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TECHNICAL WHITEPAPER

Breaker Guard (BG2502K): Made-in-India Electromechanical Safety Interlock for Power Distribution

Patented Innovation: Indian Patent Application No. 202411068969 / 202411749873

Maturity Level: Technology Readiness Level 7 (TRL-7 Field Validated)

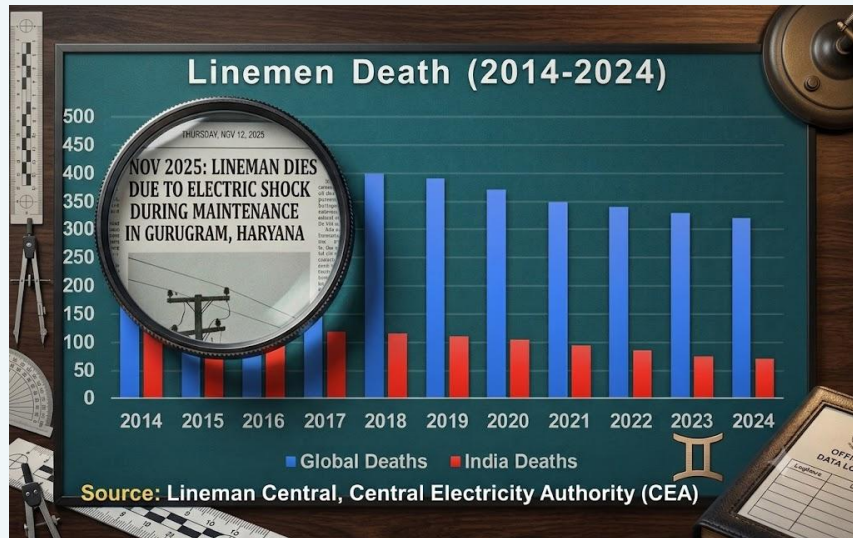
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1. Executive Summary & Strategic Mandate

Every year across India's electrical distribution networks, preventable electrical accidents claim the lives of dozens of utility technicians — resulting in over 1,000 lineman fatalities across the past decade and approximately 70 in 2024 alone (Central Electricity Authority / Lineman Central data). These tragedies stem from a systemic operational failure: reliance on verbal phone calls, manual paper Permits-to-Work (PTW), and mechanical padlocks (LOTO) that provide zero physical or cryptographic enforcement at the circuit breaker faceplate.



Breaker Guard (Model BG2502K, Indian Patent App. Nos. 202411068969 / 202411749873) bridges this life-or-death vulnerability. Engineered at IIT Kanpur and field-validated at Technology Readiness Level 7 (TRL-7), Breaker Guard is a 100% indigenous, bolt-on retrofit interlock that integrates into existing 11 kV and 33 kV Vacuum Circuit Breaker (VCB) and Air Circuit Breaker (ACB) control panels. It physically and electronically immobilizes the breaker closing loop until the assigned field lineman enters or authorizes a unique, task-scoped, single-use One-Time Password (OTP). Operating across 50 active units in 11 substations across all 5 UPPCL DISCOMs (KESCo, Lucknow, Agra, Meerut, Varanasi), Breaker Guard places the physical power of life and death directly into the hands of the technician working on the de-energized line.

2. The Operational Safety Gap & Systemic Root Causes

In Tier-2, Tier-3, semi-urban, and rural distribution circles spanning India's 60+ DISCOMs, advanced Supervisory Control and Data Acquisition (SCADA) and Automated Distribution Management Systems (ADMS) remain largely absent. Safety enforcement relies almost entirely on informal voice calls between field line technicians and Substation Operators (SSOs). This convention exposes utilities to four fatal failure modes:

- **Unrestricted Breaker Operation:** Conventional panels lack mechanical or digital closing blocks. Accidental, unauthorized, or premature breaker re-energization can occur at any moment while linemen are actively working on downstream conductors.
- **Feeder Misidentification Under Fatigue:** High visual panel density and cognitive exhaustion frequently lead operators to switch the wrong breaker among rows of identical panels, re-energizing a live maintenance zone instead of an isolated feeder.

- **Diffuse Accountability & Verbal Handoffs:** Permit-to-Work execution conducted via mobile phone calls or paper logbooks creates ambiguity and unrecorded instructions. When electrocutions occur, contract linemen bear the catastrophic consequences without verifiable operational records.
- **Inefficient Key Custody & Outage Duration:** Conventional dual-key trapped-key systems depend on physical custody. Lost keys, unauthorized duplication, and travel delays between line spans inflate SAIDI/SAIFI reliability penalties.

2.1 Operational Risk vs. Breaker Guard Failsafe Workflow

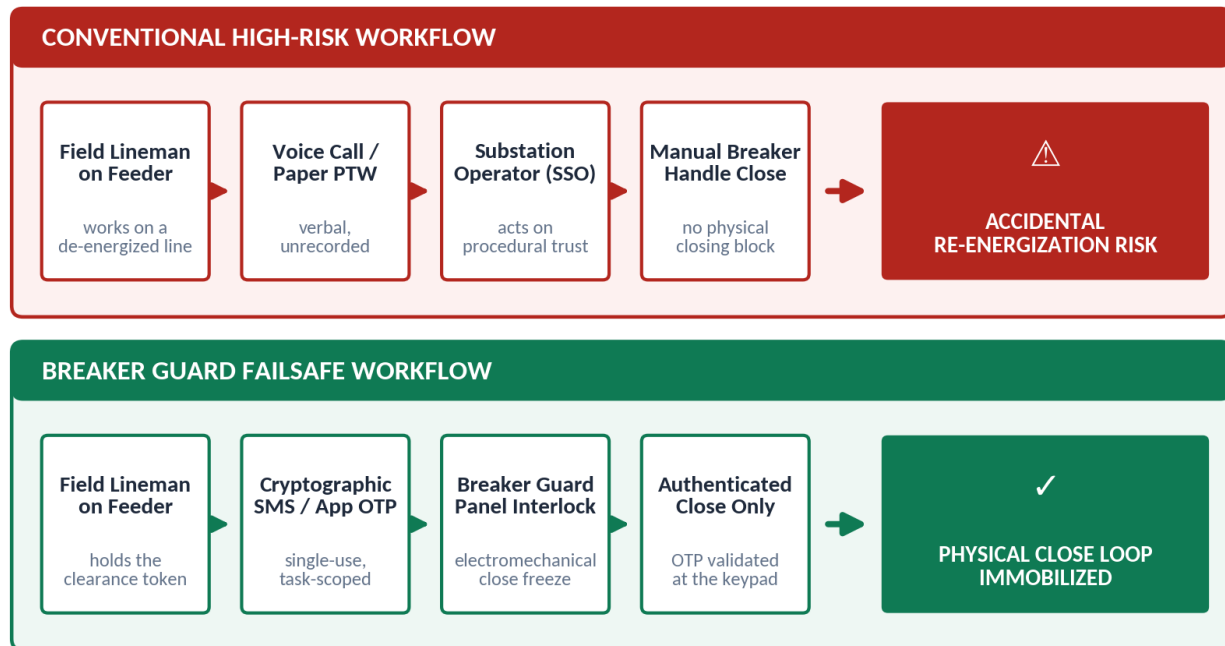


Fig. 1 — Conventional high-risk switching workflow versus the Breaker Guard failsafe workflow

3. Primary Stakeholder Impact: Lineman Safety Centricity

Breaker Guard transforms the occupational safety hierarchy of power distribution. The field lineman — who physically applies portable earths, climbs distribution poles, and handles bare conductors — has historically borne all residual risk arising from human error at the substation. Breaker Guard shifts the safety guarantee from procedural trust to deterministic hardware: re-energization is mathematically and physically impossible without that specific lineman's cryptographic sign-off.

Secondary utility stakeholders benefit equally: Junior Engineers (JEs) and Substation Operators gain an unalterable, legally defensible audit trail of every operational permit and bypass action; DISCOM leadership mitigates statutory compensation claims, legal liabilities, and public reputational crises; and system consumers experience faster restoration times and reduced unserved energy through digitized outage handshakes.

4. Technical Architecture, Hardware Specifications & Front Panel

Breaker Guard installs directly onto the faceplate of existing switchgear without requiring panel replacement or busbar redesign. It splices into the low-voltage auxiliary tripping and closing circuits, maintaining an electromechanical freeze on the close coil until cryptographic clearance is achieved.



Fig. 2 — Industrial Breaker Guard Field Unit (Model BG2502K)

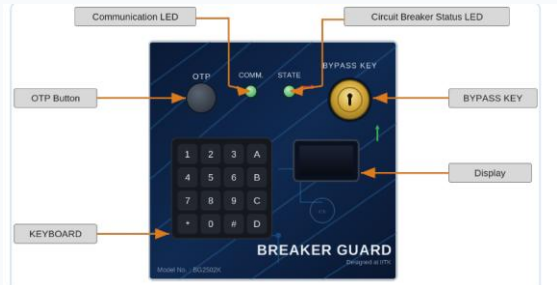


Fig. 3 — Front-Panel Component Layout & Interface Elements

4.1 Comprehensive Technical & Electrical Specifications

Electrical / System Parameter	Specification / Rating	Hardware / Interface	Technical Capability
Model Designation	BG2502K (Patent App. 202411068969)	Core Processor	Dual-Core 32-bit (80 / 240 MHz clock)
Operating Voltage	110–250 V AC / 24 V DC auxiliary	Telecommunications	Integrated 5G/GSM Gateway + 802.11 b/g/n Wi-Fi
Power Consumption	< 5 W nominal (< 1.0 A continuous)	Primary Display	1.3-inch high-contrast industrial OLED
Enclosure Protection	IP54 dust and splash-proof panel mount	User Input Array	4×4 Weatherproof Membrane Keypad
Physical Dimensions	14.06 cm × 10.6 cm × 5.6 cm	Manual Override	90° Industrial Rotary Key Switch (SSO Custody)
Relay Interlock Loop	Fail-safe electromechanical close inhibit	Audit Storage	Non-volatile on-board Flash + Cloud Database

4.2 Front Panel Diagnostic LED Telemetry Matrix

Indicator Component	Optical State	Operational State & Hardware Behavior
COMM. LED (Network)	Solid Red	Gateway disconnected / zero cellular or Wi-Fi coverage found
COMM. LED (Network)	Solid Green	Connected to Wi-Fi / active GSM cloud synchronization operational
COMM. LED (Network)	Flashing Green	Connected to network layer; cloud server ping pending or unacknowledged
COMM. LED (Network)	Flashing Blue	Local Wi-Fi Access Point (AP) mode active for field provisioning
STATE LED (Breaker)	Pulsing Blue	OTP verification active / system awaiting cryptographic token input
STATE LED (Breaker)	Solid Green	OTP authentication successful — interlock loop de-energized; closing allowed

5. Standard Operating Workflow: Five-Step Failsafe Sequence

Breaker Guard converts breaker closing into a deterministic cryptographic sequence. The procedure enforces multi-gang crew clearance and provides dual-path verification across remote areas with intermittent telecom coverage:

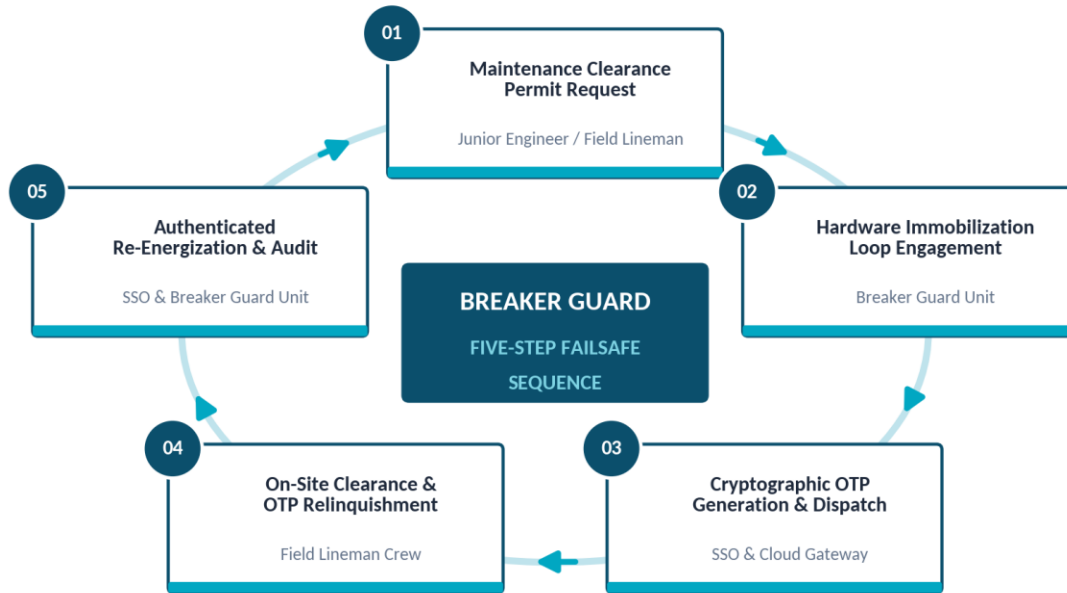


Fig. 4 — The five-step failsafe sequence: no breaker close is possible without the field crew's cryptographic sign-off

Step	Operational Phase	Responsible Actor	Technical Logic & Protocol
Step 01	Maintenance Clearance Permit Request	Junior Engineer (JE) / Field Lineman	Crew requests line shutdown via Breaker Guard Mobile App or control center. Substation Operator (SSO) trips the feeder breaker. JE assigns the task to specific lineman mobile credentials.
Step 02	Hardware Immobilization Loop Engagement	Breaker Guard Unit	Upon breaker tripping, Breaker Guard automatically engages its electromechanical interlock loop across the closing auxiliary circuit. Faceplate closing switches and remote trip/close commands are physically frozen.
Step 03	Cryptographic OTP Generation & Dispatch	SSO & Cloud Gateway	SSO depresses the dedicated physical OTP Button on the panel. The cloud gateway generates an encrypted, task-scoped, time-decay 6-digit OTP token and transmits it directly to the registered phone(s) of the lineman crew.
Step 04	On-Site Clearance & OTP Relinquishment	Field Lineman Crew	Field crew completes mechanical repair, physically detaches earthing leads, confirms clearance of all personnel, and communicates their received OTP token back to the substation control desk.

Step 05	Authenticated Re-Energization & Audit Write	SSO & Breaker Guard Controller	SSO inputs the OTP token(s) via the 4×4 keypad. The controller validates the cryptographic token, de-energizes the interlock relay, grants closing permission, and logs the millisecond-stamped event to non-volatile flash and cloud servers.
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6. Comparative Benchmark Analysis: SCADA, Dual-Key LOTO & Breaker Guard

Conventional distribution operations rely on either centralized SCADA systems utilizing electronic Permits-to-Work (e-PTW) or decentralized mechanical dual-key (trapped-key) interlocking. As demonstrated below, both architectures possess structural failure modes that leave field crews exposed to fatal accidents:

Evaluation Dimension	SCADA / e-PTW Infrastructure	Dual-Key (Trapped-Key) LOTO	Breaker Guard (BG2502K)
Physical Breaker Close Lockout	No — software inhibit only; faceplate switch remains operable	Yes — mechanical key trapped in lock mechanism	Yes — electromechanical interlock + cryptographic OTP token
Local Panel Access Risk	Vulnerable to local faceplate operator override or comms glitch	Key-dependent; prone to master-key bypassing / bolt-cutters	Physically frozen at faceplate until multi-party OTP entry
Real-Time Telemetry & Visibility	High — control-center SCADA visibility only	Zero — decentralized, isolated manual paper logbooks	High — synchronized cloud dashboard, mobile app, and flash audit
Multi-Crew Scalability	Requires manual control-room coordination across crews	Inflexible; cannot scale dynamically across independent gangs	Dynamic multi-lineman registration (up to 5 crews per feeder)
Emergency Bypass Control	Control room software override	Unregulated physical master key / mechanical lock removal	SSO rotary key switch with instant automated cloud escalation
Capital Expenditure (CapEx)	Very High — multi-crore SCADA, RTU, and comms network overhaul	Low CapEx, but purely procedural with heavy operational friction	Low — bolt-on non-disruptive retrofit across legacy panels

7. Field Deployment, Utility Validation (TRL-7) & Operational Insights

Breaker Guard has proven field robustness through extensive Technology Readiness Level 7 (TRL-7) validation across Uttar Pradesh Power Corporation Limited (UPPCL) infrastructure, anchored by Kanpur Electricity Supply Company (KESCO):

Field Deployment Parameter	Operational Metric & Utility Performance
Total Installed Base	50 industrial Breaker Guard units deployed and commissioned

Substations Commissioned	11 primary distribution substations operating at 11 kV / 33 kV voltage classes
Geographical Reach	Spanning all 5 UPPCL DISCOMs across Kanpur (KESCo), Lucknow, Agra, Meerut, and Varanasi
Key Deployment Sites	KESCo Lighthouse 11 kV Feeder, New RPH Substation, and Kesa Colony Substation, Kanpur
Installation Velocity	Rapid 1-day turnaround per substation (5 to 10 breaker panels retrofitted per single day)
Operational Interruption	Zero downtime retrofit integration without altering busbars, relays, or internal breaker mechanics

7.1 Operational Lessons & Standardized Pre-Check Protocols

- **TNC Switch Health Verification:** Field validation demonstrated the necessity of inspecting the physical health of existing Trip-Neutral-Close (TNC) switches prior to retrofitting. A standardized pre-check protocol has been incorporated into national deployment playbooks.
- **Cellular Failover Redundancy:** Substations located in dense or low-elevation urban areas occasionally experience spot carrier attenuation. Breaker Guard's dual-path GSM/Wi-Fi architecture guarantees uninterrupted cryptographic dispatch and offline token caching.
- **Tamper-Proof JSON Audit Logging:** 100% of feeder shutdowns, lineman OTP entries, and manual key bypasses are streamed into immutable JSON database logs, providing DISCOM leadership with tamper-proof compliance visibility.

8. Scale-Up Roadmap & Commercial OEM Integration

Commercial scale-up shall proceed in four validated stages, moving from a completed utility pilot to factory-level integration inside the switchgear supply chain:

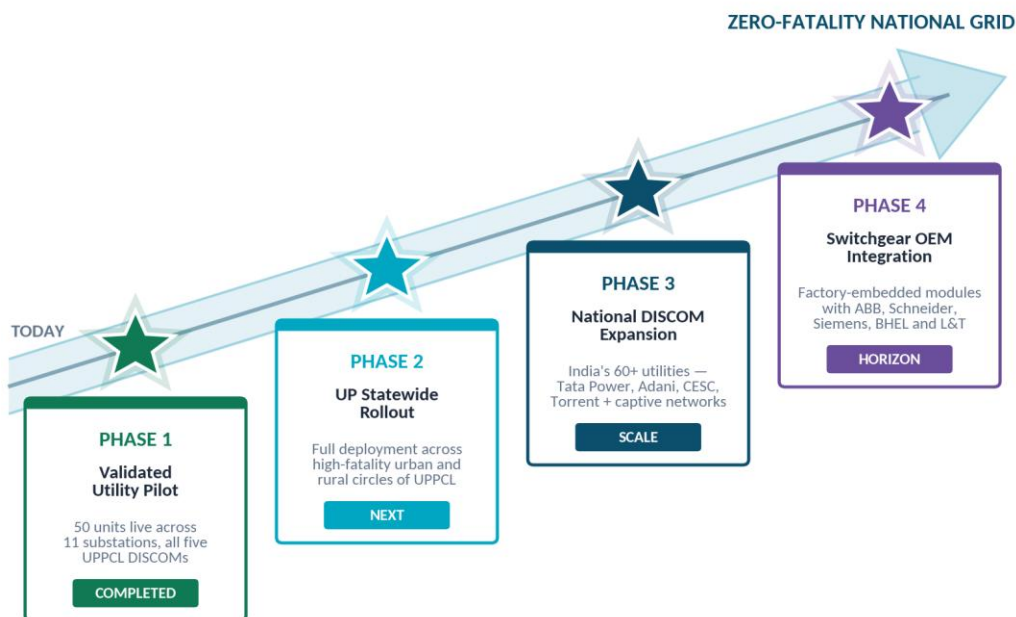


Fig. 5 — Scale-up roadmap: from validated UPPCL pilot to national DISCOM deployment and switchgear OEM integration

9. Strategic Value for Utility Leadership & Call to Action

For DISCOM Managing Directors, Technical Directors, and Chief Safety Officers, Breaker Guard delivers tangible institutional, financial, and legal benefits:

- **Zero-Fatality Realization:** Eliminates the human-error window by replacing fragile verbal handoffs with an unbypassable, cryptographic mobile handshake.
- **CapEx-Efficient Modernization:** Delivers advanced digital safety interlocking across legacy distribution substations at a tiny fraction of the cost of full SCADA/ADMS automation overhauls.
- **100% Indigenous Technology (Aatmanirbhar Bharat):** Engineered, patented, and manufactured entirely in India out of the IIT Kanpur innovation ecosystem, ensuring sovereign technological self-reliance.
- **Statutory & Legal Risk Elimination:** Safeguards utility executives and engineers against statutory liabilities, industrial court penalties, and reputational backlash caused by occupational electrocutions.

URGENT CALL TO ACTION FOR DISCOM LEADERSHIP

Lineman electrocutions are not unavoidable occupational hazards — they are systemic failures of obsolete manual processes.

With a modest investment in technology adoption, utility leadership can protect frontline personnel, enforce uncompromised operational discipline, and lead India's smart grid modernization. We invite DISCOM decision-makers, industrial grid operators, and OEM partners to join the Breaker Guard national rollout and establish zero-fatality power networks.

10. Intellectual Property, Institutional Contacts & Glossary

The underlying hardware architecture, digital interlocking mechanism, and fail-safe cryptographic workflows are protected under Indian Patent Application Nos. 202411068969 and 202411749873 (Inventors: Ritik Rajput, Manish K. Gupta, Pratik Sharma, Ankush Sharma).

COMMERCIAL ENQUIRIES & INSTITUTIONAL PROCUREMENT

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Technical Glossary

Term / Acronym	Technical & Operational Definition
OTP	One-Time Password; dynamic single-use, time-decay cryptographic token.
LOTO	Lockout-Tagout; conventional manual electrical isolation and padlock tagging.
PTW / e-PTW	Permit-to-Work / Electronic Permit-to-Work system for authorized line clearance.

SBO	Select-Before-Operate; remote-switching safety command protocol (IEC 61850 / DNP3).
DISCOM	Power Distribution Company (e.g., UPPCL, KESCo, PVVNL, DVVNL, MVVNL, PuVVNL).
SSO	Substation Operator / Shift Safety Officer; designated custodian of panel operations.
TNC Switch	Trip-Neutral-Close switch utilized on medium-voltage breaker faceplates.
SAIDI / SAIFI	System Average Interruption Duration / Frequency Index; utility reliability benchmarks.

Authoritative Industry References

- [1] Central Electricity Authority (CEA), Ministry of Power, National & State Electrical Safety and Fatality Reports.
- [2] Lineman Central, Global Power Utility Lineman Safety & Electrocution Statistical Records, 2024–2025.
- [3] Innovative Grid Services Pvt. Ltd., Comparative Safety Benchmark: SCADA e-PTW, Trapped-Key Interlocks, and Breaker Guard IoT Architecture, 2026.
- [4] R. Rajput, M. K. Gupta, P. Sharma, A. Sharma, Electromechanical Interlocking Mechanism for Power Distribution Switchgear, Indian Patent Application Nos. 202411068969 / 202411749873, IIT Kanpur.
- [5] Innovative Grid Services Pvt. Ltd., Breaker Guard Engineering Datasheet & User Operation Manual (BG2502K), June 2026.

ABOUT INNOVATIVE GRID SERVICES

Innovative Grid Services Pvt. Ltd. (IGS) is a deep-tech engineering enterprise incubated at the Startup Incubation and Innovation Centre (SIIC), Indian Institute of Technology (IIT) Kanpur. Operating at the intersection of electrical power-systems engineering, embedded systems, and industrial IoT, IGS is mandated to resolve systemic, life-critical operational hazards across India's electrical transmission and distribution infrastructure. Breaker Guard represents the company's flagship hardware innovation — conceived, engineered, and validated out of field research into actual electrical maintenance accidents inside live distribution substations.