



## A CASE STUDY ON PERSONAL PROTECTIVE EQUIPMENT USE IN TRANSMISSION AND DISTRIBUTION CONSTRUCTION

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### ABSTRACT

Transmission and Distribution (T&D) construction projects in India are among the most hazardous segments of the infrastructure sector, involving frequent work at height, proximity to live electrical components, and heavy equipment operation. Despite regulatory frameworks mandating the use of Personal Protective Equipment (PPE), compliance on ground remains inconsistent and often compromised by various socio-environmental and managerial factors. This study investigates the real-world patterns of PPE usage in the Indian T&D construction Context through a mixed-methods case study approach involving field observations, structured interviews, and worker surveys at three project sites.

The results indicate high awareness of PPE guidelines among workers and site engineers, but actual and consistent usage remains suboptimal. Key barriers include discomfort due to climatic conditions (e.g., heat making gloves and reflective jackets unbearable), delays in PPE distribution, inadequate stock management, and lack of regular training. Interviews with safety officers and supervisors reveal that strong supervision and periodic audits are directly linked to better compliance. Worker behavior and attitudes, shaped by cultural norms and peer influence, also play a critical role in safety practice adoption.

The paper concludes with a set of targeted recommendations, such as integrating climate- appropriate PPE, strengthening enforcement through site-level accountability, adopting digital PPE tracking, and using behavioral-based training programs. The research fills a crucial gap by offering field-driven insights and actionable strategies to improve PPE adoption and safety outcomes in T&D projects in India. These findings are relevant for policymakers, public utilities, private contractors, and international agencies aiming to enhance worker welfare and reduce occupational hazards in the Indian power infrastructure sector.

**Keywords:** Personal Protective Equipment (PPE), Transmission and Distribution (T&D) Construction, Occupational Health and Safety (OHS), Safety Compliance, Construction Worker Behavior, Field Safety Practices, PPE Usage Challenges, High Voltage Line Safety, Safety Culture in Construction.

### 1. Introduction

Transmission and Distribution (T&D) line construction is one of the most hazardous tasks in the power sector. Workers are exposed to electrical, mechanical, and environmental risks such as falls from height, arc flashes, electrocution, and struck-by hazards. Personal Protective Equipment (PPE) plays a vital role in reducing the severity of injuries during such operations. This literature review examines scholarly research, international standards, and field reports regarding the effectiveness, compliance, and challenges of PPE use in T&D line construction, in support of a case study on real-world applications.

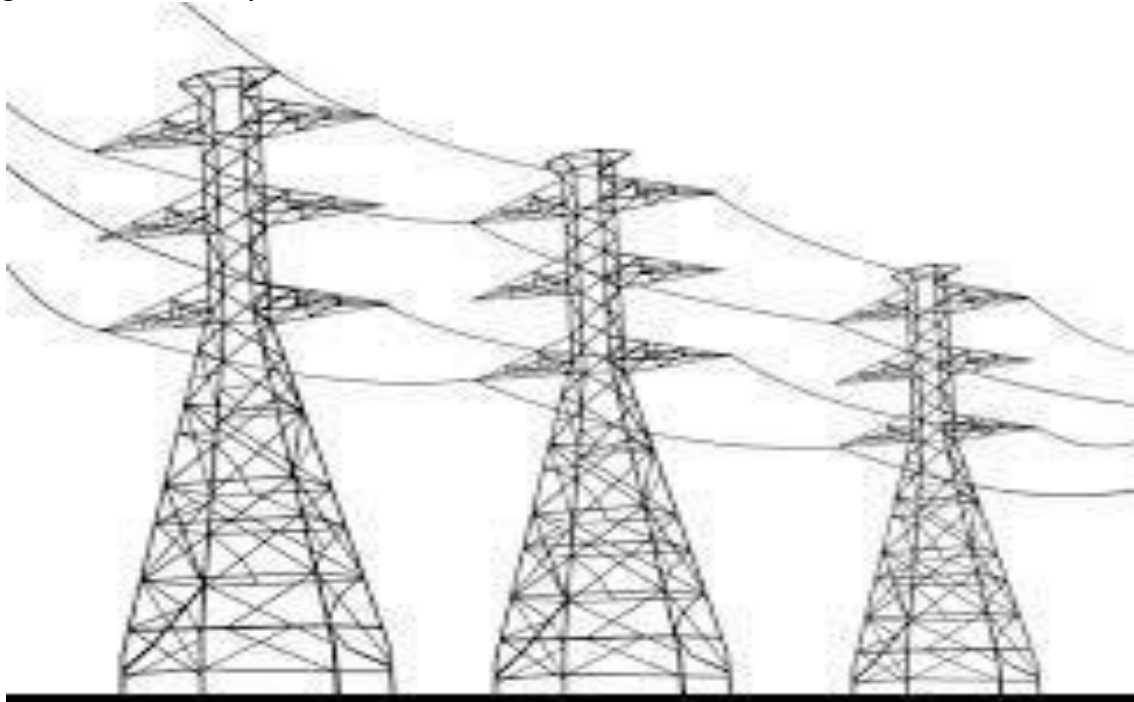
A transmission line is a high voltage power line that carries Electricity over long distances from power generation sources (such as power plants) to substations. These lines operate at voltages typically ranging from 66 kV to 765 kV to minimize energy losses. They are supported by large towers.

Towers parts are primarily constructed using galvanized steel due to its exceptional strength, Durability and ability to withstand environmental factors. The galvanization process involves Coating the steel with a layer of zinc, which enhances its resistance to corrosion, the selection of

materials for transmission towers depends on factors such as voltage requirements, environmental conditions, and economic considerations. Ensuring longevity even under harsh weather conditions. And use conductors designed for efficient power transfer from One place to another place.

It is made by Aluminum due to its lightweight nature and good conductivity, aluminum is extensively used in transmission lines. Its lower density reduces the overall weight of the conductors, leading to decreased sag and reduced structural support requirements. However, aluminum has lower tensile strength compared to some alternatives.

Aluminum Conductor Steel Reinforced (ACSR): This composite conductor consists of an inner core of steel strands surrounded by aluminum strands. The steel core provides high tensile strength, allowing for longer spans between support structures, while the aluminum strands ensure good conductivity. ACSR is widely used in high-voltage transmission lines due to its favorable balance of strength and conductivity.



**Fig: 1.1 Transmission towers and conductors**

## **2. METHODOLOGY**

This chapter outlines the research design, methodology, and procedures used to investigate the application, effectiveness, and challenges of Personal Protective Equipment (PPE) usage in transmission and distribution (T&D) construction projects in India. The study adopts a qualitative-dominant mixed-methods case study approach, incorporating observations, interviews, surveys, and document analysis from selected construction sites.

Aspect	Details
Research Design	Case Study Method
Location	3 T&D Construction Sites
Participants	30 (Workers, Engineers, Supervisors)
Tools Used	<ul style="list-style-type: none"> <li>• Interviews,</li> <li>• Survey</li> <li>• Observation</li> <li>• Document Review</li> </ul>
Analysis	Thematic & Descriptive Statistics
Ethical Considerations	<ul style="list-style-type: none"> <li>• Consent</li> <li>• Anonymity</li> <li>• Voluntary Participation</li> </ul>

**Table 1: Research Methodology Frame Work**

### 2.1 Research Design

A case study research design was chosen to provide an in-depth understanding of real-world PPE use in T&D construction. This approach allows detailed exploration of behavioral patterns, site conditions, organizational policies, and safety practices.

Approach: Mixed methods (qualitative and quantitative) Type: Exploratory and descriptive

Scope: Focused on three active transmission and distribution projects in [State/Region], India

### 2.2 Study Area and Site Selection

Three T&D line construction sites were purposively selected in India based on the following criteria:

Active construction of high-voltage overhead lines (132 kV and above) Availability of documented PPE procedures

Willingness of project managers to provide access for research Representation of public sector (e.g., Power Grid) and private contractors

### 2.3 Sample Population and Size

A total of 30 participants were selected across the three sites using purposive and snowball sampling:

Category	Number of Participants
Field Workers 15	15
Safety Supervisors	5
Site Engineers	5
Project Managers	3
Store/PPE Managers	2

**Table 2: Numbers of Participants**



## 2.4 Data Collection Methods

- **Observations**

Conducted during daily operations including tower erection, stringing, and foundation work Observed real-time PPE usage, worker behavior, and safety supervision

Used structured checklists aligned with BIS/OSHA standards

- **Semi-Structured Interviews**

Conducted with engineers, safety officers, and workers

Topics included PPE availability, training, comfort, quality, and enforcement Each interview lasted approximately 25–35 minutes

- **Questionnaires**

Distributed to 20 field workers in Hindi and English

Focused on awareness, usage frequency, comfort, and perceptions of PPE Used a mix of Likert-scale and open-ended questions

- **Document Review**

Reviewed incident records, PPE issue logs, training materials, and inspection reports Cross-verified reported PPE practices with observed compliance

## 2.5 Data Analysis Techniques

Qualitative Data: Thematic analysis was applied to interview transcripts and field notes using manual coding

Quantitative Data: Responses from the surveys were analyzed using descriptive statistics (percentages, means) to assess trends

Triangulation: Findings from observations, interviews, and documents were cross-verified to ensure reliability

## 2.6 Ethical Considerations

Informed consent was obtained from all participants Confidentiality and anonymity were maintained

Ethics clearance was granted by the academic institution Respondents were informed of their right to withdraw at any stage

## 2.7 Limitations

Study limited to three construction sites in one region, affecting generalizability Self-reporting bias may exist in survey responses

Weather and access issues occasionally limited site observation

## 2.8 Methodology Diagram

(Refer to Table 1: Research Methodology Framework on page 37) Visual diagram showing the flow from

**Research Design → Site Selection → Data Collection → Analysis**

## 2.9 Conclusion

This chapter established the research framework for investigating PPE usage in Indian T&D construction sites. By using a case study design with multiple data collection techniques, the methodology enables a rich and detailed exploration of PPE-related issues that directly affect worker safety and compliance in high-risk environments.

## 3. Data Analysis and Discussion

This chapter presents the findings from the field data, observations, interviews, and surveys conducted as part of the case study on Personal Protective Equipment (PPE) usage in transmission and distribution construction sites. The discussion compares the observed practices with safety standards and highlights key issues, trends, and opportunities for improvement.

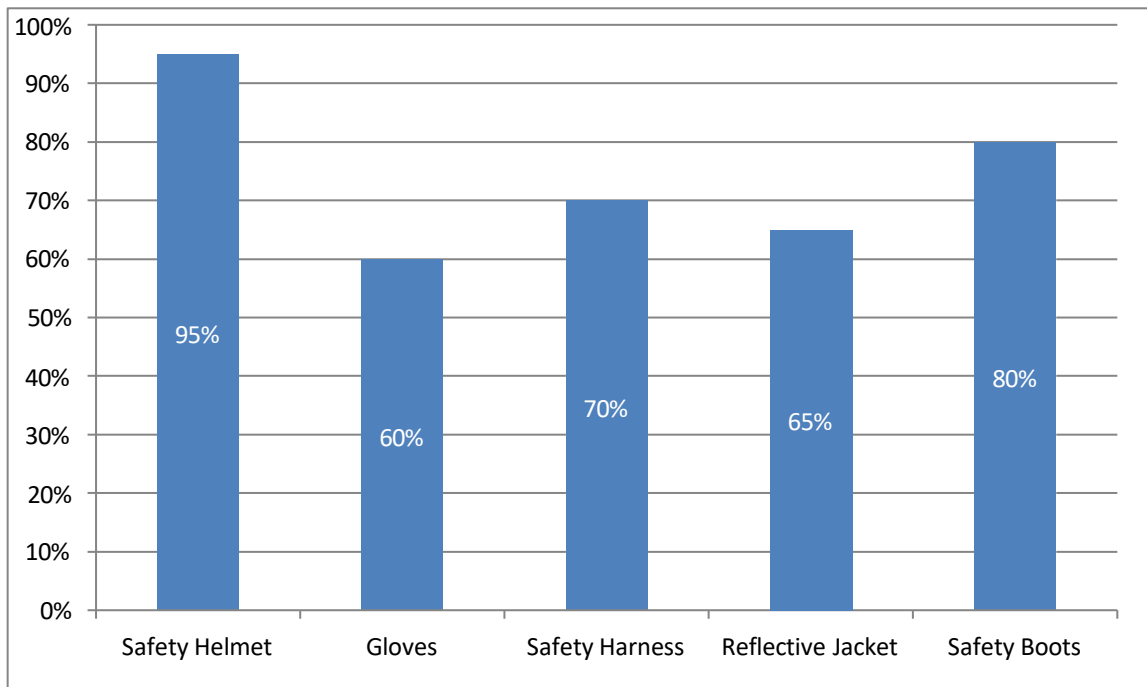
### 3.1 Overview of Field Observations

Field visits to three active T&D construction sites revealed the following:

Helmet usage was near-universal; however, compliance with other PPE (e.g., gloves, safety harnesses, insulated boots) was inconsistent.

Supervisors enforced PPE usage primarily during formal inspections or management visits. In extremely hot weather, workers often removed PPE citing discomfort and fatigue.

**Fig 5.1: PPE Usage by Type (Survey Results)**



This graph represents the reported usage percentage of various types of Personal Protective Equipment (PPE) by T&D construction workers based on field survey data.

### 3.2 Interview Insights

Interviews with site Labor and safety officers, Supervisor identified the following issues: Budget limitations affected the quality and quantity of PPE supplied.

Some workers were using expired or worn-out equipment due to delayed procurement cycles. PPE training was provided, but not regularly updated or assessed for effectiveness.

Supervisors noted behavioral resistance, especially among senior workers who believed PPE slowed them down.

#### Example quote from a safety officer:

We distribute PPE regularly, but many workers either don't use it correctly or avoid it when we're not watching."

### 3.3 Interview Questions and Sample Responses

#### ➤ Interview with T&D Line Construction Workers

• **Q:** Are you aware of the PPE you are required to wear during T&D construction activities?

**A:** Yes, we are told to wear helmets, gloves, boots, and harnesses while working, especially at height.

• **Q:** Which PPE do you use regularly on site? Why?

**A:** I always wear the helmet and boots because it is strictly checked. Gloves are sometimes uncomfortable, so I avoid them.

• **Q:** Are there any PPE items you avoid using? If yes, what are the reasons?

**A:** I usually avoid harnesses during light work because they are heavy and restrict movement.

• **Q:** Have you received any safety training or toolbox talks regarding PPE use?

**A:** Yes, during the start of the project .But no regular sessions after that.

**Q:** Do you feel PPE affects your speed or performance while working?



A: Sometimes, yes. In hot weather, gloves and jackets make it harder to work fast.

• Q: Have you ever faced any safety incident or near-miss where PPE helped or could have helped?

A: Yes, once a stone fell from above, but my helmet protected me. Without it, I could've been badly hurt.

• Q: What improvements would you suggest in the current PPE provided?

A: Better-quality gloves and lighter harnesses. Also , jackets that don't cause too much sweating.

#### ➤ Interview with Safety Officers/Supervisors

• Q: What are your responsibilities regarding PPE enforcement at the site?

A: I check PPE usage daily and ensure every worker has access to complete gear.

• Q: How often do you conduct safety checks or audits for PPE compliance? A: Weekly audits and daily random checks.

• Q: What are the most common PPE violations you observe?

A: Gloves not being worn, loose harness belts, and missing reflective jackets at night.

• Q: What steps do you take when a worker is found not using PPE?

A: First, I warn them. If repeated, I report to HR for disciplinary action.

• Q: Are there challenges in distributing or maintaining the stock of PPE?

A: Yes. Sometimes we face delays in new stock arrival or wrong sizes being issued.

• Q: Do workers report issues with PPE quality or comfort?

A: Yes, especially with gloves and boots. We inform procurement, but solutions take time.

### 3.4 Survey Results from Workers

Out of 20 survey respondents:

65% said they wear full PPE only when supervisors are present. 55% reported that the PPE was uncomfortable or poorly fitted.

70% understood the importance of PPE but felt its design made tasks more difficult. 40% said they never received refresher training.

This suggests that knowledge does not always translate into behavior, especially when comfort, workload, or peer pressure interferes.

### 3.5 Comparison with Safety Standards

According to OSHA, IEC 61482, and local safety regulations, full PPE—including arc-rated clothing, gloves, face shields, and insulated footwear—is mandatory during high-voltage operations.

However, the data indicates:

Partial compliance is common.

Quality assurance of PPE is inconsistent. Enforcement mechanisms are weak on most sites.

### 3.6 Root Causes of Non-Compliance

Analysis of qualitative and quantitative data reveals the following root causes:

Root Cause	Description
Discomfort/Ergonomics	PPE is too hot, heavy, or poorly designed for tropical climates
Poor Enforcement	Supervisory follow-ups are irregular, especially in remote locations
Supply Chain Issues	Delays in ordering or restocking PPE
Cultural Attitudes	Senior workers resist using full PPE, influencing newer staff
Insufficient Training	Many workers lack proper instruction on PPE purpose and correct usage

**Table 3: Root Causes of Non- Compliance**



### 3.7 Implications for Project Performance

- PPE non-compliance has significant implications:
- Increased incident risk (e.g., arc flash, electrical burns, falls).
- Legal liability for contractors and utilities.
- Delays and cost overruns due to workplace accidents.
- Reduced worker morale when safety is not prioritized.

### 3.8 Discussion Summary

The gap between PPE availability and actual usage reflects broader issues in construction safety culture, logistics, and leadership. While PPE is widely distributed, proper usage, comfort, and reinforcement are lacking. Addressing these issues requires a multidimensional approach that includes worker education, equipment improvement, and stronger accountability systems.

## 4. CONCLUSION AND RECOMMENDATION

### 4.1 Conclusion

This research was conducted to investigate the use, challenges, and effectiveness of Personal Protective Equipment (PPE) in Transmission and Distribution (T&D) construction projects in India. Based on literature review, field observation, interviews, and survey data from selected sites, several key findings emerged:

#### 1. High Awareness but Low Consistent Use:

While most workers were aware of PPE requirements, consistent usage was lacking—especially for gloves, reflective jackets, and safety harnesses.

#### 2. Major Challenges:

- Environmental discomfort (e.g., heat and humidity making helmets/gloves uncomfortable)
- Inadequate supply or poor quality of PPE
- Weak supervision and enforcement by safety officers
- Limited training or orientation for new workers

#### 3. Positive Impact of Supervision and Training:

Sites with regular safety audits, toolbox talks, and supervisory presence showed significantly higher PPE compliance.

#### 4. Gap Between Policy and Practice:

Although PPE rules exist on paper, their implementation varies widely between contractors and regions.

#### 5. Cultural and Behavioral Factors:

Some workers resist PPE due to beliefs that it slows them down or that "accidents are fate." These attitudes highlight the need for behavioral change programs in addition to technical enforcement.

### 4.2 Recommendations

Based on the findings of this study, the following measures are recommended:

#### 4.2.1 Policy and Enforcement

- Mandatory appointment of safety officers on all sites above 33kV construction
- Regular third-party safety audits with penalties for non-compliance

#### 4.2.2 Training and Awareness

- PPE induction training for all workers, with language-specific content
- Use of visual aids and safety demonstrations for illiterate workers

#### 4.2.3 Supply and Comfort

- Provision of ergonomically designed PPE suitable for Indian climates
- Feedback mechanism for workers to report issues with PPE quality

#### 4.2.4 Technology Integration

- Encourage adoption of AI-based PPE compliance monitoring on larger sites



- Use mobile apps for PPE inventory tracking and distribution logs

#### 4.2.5 Cultural Shifts

- Reward-based programs for consistent PPE use (e.g., “Safe Worker of the Month”)
- Engage local leaders or experienced workers as PPE ambassadors

#### 4.3 Contribution of the Study

This case study adds to the limited literature on PPE implementation in India's T&D construction sector. It provides real-world insight into behavioral and operational barriers to safety compliance and offers actionable recommendations tailored to the Indian context.

#### 4.4 Future Research Scope

- Long-term impact of digital safety training and AI-based PPE monitoring
- Comparative studies between government and private sector T&D projects
- Correlation between PPE compliance and accident reduction statistics over time

#### 4.5 Final Remarks

The safe construction of transmission and distribution infrastructure is vital for national development and energy reliability. Ensuring that workers are protected through proper use of PPE is not only a regulatory obligation but a moral imperative. This study reinforces the need for continuous improvement in safety practices, investment in quality equipment, and a shift in safety culture—making protection as important as productivity on every T&D construction site

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