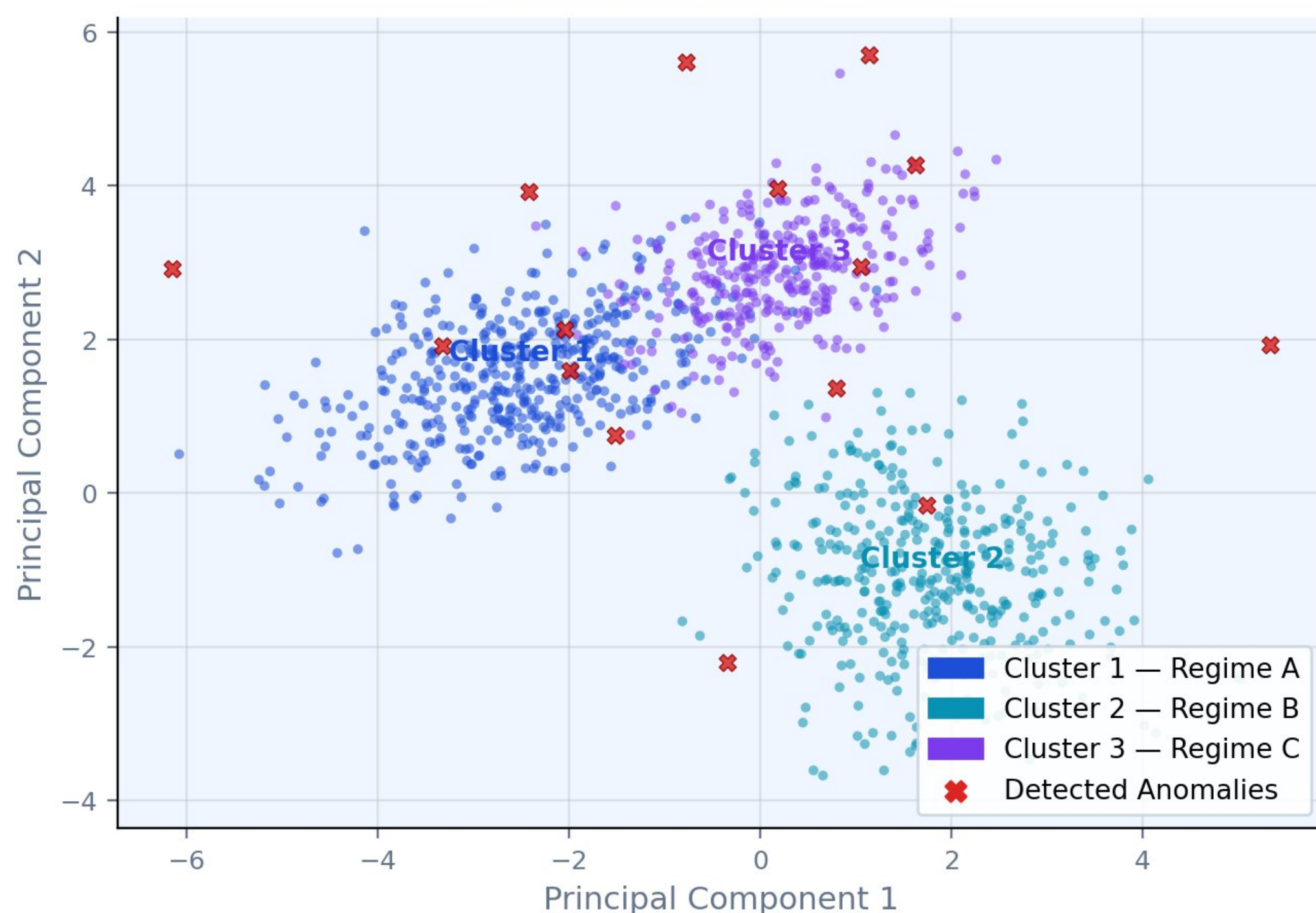
CV 0.96 vs 1.52
→ Fewer false alarms, less operator fatigue

51×

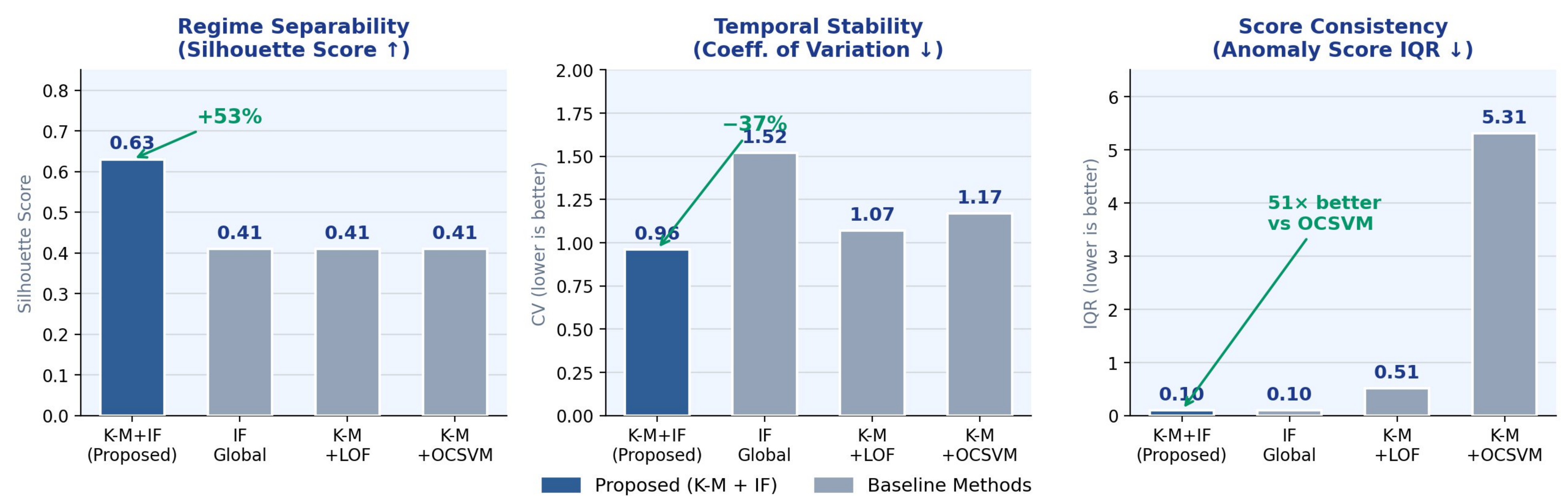
Score Consistency

IQR 0.10 vs 5.31
→ A single threshold works for all regimes

Operational Regime Segmentation (PCA Projection)
Silhouette Score = 0.63



Comparison of Anomaly Detection Methods



Method	Detection Rate (%) ①	Temporal CV	Score IQR
K-M + IF (Proposed)	1.00	0.96	0.10
IF Global (Baseline)	1.00	1.52	0.10
K-M + LOF	0.90	1.07	0.51
K-M + OCSVM	1.01	1.17	5.31

Dataset: 47,493 samples · 2.5 months · electrical sensor (15 variables: voltage, current, active/reactive/apparent power, power factor, frequency)

HOW TO READ THESE METRICS

Silhouette ↑ (>0.5 = strong cluster structure)

Coefficient of Variation ↓ lower = fewer erratic alarms.

Score IQR ↓ lower = comparable thresholds.

DISCUSSION — WHY THIS MATTERS

All methods detect anomalies at the same ~1% rate — detection rate is NOT the differentiator. The hybrid produces stable, comparable scores across regimes, enabling a single alarm threshold for the entire production line — something global IF cannot achieve.

CONCLUSIONS

- ✓ Context-aware approach achieves 53% better regime separability compared to global methods
- ✓ 37% improvement in temporal stability effectively reduces erratic alarm peaks
- ✓ Maintains equivalent detection rate (1.0%), confirming gains arise from contextual adaptation rather than sensitivity increase
- ✓ Successfully deployed in production environment, demonstrating practical viability for industrial predictive maintenance

FUTURE WORK / ACKNOWLEDGMENT

FUTURE WORK

Multimodal sensor fusion

Combine electrical signals with vibration, temperature, and acoustic data to capture failure modes invisible to electrical monitoring alone.

Fault prognosis & Remaining Useful Life

Evolve from anomaly detection to predictive prognosis: estimate the Remaining Useful Life of components from cluster transitions and anomaly score evolution over time.

ACKNOWLEDGMENT

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.