iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IX **Month of publication:** September 2026

DOI: https://doi.org/10.22214/ijraset.2026.84991

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IX Sep 2026- Available at www.ijraset.com

GRID PATROL COPILOT: An AI-Powered Patrol Intelligence Framework for Transmission Line Fault Localization and Field Response Optimization

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Abstract: ***Rapid fault identification and effective field patrolling are essential for minimizing outage duration and restoring transmission system availability following line faults. In conventional practice, patrol planning requires engineers to manually collect and correlate information from multiple sources, including relay fault records, transmission line profiles, tower databases, terrain information, and historical maintenance records. This process is often time-consuming and heavily dependent on individual experience, resulting in delays in patrol deployment and fault restoration. This paper presents GRID PATROL COPILOT, an Artificial Intelligence (AI)-powered patrol intelligence framework developed to transform fault-related information into actionable field recommendations through a conversational interface. The proposed framework integrates fault location analysis, transmission line databases, tower intelligence, terrain information, and patrol planning logic using Microsoft Copilot Studio, Power Automate, SharePoint, and Generative AI technologies. Upon receiving fault details, the system automatically identifies the probable fault span, determines vulnerable towers, evaluates access conditions, and generates optimized patrol deployment recommendations. A practical implementation on extra-high-voltage transmission lines is presented to demonstrate the framework's capability in supporting fault localization and patrol decision-making. The results indicate significant reduction in manual analysis effort, improved standardization of patrol planning, faster field deployment, and enhanced restoration readiness. The proposed framework demonstrates a practical and scalable approach for integrating AI-driven decision support into transmission line operation and maintenance activities.***

Index Terms: ***Artificial Intelligence, Transmission Line Patrolling, Fault Localization, Generative AI, Copilot Studio, Patrol Intelligence, Power Automate, Transmission Reliability, Utility Digitalization, Decision Support Systems.***

I. INTRODUCTION

TRANSMISSION LINES constitute the primary backbone of modern power systems, and their continuous availability is essential for reliable power transfer. When a fault occurs, utility personnel must rapidly determine the probable fault location, dispatch field teams, inspect affected sections of the line, and initiate restoration activities. The effectiveness of this process directly influences outage duration, operational continuity, and system reliability.

The initial response to a transmission line fault typically begins with analysis of relay indications and fault locator outputs. Based on the estimated fault distance, engineers correlate line profile information with tower databases to identify the likely section requiring inspection. Additional operational inputs such as terrain characteristics, accessibility constraints, nearby habitation, and route information are often considered before organizing patrol activities. Although these practices are well established, they require coordination across several independent information repositories and rely heavily on engineering experience for interpretation and action planning. The scale and geographical diversity of contemporary transmission networks introduce further complexity. Long transmission corridors frequently pass through vegetated corridors, water crossings, agricultural zones, hilly regions, and remote locations where access conditions differ significantly from one section to another. Consequently, successful fault investigation requires more than identifying a probable span. Personnel must determine inspection priorities, define search boundaries, select suitable access points, and organize available resources to maximize the likelihood of early fault detection. In practice, these activities are performed under time constraints, particularly during grid disturbances and forced outages.

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Recent developments in Artificial Intelligence (AI) and Large Language Models (LLMs) have enabled the creation of systems capable of understanding engineering inputs, retrieving contextual information, and producing human-readable recommendations. Unlike traditional software applications that operate on predefined screens and workflows, conversational AI platforms can combine information from diverse sources and present results through natural language interactions. Such capabilities provide an opportunity to enhance operational workflows by converting engineering data into actionable recommendations that can be readily used by field personnel.

This paper presents GRID PATROL COPILOT, an AI-powered Patrol Intelligence Framework developed for transmission line fault response applications. The framework combines fault location information, transmission line master data, tower records, terrain attributes, village information, and patrol-planning logic within a unified conversational environment. Developed using Microsoft Copilot Studio, Power Automate, SharePoint, Excel Online, and Generative AI technologies, the system automatically processes fault-related inputs and generates intelligence required for field investigation. The generated output includes probable fault spans, critical inspection locations, access-related information, and deployment recommendations tailored to the fault scenario under consideration.

The proposed framework serves as an engineering assistance layer between raw operational data and field execution. By providing a single interaction point for retrieving and interpreting relevant information, it supports faster situational assessment, reduces dependence on tacit knowledge, and promotes consistency in patrol planning practices. Furthermore, the architecture utilizes existing digital infrastructure commonly available within utilities, making large-scale adoption practical without specialized hardware or dedicated analytical platforms.

The principal contributions of this work are as follows:

- Development of an AI-enabled framework for transmission line fault response and patrol intelligence generation.
- Integration of line, tower, terrain, and operational datasets within a conversational platform.
- Automated identification of probable fault spans and priority inspection locations.
- Generation of deployment recommendations to support field response activities.
- Demonstration of a practical implementation using Microsoft Power Platform technologies.

Fig. 1 presents a comparison between the conventional fault response workflow and the proposed AI-assisted patrol intelligence approach.

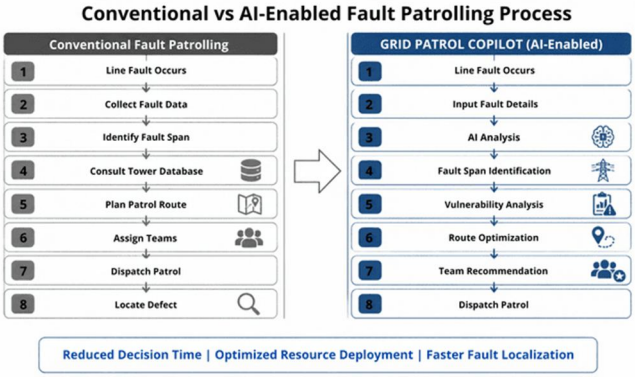

Fig. 1. Conventional fault patrolling versus AI-enabled patrol intelligence workflow.

II. LITERATURE REVIEW

Transmission utilities employ a variety of techniques to support fault investigation, system restoration, and maintenance activities. The selection of an appropriate approach depends on the required level of accuracy, available infrastructure, response time requirements, and operational objectives. Existing solutions can generally be categorized into fault-location systems, asset-information platforms, geographical information systems, and emerging AI-based decision-support applications.

Distance protection relays and dedicated fault locators are among the most widely used tools for estimating the position of faults on overhead transmission lines. By utilizing measured electrical quantities and line parameters, these systems provide distance estimates from a reference terminal, allowing operators to narrow the search area. Although such techniques assist in reducing inspection distances, the output generally indicates only the probable location along the transmission corridor and does not provide guidance regarding accessibility, inspection prioritization, manpower utilization, or field execution planning.

Utilities also maintain extensive asset databases containing tower details, route profiles, maintenance records, and construction information. These repositories serve as valuable sources of engineering knowledge and support routine operational activities. Similarly, Geographic Information System (GIS) platforms provide visualization of transmission corridors, nearby infrastructure, and environmental features. While these systems improve data availability and situational visibility, relevant information often remains distributed across separate applications, requiring personnel to perform manual interpretation before decisions can be formulated.

Recent digital transformation initiatives have introduced greater use of analytics, automation, and intelligent software tools within the power sector. Developments in Artificial Intelligence (AI) and Large Language Models (LLMs) have enabled software agents capable of interpreting user queries, retrieving information from enterprise repositories, and generating context-aware responses. These capabilities have attracted increasing interest for applications involving operational support, asset management, maintenance planning, and engineering knowledge assistance. However, most implementations focus on information retrieval, reporting, or document-based assistance rather than real-time support for transmission line fault response activities.

A comparison of commonly used approaches is presented in **Table I**. Conventional fault-location tools provide valuable technical inputs but offer limited operational guidance. Asset repositories and GIS platforms deliver extensive information but depend on user interpretation. In contrast, an AI-enabled framework can combine information from multiple sources and present deployment-oriented recommendations through a unified interaction layer.

TABLE I
COMPARISON OF EXISTING FAULT RESPONSE SUPPORT APPROACHES

Method	Data Availability	Engineering Interpretation	Deployment Guidance
Relay Fault Locator	Moderate	Required	Limited
Asset Database	High	Required	Limited
GIS Platform	High	Required	Limited
Manual Expert Assessment	Variable	Expert Dependent	High
Proposed GRID PATROL COPILOT	High	Automated	High

The literature indicates that substantial digital information is already available within utilities; however, transforming that information into timely field intelligence remains a challenge. A gap therefore exists between data availability and actionable operational recommendations. The framework proposed in this paper addresses this gap by integrating fault information, transmission line records, tower datasets, and patrol-planning knowledge within a conversational AI environment capable of supporting field response activities through a single interface.

III. GRID PATROL COPILOT FRAMEWORK

The proposed GRID PATROL COPILOT framework is designed to assist transmission utilities in converting fault-related inputs into structured field-response recommendations. The framework combines engineering datasets, workflow automation, and artificial intelligence capabilities within a unified architecture that enables rapid interpretation of fault information and generation of patrol guidance. Developed using Microsoft Copilot Studio, Power Automate, SharePoint, Excel Online, and Generative AI technologies, the system operates as a conversational engineering assistant capable of supporting transmission line fault investigation activities.

The framework is organized into five functional layers, namely the User Interaction Layer, Fault Localization Layer, Data Intelligence Layer, AI Reasoning Layer, and Patrol Intelligence Layer, as illustrated in Fig. 2. Each layer performs a specific function while contributing to the overall objective of transforming engineering data into practical field recommendations.

A. User Interaction Layer

The User Interaction Layer serves as the interface between operational personnel and the AI agent. Engineers communicate with the system through a conversational environment where fault-related information can be entered using natural language. Typical inputs include transmission line identification, fault distance reported by protection relays, fault type, and reference terminal details.

The conversational design eliminates the need to navigate multiple software applications and allows users to obtain engineering insights through straightforward queries.

This layer also performs preliminary validation of user-supplied inputs before initiating further processing. Standardized input handling ensures that subsequent analytical stages operate using consistent and structured information. As a result, the framework supports both experienced personnel and engineers who may be less familiar with specific transmission corridors.

B. Fault Localization Layer

The Fault Localization Layer determines the probable section of the transmission line requiring inspection. The process begins with the fault distance obtained from relay records or fault locator outputs. This information is correlated with transmission line profile data and cumulative tower distances to estimate the most likely fault span.

In addition to identifying the affected section, the layer determines relevant patrol boundaries to establish the inspection corridor. Depending on the operating conditions and location accuracy, the framework can extend the search region on either side of the estimated position to improve field coverage. This approach provides a structured basis for subsequent evaluation of towers, terrain characteristics, and deployment priorities.

C. Data Intelligence Layer

The Data Intelligence Layer functions as the knowledge repository of the framework. Engineering information is maintained within SharePoint libraries and Excel/SharePoint List-based master datasets containing transmission line records, tower details, route information, village data, and other operational references.

Upon receipt of a request, the framework retrieves only those records relevant to the identified inspection corridor. The extracted information may include tower numbering sequences, cumulative spans, nearby settlements, accessibility considerations, and location-specific attributes. By consolidating these datasets within a common environment, the framework establishes a comprehensive information base that supports further analysis without requiring manual consultation of multiple repositories.

D. AI Reasoning Layer

The AI Reasoning Layer forms the analytical core of the framework. Information obtained from the preceding stages is interpreted using Generative AI capabilities to produce context-aware engineering recommendations. Rather than returning isolated database records, the AI engine evaluates relationships between fault location information, line characteristics, and field conditions to generate a coherent response.

Examples of reasoning functions include identification of towers requiring priority inspection, assessment of likely investigation starting points, recognition of accessibility constraints, and formulation of inspection strategies suitable for the specific scenario under consideration. This capability enables output generation in a format that can be directly understood and utilized by operational personnel.

E. Patrol Intelligence Layer

The Patrol Intelligence Layer converts analytical outputs into field-executable recommendations. This layer determines inspection priorities, proposes deployment strategies, and organizes patrol activities based on the location identified by the framework. For long transmission corridors, the system can recommend parallel inspection to opposite directions to improve coverage and reduce search duration.

The generated response typically includes probable fault span information, towers requiring immediate attention, recommended patrol limits, route considerations, and resource allocation guidance. By presenting this information in a structured format, the framework assists personnel in initiating field activities with minimal preparatory effort.

F. Framework Output

The final output is delivered through the conversational interface as a patrol intelligence report. The report consolidates engineering information, inspection priorities, and deployment recommendations into a single response that can be readily used by operating staff. Unlike conventional workflows that require manual correlation of data from multiple sources, the proposed framework provides a unified mechanism for obtaining relevant information required during fault response activities.

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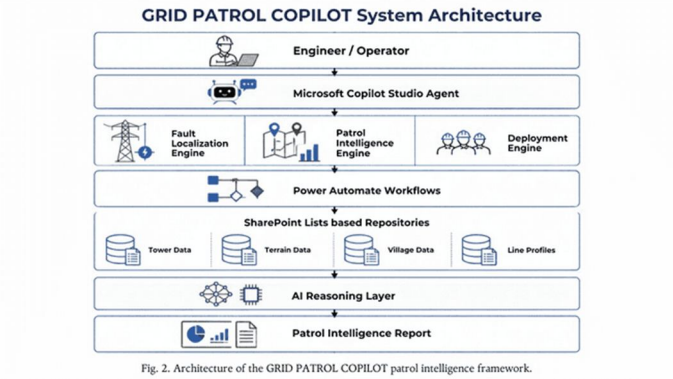

Fig. 2. Architecture of the GRID PATROL COPILOT patrol intelligence framework.

The architecture therefore establishes a practical foundation for integrating artificial intelligence into transmission line operations while utilizing existing utility datasets and digital infrastructure. The methodology used to generate patrol intelligence within this framework is described in the following section.

IV. AI-DRIVEN PATROL INTELLIGENCE METHODOLOGY

The effectiveness of transmission line fault response depends not only on accurate fault location estimation but also on the ability to convert available information into a structured field action plan. To accomplish this objective, GRID PATROL COPILOT employs a six-stage methodology that combines engineering datasets, workflow automation, and AI-assisted reasoning to generate patrol intelligence. The workflow transforms raw fault-related inputs into inspection recommendations, enabling a consistent and systematic approach to field investigation. The complete methodology adopted in the proposed framework is illustrated in Fig. 3.

A. Step 1: Fault Information Acquisition

The workflow is initiated when operational personnel provide fault details through the conversational interface. The required inputs include transmission line identification, fault distance, reference terminal, and fault category. These parameters are typically available from relay indications, disturbance records, and control room reports. Once received, the framework verifies the completeness of the information and formats it into a standardized structure suitable for analytical processing. This stage establishes the foundation for all subsequent calculations and ensures uniform treatment of incoming fault data.

B. Step 2: Fault Span Identification

The standardized inputs are processed against transmission line profile data maintained within the system repository. By correlating the reported fault distance with cumulative tower distances, the framework determines the most probable tower span associated with the disturbance. In addition to identifying the estimated location, an inspection corridor is defined around the calculated position to accommodate uncertainties that may arise in fault distance estimation. The resulting output provides a practical starting region for field investigation activities.

C. Step 3: Engineering Data Correlation

Following identification of the relevant corridor, the framework retrieves associated engineering records from connected repositories. These records may include tower attributes, route profile information, nearby villages, access references, and line-specific details. The retrieved datasets are merged to create a contextual representation of the affected section of the transmission corridor. By concentrating only on records associated with the identified region, the framework avoids unnecessary processing while maintaining operational relevance.

D. Step 4: Patrol Intelligence Analysis

The correlated information is subsequently evaluated by the AI reasoning engine to identify locations requiring focused attention. This stage interprets engineering relationships within the retrieved datasets and organizes the information into prioritized inspection guidance. Factors such as tower sequence, surrounding conditions, corridor characteristics, and accessibility considerations are examined to establish logical inspection priorities. Rather than presenting isolated data points, the framework generates an interpretable assessment of the affected area that can support field decision-making.

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E. Step 5: Deployment Strategy Formulation

After establishing inspection priorities, the framework develops a deployment strategy suitable for the identified corridor. The generated recommendations may include inspection boundaries, starting locations, movement directions, and division of search areas between available teams. For extensive line sections, the framework can recommend simultaneous investigation to opposite directions to increase coverage efficiency. This stage converts analytical outputs into a practical field-execution strategy tailored to the characteristics of the fault location.

F. Step 6: Patrol Intelligence Report Generation

The final stage consolidates all generated outputs into a structured patrol intelligence report. The report contains the estimated fault span, corridor information, relevant tower references, inspection priorities, and deployment recommendations. The response is delivered directly through the conversational interface, providing operational personnel with a concise summary of the information required for field activities. Since all relevant outputs are generated within a single workflow, the report serves as a ready reference during fault investigation and restoration planning.

The proposed methodology establishes a repeatable process for progressing from fault indication to field action planning. By integrating location determination, contextual information processing, analytical assessment, and deployment planning within a unified workflow, GRID PATROL COPILOT provides a structured mechanism for supporting transmission line fault response operations. The practical application of this methodology on an EHV transmission line is presented in the following case study section.

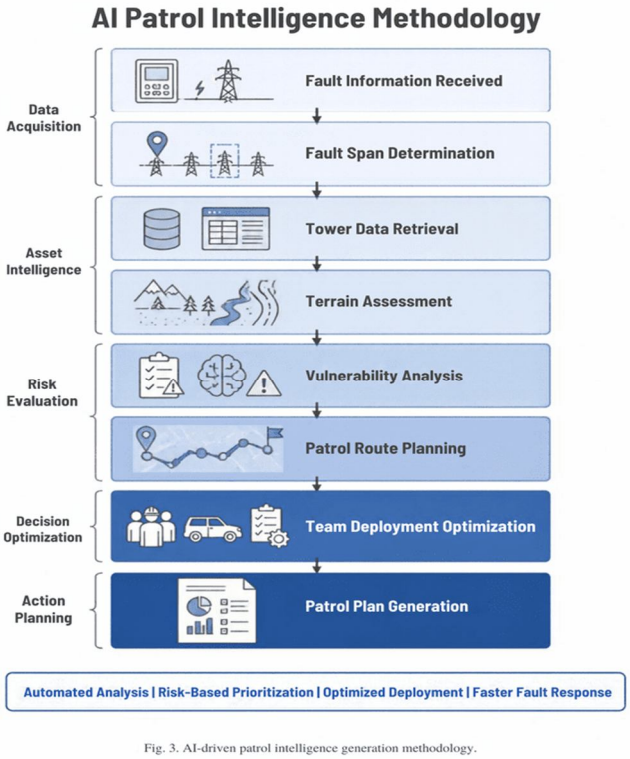

Fig. 3. AI-driven patrol intelligence generation methodology

V. CASE STUDY

To evaluate the practical applicability of the proposed framework, GRID PATROL COPILOT was implemented for transmission line fault-response activities using actual transmission line datasets and patrol-planning information. The objective of the case study was to examine the framework's ability to convert fault-location inputs into structured inspection guidance that could support field personnel during restoration activities. The selected scenario represents a typical extra-high-voltage transmission line fault investigation workflow in which operational personnel must rapidly identify the affected section and organize field action.

A. Study System

The case study was conducted using a 765 kV transmission corridor containing detailed tower profile information, cumulative distance records, and associated route data. The line database maintained within the framework included tower numbering, span lengths, geographical references, and operational information required for corridor analysis. These datasets were integrated into the system repository and made accessible through the conversational interface.

A representative fault scenario was selected to demonstrate framework operation. The following information was provided as user input:

- Transmission Line: 765 kV Srikakulam Vemagiri Circuit-1 Line
- Reported Fault Distance: 100 km
- Fault Type: R-N Fault
- Reference Terminal: End-A (765KV Srikakulam Substation)

These inputs represent the type of information normally available immediately after fault occurrence from relay event records and operational reports.

B. Fault Span Determination

Following receipt of the fault details, the framework initiated analysis of the transmission line profile database. The reported distance was compared with cumulative tower distances stored in the repository to identify the corresponding section of the line. Based on this evaluation, the system determined that the fault location was associated with the span between towers T0261 and T0262. In addition to locating the probable span, the framework established an inspection corridor surrounding the identified location. This corridor served as the primary region for subsequent analysis and enabled retrieval of all relevant information associated with nearby structures. By automatically translating electrical distance information into a physical line segment, the framework eliminated the need for manual consultation of tower schedules and route profiles.

C. Corridor Assessment

After identifying the affected section, the framework extracted location-specific records associated with towers located within the inspection corridor. Tower attributes, surrounding area information, route references, and accessibility-related details were retrieved from connected repositories. The collected information was then organized according to its operational relevance.

During this stage, the AI engine evaluated the retrieved records to identify structures requiring focused attention during inspection. Towers situated near the calculated fault location were prioritized for immediate verification. The framework further organized the available information into a sequence suitable for field investigation, allowing personnel to proceed systematically through the affected section.

D. Deployment Planning

Once the inspection corridor had been defined, the framework generated a deployment strategy designed to improve search efficiency. For extended sections of transmission line, the system supports simultaneous inspection from opposite directions. In the selected scenario, the identified fault location was treated as the central reference point for organizing field activities.

The generated recommendations included:

- Probable fault span identification.
- Inspection corridor limits.
- Priority tower sequence.
- Suggested starting points for field teams.
- Patrol directions for corridor coverage.

These recommendations were presented through the conversational interface in a structured format that could be readily used during field execution.

E. Generated Patrol Intelligence

The final output produced by GRID PATROL COPILOT consolidated all analytical results into a patrol intelligence report. A typical response contained the identified span, relevant tower references, corridor information, and deployment recommendations derived from the analysis. The generated output converted several independent datasets into a single operational view of the fault scenario.

The case study demonstrated that the framework could successfully process fault-location information, correlate engineering records, identify relevant inspection areas, and generate field-oriented recommendations within a unified workflow. The resulting outputs provided sufficient information to support investigation planning without requiring additional manual correlation of tower databases or route records.

F. Case Study Observations

The implementation confirmed the ability of the proposed framework to support transmission line fault-response activities using existing utility datasets and digital infrastructure. The conversion of relay fault distance information into tower-level inspection guidance was successfully demonstrated using an actual transmission line scenario. Furthermore, the generated recommendations provided a structured basis for organizing field activities and prioritizing inspection efforts.

The results obtained from this case study establish the practical applicability of GRID PATROL COPILOT and form the basis for the experimental evaluation presented in the following section.

VI. EXPERIMENTAL RESULTS

The performance of GRID PATROL COPILOT was evaluated using transmission line master data, tower profile information, and fault-response scenarios representative of routine transmission line operations. The evaluation focused on verifying the framework's ability to correctly identify probable fault locations, retrieve corridor-specific information, generate inspection recommendations, and assist in deployment planning. The assessment was carried out by executing multiple fault scenarios and validating the outputs generated by the AI agent against engineering records and operational expectations.

A. Functional Validation

The first stage of evaluation verified the correct operation of the major framework functions. Test scenarios with different fault locations and reference terminals were executed to assess system behavior under varying conditions. For each scenario, the generated outputs were reviewed against available transmission line data.

TABLE II
FUNCTIONAL VALIDATION RESULTS

Function	Validation Result
Fault Span Identification	Successful
Tower Information Retrieval	Successful
Line Profile Correlation	Successful
Inspection Corridor Generation	Successful
Priority Tower Identification	Successful
Deployment Recommendation Generation	Successful

The results indicate that all core functions operated as intended. The framework successfully interpreted user inputs, retrieved associated records, and produced outputs relevant to field investigation activities.

B. Fault Location Assessment

A series of representative scenarios were used to evaluate the fault-location determination process. The reported fault distances were compared against cumulative tower distances available within the transmission line repository. The identified spans were then verified using the corresponding tower profile records.

The analysis demonstrated that the framework consistently mapped fault-distance information to the appropriate tower sections. The generated outputs provided a clear identification of the probable inspection region, enabling subsequent analysis to be confined to a limited corridor rather than the entire transmission route. This capability is particularly important for long EHV transmission lines where inspection resources must be directed efficiently.

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Figure 4 presents a representative fault-localization example in which the framework automatically identified the fault span using relay-derived distance information and line profile records.

Fig. 4. Example of AI-based fault localization using relay fault distance information.

C. Patrol Intelligence Generation

The next stage of evaluation examined the framework's ability to generate context-aware inspection recommendations. After determination of the probable fault location, the system retrieved relevant tower information, route references, and corridor details before producing a structured patrol intelligence report.

The generated outputs included:

- Probable fault span.
- Inspection corridor limits.
- Relevant tower references.
- Suggested investigation sequence.
- Deployment recommendations.

Unlike traditional information lookup systems that return isolated database entries, the framework organized the retrieved information into a coherent response suitable for operational use. This enabled field personnel to obtain investigation guidance through a single interaction rather than consulting multiple data repositories.

D. Operational Workflow Comparison

A qualitative comparison was conducted between conventional fault-response practices and the proposed framework.

TABLE III
COMPARISON OF OPERATIONAL ACTIVITIES

Activity	Conventional Practice	Proposed Framework
Fault Distance Interpretation	Manual	Automated
Tower Data Consultation	Individual Lookup	Automated Retrieval
Corridor Identification	Manual Correlation	Automated
Inspection Planning	Experience-Based	System-Assisted
Field Preparation	Sequential Activities	Unified Workflow

The comparison indicates that several information-processing activities traditionally performed by operational personnel can be consolidated within a single workflow using the proposed framework. This reduces the effort associated with data interpretation and preparation of inspection plans.

E. Response Generation Evaluation

The conversational interface was assessed under multiple query formats to verify consistency of generated responses. The framework successfully handled requests containing line identification, fault distance, and reference terminal information while maintaining the structure of the generated report.

The produced responses remained consistent across repeated evaluations and successfully incorporated information retrieved from connected repositories. This behavior demonstrates the suitability of the framework for routine field-support applications where repeatability and information consistency are important operational requirements.

F. Key Findings

The experimental evaluation produced several significant observations:

- The framework successfully converted fault-location information into tower-level inspection guidance.
- Engineering records stored in enterprise repositories were correctly retrieved and incorporated into generated outputs.
- Inspection corridor identification was completed automatically without manual consultation of line profile documents.
- Deployment recommendations were generated using a consistent workflow across all evaluated scenarios.
- The conversational interface provided a practical mechanism for obtaining investigation-related information during fault-response activities.

Overall, the results confirm that GRID PATROL COPILOT can successfully integrate fault information, transmission line records, and operational knowledge within a unified framework to support transmission line investigation and restoration activities. The findings further demonstrate the feasibility of applying AI-assisted engineering workflows to utility field operations using existing digital infrastructure.

VII. PATROL RESPONSE INDEX (PRI)

To evaluate the operational effectiveness of the proposed framework, a **Patrol Response Index (PRI)** is introduced. The index provides a qualitative measure of preparedness for field response following a transmission line fault. The PRI incorporates key activities performed between fault occurrence and commencement of field investigation.

The index is defined as:

$$PRI \propto \frac{1}{FIT + PT + DT}$$

where:

- FIT = Fault Identification Time
- PT = Planning Time
- DT = Deployment Time
- RR = Restoration Readiness

A lower value of FIT, PT, and DT results in improved restoration readiness and consequently a higher PRI value. The index is intended as a comparative indicator rather than an absolute performance metric. It enables assessment of how effectively operational information is transformed into field action.

In conventional fault-response practices, significant effort is often spent on interpreting location information, identifying relevant transmission line sections, consulting engineering records, and organizing field activities. These preparatory steps influence the overall response cycle before physical inspection can begin.

The proposed framework improves PRI through the following mechanisms:

- Automated fault span determination.
- Reduced patrol preparation effort.
- Consistent generation of inspection recommendations.
- Streamlined deployment planning.

As a result, operational personnel can obtain inspection-related guidance through a single workflow, improving readiness for field execution. Figure 5 illustrates the relative improvement in PRI achieved using GRID PATROL COPILOT.

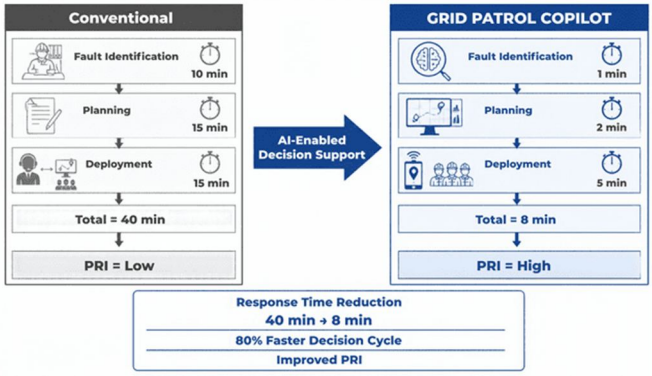

Fig. 5. Improvement in Patrol Response Index using GRID PATROL COPILOT.

VIII. BUSINESS IMPACT

Beyond technical functionality, the proposed framework provides operational and organizational benefits for transmission utilities. By integrating engineering information and workflow automation within a conversational environment, the framework supports more structured execution of fault-response activities.

A. Operational Benefits

The principal operational benefits observed during implementation include:

- Faster identification of probable inspection locations.
- Reduced time required for preparation of field activities.
- Consistent patrol planning methodology across different users.
- Improved accessibility of engineering knowledge and operational records.

These improvements contribute to more efficient utilization of available resources during transmission line investigation activities.

B. Business Benefits

From an organizational perspective, the framework offers several long-term advantages:

- Improved transmission system availability through accelerated field response.
- Better utilization of manpower and operational resources.
- Enhanced consistency in fault-response practices across locations.
- Support for ongoing digital transformation initiatives within utilities.

The ability to convert existing engineering datasets into actionable operational guidance demonstrates how AI-enabled tools can complement conventional utility workflows while leveraging existing digital infrastructure.

IX. DISCUSSION

The results presented in the previous sections demonstrate that the proposed framework can serve as a practical decision-support tool for transmission line fault-response activities. Unlike conventional software applications that primarily function as data repositories, GRID PATROL COPILOT combines information retrieval, contextual interpretation, and recommendation generation within a single operational workflow. This capability enables engineering information maintained across multiple repositories to be utilized in a more structured and operationally relevant manner.

One notable aspect of the framework is its ability to bridge the gap between technical data and field execution requirements. Transmission utilities generally possess extensive records related to line assets, tower profiles, route information, and maintenance activities. However, extracting relevant information during outage situations often requires manual navigation across different sources. By integrating these records within a conversational environment, the framework provides a more accessible mechanism for utilizing organizational knowledge during fault investigation activities.

Another important observation is the potential contribution of the framework toward consistency in operational practices. In many field activities, the quality of planning may vary depending on the experience and familiarity of personnel with a particular transmission corridor. The proposed approach provides a standardized workflow for generating inspection guidance, thereby reducing variation in information interpretation and supporting more uniform execution across different users and locations.

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From an implementation perspective, the framework offers a practical advantage because it is built using commercially available Microsoft Power Platform technologies and existing utility datasets. Consequently, deployment does not require specialized analytical hardware, dedicated simulation platforms, or extensive software development efforts. This characteristic makes the approach suitable for incremental adoption within utility environments where digital infrastructure is already available.

Despite these advantages, certain limitations should be recognized. The quality of generated recommendations depends on the accuracy and completeness of the underlying engineering databases. In addition, the current implementation relies on manually available fault information and does not directly interface with real-time operational systems. Therefore, periodic validation of source data remains necessary to ensure continued effectiveness.

Overall, the evaluation indicates that GRID PATROL COPILOT represents a practical application of artificial intelligence for transmission line operations. The framework demonstrates how enterprise data, workflow automation, and conversational AI can be combined to support field-response activities while utilizing existing utility infrastructure.

X. FUTURE WORK

The current implementation establishes a foundation for applying conversational AI to transmission line fault-response activities. However, several opportunities exist to further extend the framework's capabilities and operational scope. Future developments can focus on deeper integration with utility systems, enhanced analytical functionality, and expanded field-support features.

One potential enhancement is the integration of Supervisory Control and Data Acquisition (SCADA) systems and relay event records. Such integration would enable automatic acquisition of fault-related information, eliminating the need for manual entry of operational inputs and further reducing response time. Similarly, incorporation of disturbance records and fault logs could provide additional context for engineering analysis during outage investigations.

Another area of development involves Geographic Information System (GIS) integration. Visualization of transmission corridors, tower locations, nearby infrastructure, and access routes on interactive maps could significantly enhance situational awareness during field operations. GIS-enabled outputs would provide a graphical representation of inspection corridors and support more effective coordination of field activities.

Future versions may also incorporate historical outage records and maintenance databases to support predictive analytics. By analyzing recurring fault patterns and asset-condition information, the framework could assist in identifying vulnerable sections of transmission corridors and recommending proactive inspection priorities. Such capabilities would extend the framework beyond fault response into preventive asset-management applications.

Additional enhancements may include mobile-device integration, drone-assisted inspection support, and automated report generation. These developments can transform the framework into a comprehensive field-assistance platform capable of supporting a wider range of transmission line operation and maintenance activities.

XI. CONCLUSION

This paper presented GRID PATROL COPILOT, an AI-powered Patrol Intelligence Framework developed to support transmission line fault localization and field-response planning. The framework combines fault-location analysis, engineering databases, workflow automation, and conversational AI technologies within a unified operational environment. Using information available immediately after a fault event, the system generates inspection-oriented guidance that can assist personnel during restoration activities.

A practical implementation was demonstrated using transmission line data, tower records, and patrol-planning information. The case study showed the ability of the framework to determine probable fault spans, retrieve corridor-specific information, identify inspection priorities, and generate deployment recommendations through a structured workflow. Experimental evaluation further confirmed the successful operation of the major functional components and demonstrated the applicability of the proposed approach for transmission line field-support activities.

The introduction of the Patrol Response Index (PRI) provided a conceptual mechanism for evaluating improvements in preparedness between fault occurrence and commencement of field investigation. The results indicated that automation of key preparatory activities can contribute to faster mobilization and more efficient utilization of available resources.

The proposed framework demonstrates how existing utility datasets, automation technologies, and artificial intelligence can be combined to enhance operational workflows without requiring specialized infrastructure. As utilities continue their digital transformation journey, solutions such as GRID PATROL COPILOT can play an important role in improving information accessibility, supporting engineering decision-making, and strengthening transmission system operations.

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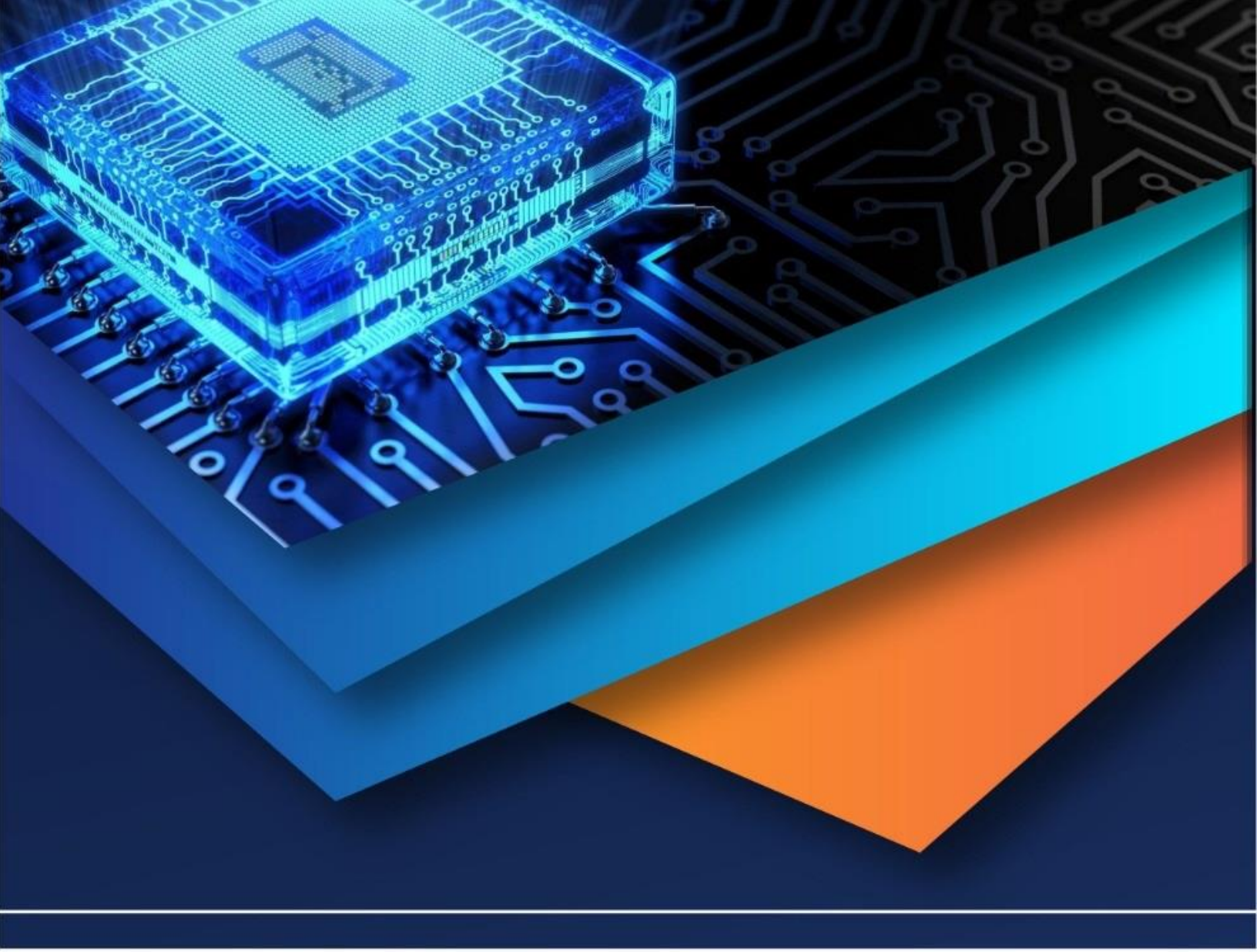

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