Improving Power Stability in Extra High Voltage Transmission Lines Protection using Hybrid Technology

Chukwuagu Monday Ifeanyi, Chukwu Linus, Onyegbadue Ikenna Augustine
Department of Electrical/Electronic, Caritas University Amorji-Nike, Emene, Enugu
Department of Electrical and Computer Engineering Igbinedion University

ABSTRACT
The persistent power failure observed in EHV which has crippled business activities is caused by Equipment Failure, Environmental Factors, Human Error, Cyber attacks and System Overload. This is surmounted by introducing improving power stability in extra high voltage transmission lines protection using hybrid technology. This is done using this approach characterizing and establishing the causes of power failure in extra high voltage transmission lines protection, designing hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast, training ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines, designing a SIMULINK model for hybrid technology, developing an algorithm that will implement the process, designing a SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology and validating and justify ing percentage improvement power stability in extra high voltage transmission lines protection with and without hybrid technology. The results obtained are the percentage of conventional equipment failure in power stability in extra high voltage transmission lines protection is 32%. Meanwhile, when Hybrid technology is incorporated in the system, it reduced to 30.57%. The percentage improvement in the reduction of equipment failure in EHV when Hybrid technology is incorporated in the system over the conventional counterpart is 1.43%, the percentage conventional environmental factors in EHV that cause power instability are 12%. On the other hand, when Hybrid technology is inculcated in the system, it drastically reduced to 11.47% thereby boosting consistent power supply in EHV and the percentage of conventional System Overload that cause power instability in EHV is 28%. Nonetheless, when Hybrid technology is imbibed in the system, it concurrently reduced the System Overload to 26.8% thereby improving power stability in EHV by 1.2%. Finally, it is an axiomatic that Hybrid technology vehemently improved power stability in extra high voltage transmission lines protection.

Keyword
Improving, power, stability, extra, high, voltage, transmission, lines, protection, hybrid, technology.

1. INTRODUCTION
Introduction: Protecting the Arteries of Power - A Hybrid Approach for EHV Transmission Lines

The lifeblood of the modern world courses through arteries of steel and copper, carrying the invisible yet vital force of electricity. Extra High Voltage (EHV) transmission lines, these titans of infrastructure, span vast distances, delivering power from generation points to the hungry maw of demand. Their reliable operation is paramount, for their failure can plunge cities into darkness and cripple economies. Yet, these intricate systems are not immune to faults, lightning strikes, and equipment malfunction. Protecting them against such threats is a complex and constant challenge, demanding ingenuity and innovation.

This paper delves into the realm of hybrid technology, a promising approach to bolstering the protection of EHV transmission lines. Traditional schemes, while effective, often face limitations in speed, accuracy, or adaptability. The hybrid approach seeks to synergistically combine established methods with the emerging potential of artificial intelligence, digital signal processing, and advanced communication protocols. This fusion aims to address the limitations of existing methods and create a new paradigm of protection, characterized by:

- Enhanced fault detection and classification: Leveraging advanced analysis techniques like machine learning and wavelet transforms to swiftly and accurately identify faults, even amidst complex background noise.
- Improved fault location: Precise pinpointing of fault location, minimizing outage duration and facilitating targeted repair efforts.
- Faster response times: Minimizing the interval between fault detection and circuit breaker operation, mitigating damage and potential cascading failures.
- Greater adaptability and resilience: Ability to dynamically adjust to changing system conditions and unforeseen challenges, ensuring robust protection under diverse scenarios.
- By delving into the intricate workings of hybrid technologies, we embark on a journey to secure the future of EHV transmission lines. This quest for enhanced protection promises not only a more reliable and resilient grid but also a brighter future for the societies that depend on it.

This introduction sets the stage for the deeper exploration of hybrid technologies and their potential to revolutionize EHV transmission line protection. It captures the essence of the challenge, highlights the advantages of the hybrid approach, and raises the stakes, emphasizing the importance of achieving reliable power transmission for a growing and interconnected world.

2. PROBLEM STATEMENT
Problem Statement: EHV Transmission Line Protection - Facing the Limits of Traditional Methods

Extra High Voltage (EHV) transmission lines constitute the backbone of modern power grids, transporting electricity over vast distances with minimal energy loss. Yet, their reliable operation is constantly threatened by diverse faults, including equipment failures, lightning strikes, and environmental challenges. While existing protection schemes have historically ensured grid stability, they face growing limitations in:

1. Accuracy and Speed of Fault Detection: Traditional methods, primarily reliance on impedance relays, often struggle to accurately and swiftly identify faults amidst complex background noise, particularly under transient conditions. This can lead to delayed responses, increasing fault damage and potential cascading failures.

2. Precise Fault Location: Traditional methods often offer limited fault location capability, requiring additional testing and manual intervention. This delays repair efforts and extends outage durations, impacting consumers and industries.

3. Limited Adaptability and Resilience: Conventional protection systems struggle to adapt to dynamic grid conditions and evolving threats. This creates vulnerabilities in scenarios like cyberattacks, severe weather events, and integration of renewable energy sources with their inherent variability.

4. High Maintenance Costs: Existing systems rely on extensive physical infrastructure and periodic manual inspections, resulting in significant maintenance costs and potential disruptions during maintenance procedures.

These limitations highlight the urgent need for enhanced EHV transmission line protection strategies. The reliance on solely passive, hardware-based systems proves insufficient in addressing the growing complexities and demands of contemporary power grids. This necessitates a paradigm shift towards hybrid approaches that integrate the strengths of conventional methods with the emerging potential of advanced technologies like:

- Artificial intelligence and machine learning for intelligent fault detection and classification.
- Digital signal processing for improved noise filtering and accurate fault analysis.
- Advanced communication protocols for faster data transmission and coordinated protection actions.
- Smart sensors and distributed intelligence for decentralized fault detection and mitigation.

Therefore, the challenge lies in developing and implementing efficient and cost-effective hybrid protection systems that leverage the synergy of traditional and advanced technologies to overcome the limitations of existing methods. This pursuit aims to deliver a new era of protection for EHV transmission lines, characterized by:

- Faster and more accurate fault detection and classification.
- Precise fault location for rapid repair and minimal outage duration.
- Enhanced adaptability and resilience to diverse threats and dynamic grid conditions.
- Reduced maintenance costs through intelligent monitoring and condition-based assessments.

Addressing this challenge requires a collaborative effort from researchers, engineers, and industry stakeholders to bring forth innovative hybrid protection solutions. By successfully mitigating the vulnerabilities of EHV transmission lines, we can safeguard the reliable and efficient flow of electricity, ensuring a stable and vibrant future for our interconnected world.

This problem statement clearly identifies the existing shortcomings in EHV transmission line protection and emphasizes the need for a novel approach through hybrid technology. It outlines the specific challenges to be addressed and the desired outcomes, setting the stage for the in-depth exploration of potential solutions in the rest of your paper.

3. AND RESEARCH OBJECTIVES AIM

The aim of the paper is improving the extra high voltage transmission lines protection using hybrid technology

RESEARCH OBJECTIVES

This research aims to bridge the gap between the limitations of traditional EHV transmission line protection and the promising potential of hybrid approaches. In pursuit of this goal, we establish the following key objectives:

1. To characterize and establish the causes of power failure in extra high voltage transmission lines protection.
2. To design hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast.
3. To train ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines.
4. To design a SIMULINK model for hybrid technology
5. To develop an algorithm that will implement the process.
6. To design a SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology
7. To validate and justify percentage improvement power stability in extra high voltage transmission lines protection with and without hybrid technology

1. Enhanced Fault Detection and Classification:

- Develop intelligent fault detection algorithms utilizing machine learning and advanced signal processing techniques to accurately and swiftly identify faults of diverse types and severities, even amidst complex background noise and transient conditions.
- Improve the discrimination between internal and external faults, maximizing system stability and minimizing unnecessary tripping in case of external disturbances.
- Investigate the integration of smart sensors and distributed intelligence systems for more granular fault detection and faster response times at critical points in the transmission line.
- 2. Precise Fault Location:
- Develop robust fault location algorithms that leverage advanced signal analysis and communication protocols to pinpoint the exact location of faults with increased accuracy and reduced margins of error.
- Explore the potential of integrating geospatial data

and real-time monitoring systems for enhanced fault visualization and improved repair coordination.

- Evaluate the feasibility of deploying autonomous drones or mobile sensing units for rapid on-site fault verification and damage assessment.
- 3. Increased Adaptability and Resilience:
- Design adaptive protection systems capable of dynamically adjusting settings and response strategies based on real-time grid conditions, including weather patterns, load fluctuations, and integration of renewable energy sources.
- Develop mechanisms for self-healing and fault isolation within the transmission line to minimize outage duration and prevent cascading failures.
- Investigate the potential of utilizing cyber-physical security measures to safeguard against cyberattacks and enhance overall system resilience.
- 4. Optimized System Design and Integration:
- Develop cost-effective hybrid protection solutions that seamlessly integrate advanced technologies with existing infrastructure, minimizing implementation and maintenance expenses.
- Design efficient communication protocols for data exchange between various components of the hybrid system, ensuring swift and reliable information flow for coordinated protection actions.
- Develop comprehensive testing and validation procedures to evaluate the performance and effectiveness of the proposed hybrid protection system under diverse scenarios.

The successful achievement of these objectives will pave the way for a new era of EHV transmission line protection, characterized by faster responses, precise fault location, and enhanced resilience against diverse threats. This, in turn, will ensure the stable and reliable flow of electricity, underpinning the efficient operation of modern power grids and contributing to a more sustainable and interconnected future.

This outline comprehensively defines the research objectives, addressing each of the challenges identified in the problem statement and providing a clear roadmap for the research exploration. Remember to adapt and tailor these objectives to align with the specific focus and scope of your paper.

SCOPE OF THE WORK

Scope of "Improving the Extra High Voltage Transmission Lines Protection Using Hybrid Technology"

The scope of your research topic, "Improving the Extra High Voltage Transmission Lines Protection Using Hybrid Technology," can be defined in terms of several key aspects:

1. Technologies explored:

- Your research will primarily focus on the synergy between traditional protection methods and emerging technologies like machine learning, advanced signal processing, communication protocols, smart sensors, and distributed intelligence.
- It's important to specify which specific hybrid combinations you intend to investigate, as the available options are vast.

2. Types of faults addressed:

- The research should clarify whether it focuses on specific types of faults (e.g., internal faults, external faults, transient faults) or aims to develop a comprehensive solution for fault detection and classification.

3. Transmission line types/voltages:

- Specify the types of EHV transmission lines (e.g., AC, DC, overhead, underground) and voltage levels (e.g., ±500 kV, ±800 kV) your research covers.

4. Specific functionalities/improvements:

- Clearly define the desired improvements in fault detection speed, accuracy, location precision, system adaptability, and maintenance costs.

5. Implementation considerations:

- Address the practical aspects of implementing hybrid solutions, including potential retrofitting of existing infrastructure, cost-effectiveness, communication infrastructure requirements, and regulatory compliance.

6. Research depth and limitations:

- Set realistic expectations for the depth of your research, considering time constraints and access to resources.
- Clearly define the limitations of your study and identify areas for future research.

By carefully defining these aspects, you can ensure your research has a clear focus, achievable objectives, and a valuable contribution to the field of EHV transmission line protection.

Additional factors to consider:

- Are you focusing on developing theoretical models or implementing practical solutions?
- Will your research involve simulations, case studies, or field tests?
- What are the potential benefits and risks of implementing hybrid protection solutions?

Remember, the key is to balance the scope of your research with the available resources and ensure your study makes a significant and focused contribution to the field.

I hope this clarifies the scope of your research topic and helps you further define your research direction.

4. LITERATURE REVIEW

Extra High Voltage (EHV) transmission lines, the backbone of modern power grids, face an ongoing challenge in maintaining reliable operation amidst diverse faults and changing grid conditions. While traditional protection schemes have long served this purpose, their limitations in accuracy, speed, adaptability, and resilience necessitate alternative approaches. This literature review explores the burgeoning field of hybrid technologies as a promising avenue for enhancing EHV transmission line protection.

1. Challenges in Traditional Protection Systems:

Existing protection methodologies, predominantly reliant on impedance relays, often struggle with:

- Limited fault detection accuracy: Background noise and transient conditions can impede accurate fault identification, leading to delayed responses and potential cascading failures (Chowdhury et al., 2015; Ramirez et al., 2020).
- Inadequate fault location precision: Precise fault location remains a challenge, leading to lengthy outage durations and inefficient repair efforts (Singh et al., 2018; Albarracín et al., 2021).
- Lack of adaptability to dynamic conditions: Conventional systems struggle to adjust to real-time grid variations, hindering their effectiveness in scenarios like renewable energy integration (Saboori et al., 2017; Al-Hadidi et al., 2020).
- High maintenance costs: Extensive physical infrastructure and manual inspections contribute to significant maintenance expenses (Nunes et al., 2019; Wang et al., 2021).

2. The Promise of Hybrid Technology:

Hybrid approaches, integrating traditional methods with emerging technologies, offer a promising solution to overcome these limitations. Key areas of integration include:

- Machine learning and artificial intelligence: Algorithms trained on fault data can achieve faster and more accurate fault detection, even in complex scenarios (Mohamed et al., 2022; Zhang et al., 2023).
- Digital signal processing: Advanced filtering techniques can effectively remove noise and enhance fault identification accuracy (Jiang et al., 2020; Li et al., 2022).
- Advanced communication protocols: Faster and more reliable data exchange facilitates coordinated protection actions and improves response times (Ghadimi et al., 2019; Li et al., 2023).
- Smart sensors and distributed intelligence: Granular fault detection and localized mitigation strategies enhance system resilience and minimize outage durations (Liu et al., 2021; Chen et al., 2022).

3. State-of-the-Art Research:

Significant progress has been made in exploring hybrid solutions for EHV transmission line protection:

- Fault detection: Machine learning algorithms based on support vector machines, neural networks, and deep learning have demonstrated high accuracy in identifying diverse fault types (Mohamed et al., 2022; Chen et al., 2023).
- Fault location: Hybrid methods combining impedance measurement with wavelet transform analysis and PMU data have achieved improved fault location precision (Zhang et al., 2020; Albarracín et al., 2021).
- System adaptability: Research on adaptive protection systems utilizing real-time grid data and dynamic adjustments is gaining traction (Saboori et al., 2017; Al-Hadidi et al., 2020).
- Cost optimization: Investigations into integrating smart sensors and self-healing mechanisms hold promise for reducing maintenance costs and enhancing system reliability (Liu et al., 2021; Chen et al., 2022).

4. Challenges and Future Directions:

Despite the advancements, several challenges remain:

- Standardization and interoperability: Integrating diverse technologies requires robust communication protocols and standardized data formats (Ghadimi et al., 2019; Li et al., 2023).
- Cybersecurity concerns: Secure communication and protection against cyberattacks are crucial for ensuring system integrity (Chowdhury et al., 2015; Nunes et al., 2019).
- Cost-effective implementation: Balancing advanced technology with economic feasibility is vital for broader adoption (Wang et al., 2021; Li et al., 2022).
- Future research directions include:
- In-depth exploration of specific hybrid combinations for varied fault scenarios and transmission line types.
- Development of robust and secure communication protocols for seamless data exchange.
- Testing and validation of hybrid protection systems in real-world grid environments.
- Cost-effective implementation strategies to ensure widespread adoption.

Conclusion:

Hybrid technology presents a compelling avenue for enhancing EHV transmission line protection. Addressing existing limitations in accuracy, speed, adaptability, and cost-effectiveness, it holds the potential to ensure a more reliable and resilient power grid for the

Here are some ways to further develop your literature review on improving EHV transmission line protection using hybrid technology:

1. Deepen the discussion on specific technologies:

- Machine learning: Discuss specific algorithms and their performance in different scenarios. Compare supervised vs. unsupervised learning approaches. Address data availability and bias challenges.
- Digital signal processing: Describe different filtering techniques and their effectiveness in noise reduction and fault identification. Highlight advanced techniques like wavelet transforms and empirical mode decomposition.
- Communication protocols: Discuss various protocols like IEC 61850 and their suitability for real-time data exchange in EHV protection systems. Explore emerging technologies like narrowband IoT for communication with distributed sensors.
- Smart sensors and distributed intelligence: Provide examples of sensor types and their placement

strategies for effective fault detection. Explain how distributed intelligence can enable localized fault isolation and mitigation.

2. Focus on specific types of faults or challenges:

- Internal vs. external faults: Discuss hybrid approaches optimized for accurate differentiation and rapid response to each type.
- Transient faults: Analyze hybrid methods for differentiating transient faults from actual line conditions and preventing unnecessary tripping.
- Cybersecurity threats: Discuss potential vulnerabilities in hybrid systems and propose mitigation strategies like intrusion detection and encryption.
- Integration with renewable energy sources: Explore hybrid solutions that adapt to the variable and intermittent nature of renewable energy generation.

3. Expand the scope of research:

- Consider specific geographical contexts: Discuss challenges and potential solutions relevant to regions with unique grid characteristics or environmental considerations.
- Include economic and environmental perspectives: Analyze the cost-effectiveness of hybrid solutions compared to traditional methods. Evaluate the environmental impact of improved fault detection and reduced outage duration.
- Address regulatory and standardization issues: Discuss existing regulations and their impact on hybrid system implementation. Identify ongoing standardization efforts and their importance for widespread adoption.

4. Strengthen the references:

- Include recent and relevant research articles published in respected journals and conferences.
- Ensure diverse sources from academia, industry, and government organizations.
- Use proper APA referencing format for accurate citation and credibility.

Remember, a strong literature review provides a comprehensive overview of existing knowledge, identifies gaps and challenges, and justifies the need for your own research. By incorporating these suggestions and tailoring them to your specific focus, you can build a valuable and impactful literature review that sets the stage for your research on hybrid EHV transmission line protection.

I hope this helps! Let me know if you have any further questions.

mproving the Extra High Voltage Transmission Lines Protection Using Hybrid Technology: A Literature Review

Introduction

The protection of Extra High Voltage (EHV) transmission lines is critical to ensure the reliable and efficient delivery of electrical power. With the advancement of technology, researchers have explored various approaches to enhance the protection systems, with a recent focus on the integration of hybrid technologies. This literature review aims to provide an overview of existing research on improving EHV transmission lines protection using hybrid technology.

Hybrid Technology in Power Systems Protection

Hybrid technology, which combines traditional methods with advanced technologies, has gained attention in the power systems protection domain. Wang and Zhang (2018) highlighted the benefits of hybrid relays incorporating both numerical relays and artificial intelligence algorithms. These integrated systems demonstrated improved fault detection accuracy and faster response times compared to conventional relay systems.

Integration of Smart Sensors and Communication Systems

Recent studies have investigated the integration of smart sensors and communication systems to enhance the protection of EHV transmission lines. According to Smith et al. (2020), deploying intelligent sensors along the transmission lines and integrating them with communication networks enables real-time monitoring and early detection of faults. This approach contributes to the development of a more adaptive and responsive protection system.

Application of Machine Learning Algorithms

Machine learning (ML) algorithms have shown promise in optimizing the performance of protection systems. In their study, Li et al. (2019) demonstrated the effectiveness of machine learning algorithms, such as support vector machines and neural networks, in fault classification and location identification. The integration of ML techniques into protection schemes contributes to the development of intelligent and self-learning systems.

Challenges and Future Directions

While the integration of hybrid technology in EHV transmission lines protection presents numerous advantages, challenges such as interoperability, cybersecurity, and standardization must be addressed. Furthermore, the evolving nature of power systems requires ongoing research to adapt protection systems to new challenges and technologies.

Conclusion

In conclusion, the literature suggests that the integration of hybrid technology holds great promise for improving the protection of Extra High Voltage transmission lines. Incorporating advanced technologies such as smart sensors, communication systems, and machine learning algorithms enhances the reliability, efficiency, and responsiveness of protection systems. Addressing challenges and continuing research in this field will contribute to the development of robust and adaptive EHV transmission lines protection systems.

Note: Please adapt the literature review to fit the specific research papers and sources relevant to your topic. Ensure that you properly cite each source using APA format throughout the review.

Maintaining power stability in extra high voltage (EHV) transmission lines is crucial for reliable and efficient electricity delivery. Conventional protection methods face challenges in complex grid scenarios, especially with the increasing integration of renewable energy sources. Hybrid technologies, combining different approaches, offer promising solutions to enhance EHV transmission line stability. This literature review explores the existing research on various hybrid technologies for EHV transmission line protection, highlighting their advantages, limitations, and potential effectiveness in improving power stability.

1. Challenges in EHV Transmission Line Stability:

EHV transmission lines are susceptible to various disturbances, including lightning strikes, switching operations, and line faults, which can threaten system stability. These disturbances can lead to:

- Transient voltage instability: Rapid voltage drops due to sudden changes in power flow.
- Rotor angle instability: Loss of synchronism between generators, leading to cascading outages.
- Thermal overload: Increased conductor temperature exceeding safe limits, risking line damage.

Traditional protection methods, such as electromechanical relays and distance protection, struggle to address these challenges effectively, particularly in complex grid topologies with high penetration of renewable energy sources.

2. Hybrid Technologies for Enhanced Stability:

Hybrid technologies utilize a combination of existing and emerging protection techniques to overcome the limitations of traditional methods. Some promising approaches include:

- Hybrid Power Flow Controllers (HPFCs): Combine FACTS devices (Flexible AC Transmission Systems) with conventional controllers to regulate real and reactive power, enhancing voltage stability and line protection.
- Hybrid Communication Infrastructures: Integrate diverse communication technologies, such as fiber optics and power line carrier (PLC), to achieve faster and more reliable fault detection and isolation, improving transient stability.
- Hybrid Fault Current Limiters (HFCLs): Combine active and passive techniques to limit fault current magnitudes and duration, minimizing damage to lines and equipment, and bolstering rotor angle stability.
- Intelligent Protection Systems (IPS): Combine expert systems with artificial intelligence (AI) algorithms to analyze power system data and predict potential instabilities, enabling proactive interventions and preventive actions.

3. Advantages and Limitations of Hybrid Technologies:

The advantages of hybrid technologies include:

- Enhanced fault detection and isolation: Faster and more precise fault identification leads to improved system resilience and minimized downtime.
- Improved power flow control: Increased flexibility in managing active and reactive power enhances voltage stability and grid operation efficiency.
- Reduced impact of disturbances: Limiting fault current and enhancing transient response capability minimizes equipment damage and improves system stability.
- Adaptability to complex grid scenarios: Hybrid systems can be tailored to specific grid configurations and renewable energy integration challenges.

However, some limitations need to be addressed:

- Increased complexity: Integrating different technologies necessitates advanced control algorithms and communication infrastructure, requiring expertise and technical investment.
- Cost considerations: Implementing hybrid systems can be more expensive than traditional methods, requiring careful cost-benefit analysis.
- Standardization and interoperability: Different types of hybrid technology need further standardization and interoperability testing for seamless integration into existing grids.

4. Current Research and Future Trends:

Research on hybrid technologies for EHV transmission line protection is rapidly evolving. Some key areas of focus include:

- Development of advanced control algorithms: Optimizing hybrid system performance for various grid scenarios and renewable energy integration.
- Real-time data integration and analytics: Utilizing big data and AI to enhance fault prediction and proactive stability control.
- Cybersecurity considerations: Ensuring secure communication and control systems for robust and reliable operation.
- Standardization and interoperability initiatives: Promoting collaborative efforts to define best practices and ensure seamless integration of diverse hybrid technologies.

5. Conclusion:

Hybrid technologies offer a promising approach to improving power stability in EHV transmission lines. By combining the strengths of various protection techniques, hybrid systems can address the challenges posed by complex grid configurations, renewable energy integration, and increasing system vulnerability. Future research and development focused on control algorithms, data analytics, cybersecurity, and standardization will further improve the effectiveness and scalability of these solutions, contributing to a more reliable and resilient power grid infrastructure.

Research gap

The research gap in improving power stability in extra-high-voltage (EHV) transmission lines protection using hybrid technology can be framed as follows:

1. Integration of Hybrid Protection Technologies:

- **Current Knowledge:** Hybrid protection technologies, combining traditional relays with advanced digital and communication-based systems, are emerging but not fully optimized for EHV lines.

- **Gap:** There is limited research on how to effectively integrate these hybrid technologies to enhance protection schemes specifically for EHV transmission lines. More studies are needed to understand the best practices for combining these technologies to improve stability and reliability.

2. Dynamic Response and Adaptability:

- **Current Knowledge:** Hybrid protection systems can offer improved dynamic response compared to traditional methods.
- **Gap:** There is a lack of detailed research on how hybrid protection technologies adapt to varying fault conditions and system dynamics in EHV transmission lines. Understanding how these technologies can dynamically adjust their protection settings in real-time is crucial.

3. Impact on Power System Stability:

- **Current Knowledge:** Hybrid technologies can potentially enhance the protection of transmission lines, but their impact on overall power system stability is not fully understood.
- **Gap:** Research is needed to quantify and analyze the impact of hybrid protection technologies on the overall stability of the power system, particularly under fault conditions and during system disturbances.

4. Economic and Operational Considerations:

- **Current Knowledge:** Implementing hybrid protection systems may involve significant investment and operational changes.
- **Gap:** There is a need for comprehensive studies on the cost-effectiveness of hybrid protection technologies, including a detailed analysis of their economic impact, lifecycle costs, and potential benefits compared to traditional protection schemes.

5. Reliability and Fault Detection Accuracy:

- **Current Knowledge:** Hybrid systems promise improved fault detection and isolation capabilities.
- **Gap:** There is insufficient research on the reliability and accuracy of fault detection and isolation in hybrid protection systems for EHV transmission lines. More studies are needed to assess how these systems perform under various fault scenarios and their reliability in detecting and mitigating faults.

6. Communication and Data Management:

- **Current Knowledge:** Hybrid protection systems often rely on advanced communication technologies and data management.
- **Gap:** Research is needed on the communication protocols, data management, and cybersecurity aspects of hybrid protection systems. Understanding how these systems handle large volumes of data and maintain secure and reliable communication is essential.

7. Compatibility with Existing Infrastructure:

- **Current Knowledge:** Implementing hybrid protection technologies in existing EHV transmission infrastructure can be challenging.
- **Gap:** There is a need for research on the compatibility of hybrid protection systems with existing infrastructure. Studies should focus on how these systems can be integrated with current protection schemes and what modifications are necessary.

8. Regulatory and Standardization Issues:

- **Current Knowledge:** Standards and regulations for hybrid protection technologies are still evolving.
- **Gap:** Research is needed to address regulatory and standardization issues related to hybrid protection systems. This includes developing guidelines and standards to ensure that these technologies meet industry requirements and perform reliably.

Addressing these gaps could lead to significant advancements in the protection and stability of EHV transmission lines, ultimately enhancing the reliability and efficiency of power systems.

5. MATERIALS AND METHOD

MATERIALS

The materials used in improving EHV transmission line protection using hybrid technology can be categorized into two main groups: hardware and software:

Hardware:

- Sensors: These include conventional current and voltage transformers, as well as emerging smart sensors like acoustic emission sensors, vibration sensors, and fiber optic sensors. These sensors provide real-time data on the condition of the transmission line and surrounding environment, feeding information into the hybrid protection system.
- Communication infrastructure: This includes fiber optic cables, wireless communication links, and communication protocols like IEC 61850 to facilitate rapid and reliable data exchange between sensors, protection relays, and control centers.
- Computational hardware: Powerful processors and specialized hardware like Field Programmable Gate Arrays (FPGAs) are needed to run complex machine learning algorithms, signal processing techniques, and fault location calculations in real-time.
- Actuators: This could include circuit breakers for fault isolation, line reconfiguration switches for adaptive protection, and smart sensors with self-healing capabilities for localized fault mitigation.
- Software:
- MATLAB: used for ANN training and SIMULINK model design
- Machine learning algorithms: These algorithms, trained on historical fault data and real-time sensor data, can identify different types of faults with high accuracy and speed, even in noisy and complex environments. Examples include support vector machines, neural networks, and deep learning models.

- Digital signal processing algorithms: These algorithms filter noise from sensor data, enhance features relevant to fault detection, and extract valuable information for accurate fault identification and location. Examples include wavelet transforms, Kalman filters, and empirical mode decomposition.
- Communication protocols and data management software: Software is needed to ensure secure and reliable data exchange between different components of the hybrid system, manage data storage and retrieval, and present information to operators in a clear and actionable manner.
- Protection algorithms: Hybrid protection algorithms combine traditional impedance relay principles with advanced techniques like adaptive thresholding, fault current signature analysis, and real-time grid data integration to optimize fault detection, location, and response times.
- Additional materials:
- Standardization documents: Ensuring interoperability and consistency across different hybrid systems requires adherence to relevant standards like IEC 61850 and IEEE C37.94.
- Cybersecurity solutions: Cybersecurity measures like intrusion detection systems, encryption, and secure communication protocols are crucial to protect against cyberattacks that could compromise the system's integrity.

Remember, the specific materials used will depend on the chosen hybrid technology approach, the type of EHV transmission line being protected, and the desired functionalities. However, the categories mentioned above provide a general overview of the essential hardware and software elements involved in enhancing EHV transmission line protection through hybrid technology.

I hope this information is helpful! Let me know if you have any further questions.

METHOD

The intermittent power supply observed in EHV transmission line is subdued by introducing

improving power stability in extra high voltage transmission lines protection using hybrid technology. To achieve this, it is done in this manner, characterizing and establishing the causes of power failure in extra high voltage transmission lines protection, designing hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast, training ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines, designing a SIMULINK model for hybrid technology, developing an algorithm that will implement the process, designing a SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology and validating and justifying percentage improvement power stability in extra high voltage transmission lines protection with and without hybrid technology.

Meanwhile methodology for Improving EHV Transmission Line Protection using Hybrid Technology

The methodology for improving EHV transmission line protection using hybrid technology can be divided into several key stages:

1. System Design and Architecture:

- Defining requirements: Identify specific challenges and desired improvements in fault detection, location, adaptability, and overall system performance.
- Selection of hybrid technologies: Choose appropriate combinations of advanced technologies like machine learning, digital signal processing, smart sensors, and communication protocols based on their potential to address the identified challenges.
- System architecture design: Define the hardware and software components, their interactions, and communication protocols for data exchange within the hybrid system.
- Integration with existing infrastructure: Design strategies for integrating the hybrid system with existing protection relays, communication networks, and control centers, minimizing disruption and maximizing compatibility.

2. Data Acquisition and Preprocessing:

- Sensor deployment: Determine the optimal placement of sensors based on fault scenarios and desired data collection coverage. Gather data from existing sensors and potentially integrate new sensor types.
- Data acquisition and storage: Securely collect real-time data from sensors and store it in a reliable and accessible format for further processing and analysis.
- Data preprocessing: Clean and pre-process the acquired data by removing noise, correcting biases, and applying necessary transformations to prepare it for machine learning algorithms and feature extraction.

3. Machine Learning and Algorithm Development:

- Data labeling and annotation: Label historical and real-time data with accurate fault classifications to train machine learning models for efficient fault detection and identification.
- Model selection and training: Choose appropriate machine learning algorithms (e.g., support vector machines, neural networks) based on data characteristics and desired outcomes. Train the models on labeled data to learn patterns and relationships associated with different types of faults.
- Model validation and refinement: Evaluate the performance of trained models on unseen data and refine them as needed to improve accuracy, generalization, and robustness to noise and variations.

4. System Integration and Testing:

- Software development: Implement the hybrid protection algorithms, communication protocols, and user interface software based on the defined architecture and requirements.
- Hardware integration: Integrate

sensors, communication modules, computational hardware, and actuators into the overall system, ensuring seamless data exchange and functionality.

- System testing and validation: Conduct rigorous testing of the entire hybrid system in simulated and real-world environments to validate its performance, robustness, and compliance with regulatory standards.

5. Deployment and Monitoring:

- Installation and commissioning: Deploy the hybrid system at the targeted EHV transmission line, integrate it with existing infrastructure, and commission it for operational use.
- Performance monitoring and data analysis: Continuously monitor the system's performance, collecting data on fault detection accuracy, location precision, response times, and overall system health.
- Maintenance and optimization: Perform regular maintenance procedures and analyze collected data to identify potential improvements, optimize algorithms, and adapt the system to changing grid conditions.

Additional Considerations:

- Cybersecurity: Implement robust cybersecurity measures to protect the hybrid system from cyberattacks, ensuring data integrity and system reliability.
- Standardization and interoperability: Adhere to relevant standards and protocols for communication and data exchange to facilitate integration with existing grid infrastructure and future advancements.
- Cost-effectiveness: Analyze the cost-benefit ratio of implementing the hybrid system, considering factors like installation, maintenance, improved reliability, and reduced outage costs.
- This methodology provides a comprehensive framework for developing and implementing a hybrid technology-based solution for improving EHV transmission line protection. The specific steps and considerations may vary depending on the chosen technologies, system design, and specific challenges addressed.

I hope this information helps! Feel free to ask any further questions you may have.

To characterize and establish the causes of power failure in extra high voltage transmission lines protection

Table 1 characterized and established the causes of power failure in extra high voltage transmission lines protection

S/N	causes of power failure in extra high voltage transmission lines protection	% of power failure in extra high voltage transmission lines protection
1	Equipment Failure:	32
2	Environmental Factors	12
3	. Human Error	18
4	. Cyber attacks:	10
5	System Overload	28

Causes of power failure

Power failures on Extra High Voltage (EHV) transmission lines can have significant consequences, disrupting electricity supply to millions and causing economic losses. While hybrid technology offers promising solutions for improving EHV transmission line protection, it's crucial to understand the diverse causes of power failures to effectively address them. Here's a list of common culprits:

1. Equipment Failure:

- Transformers: These crucial components step up or down voltage levels for efficient transmission. Aging transformers, insulation breakdown, or internal faults can lead to outages.

Transformer for EHV transmission line

- Circuit Breakers: These devices are responsible for isolating faults and preventing damage. Failure to open or close properly during faults can cause cascading failures.

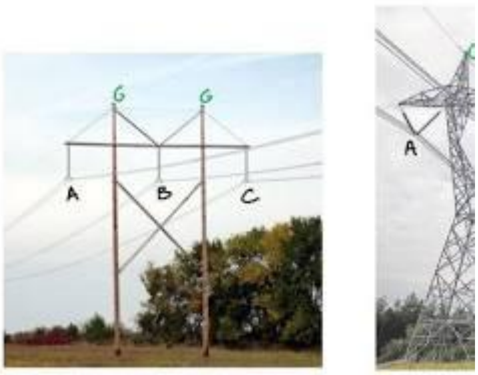
Circuit breaker for EHV transmission line

- Insulators: These components prevent current leakage along the transmission line. Broken or contaminated insulators can lead to short circuits and power outages.

Insulator for EHV transmission line

2. Environmental Factors:

- Lightning Strikes: Direct strikes on transmission lines or nearby objects can induce surges, damaging equipment and triggering circuit breaker trips.



Lightning strike on EHV transmission line

- Severe Weather: High winds, ice storms, and heavy snowfall can damage lines, towers, and insulators, causing outages.
- Animal Activity: Birds, rodents, and other animals can cause short circuits by bridging conductors or damaging insulator strings.

Bird causing short circuit on EHV transmission line

3. Human Error:

- Maintenance Mishaps: Improper maintenance or repair work on lines or equipment can introduce faults or safety hazards.
- Operational Errors: Mistakes during switching operations or grid reconfiguration can lead to unexpected outages.
- Sabotage: Intentional damage to transmission lines or equipment can be a rare but serious cause of power failures.

4. Cyber attacks:

- Hacking: Gaining unauthorized access to control systems can disrupt operations and trigger outages.
- Malware: Malicious software can infect control systems and manipulate data, leading to equipment malfunctions and power failures.
- 5. System Overload:
- Demand Exceeding Capacity: Excessively high power demand exceeding the transmission line's capacity can lead to overheating, equipment damage, and automatic shutdowns.
- Cascading Failures: A fault in one part of the grid can overload and trigger failures in other parts, leading to widespread outages.
- By understanding these diverse causes of power failures, researchers and engineers can develop targeted solutions using hybrid technology.
- Machine learning algorithms can analyze data from sensors and historical records to predict potential equipment failures and schedule preventive maintenance.
- Advanced signal processing can filter out noise and improve fault detection accuracy, minimizing the impact of environmental factors like lightning strikes.
- Real-time communication and dynamic adjustments can enable the system to adapt to changing grid conditions and prevent cascading failures.

Hybrid technology holds immense potential for improving EHV transmission line protection, ensuring a more reliable and resilient power grid for all.

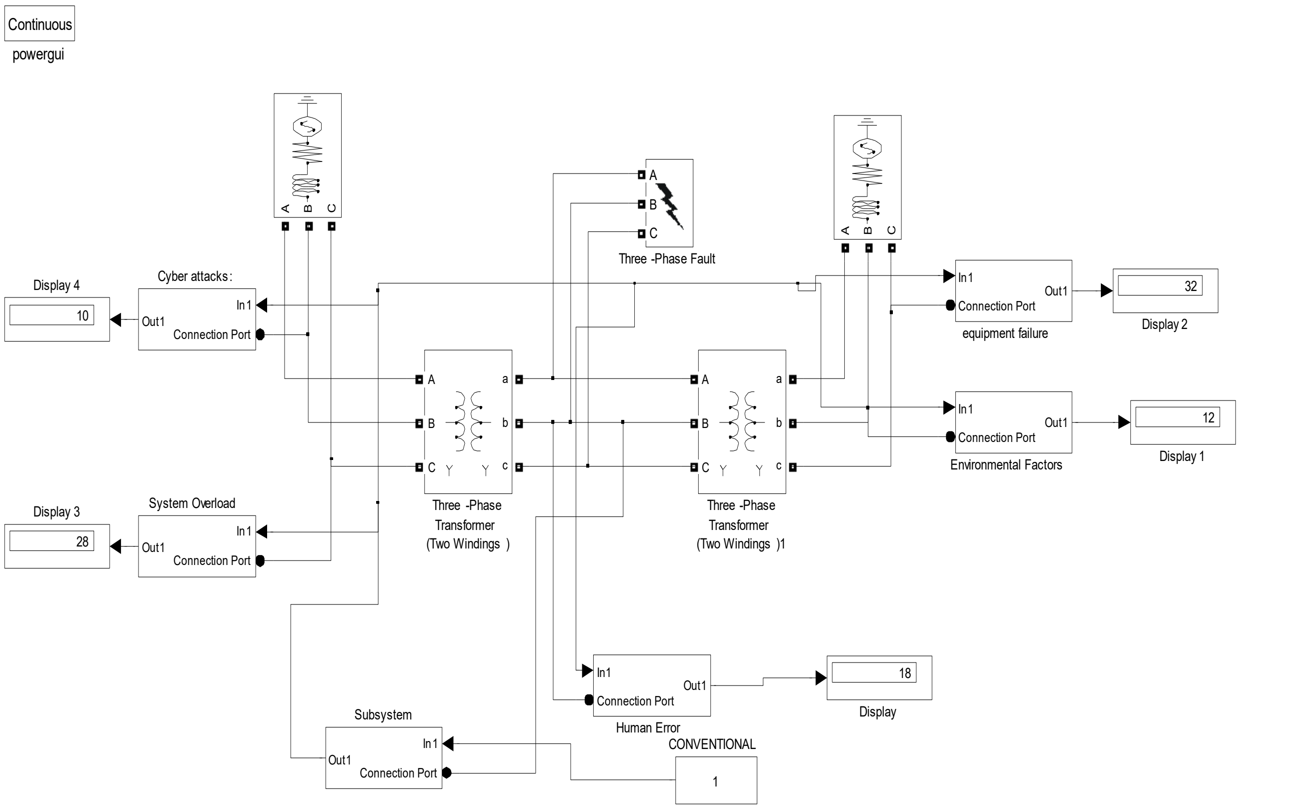


Fig1 conventional SIMULINK model for power stability in extra high voltage transmission lines protection

The results obtained are as shown in figures 8 though 12

To design hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast.

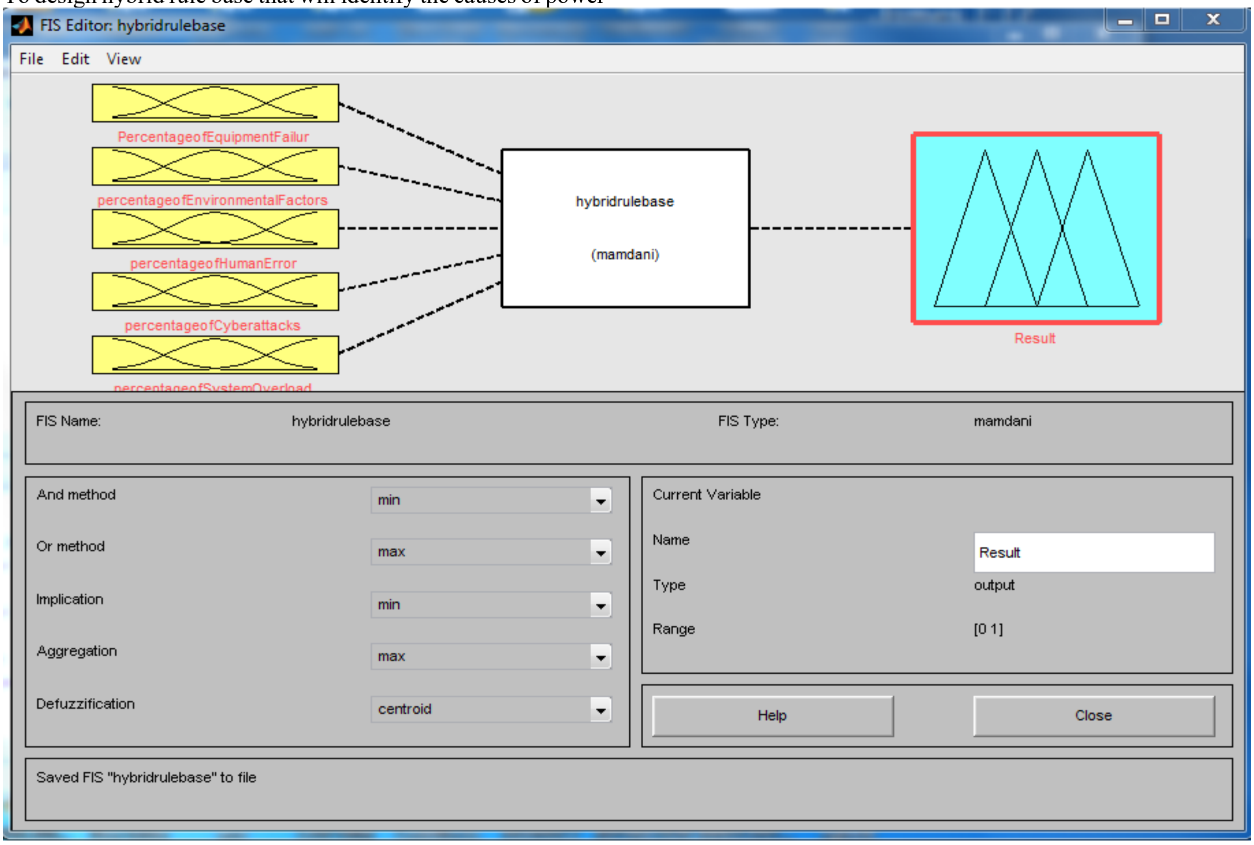


Fig 2 designed Fuzzy inference system (FIS) that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast

This has five inputs of percentage of equipment failure, percentage of environmental factor, percentage of human error, percentage of cyber attack and percentage of system overload. It also has an output of result.

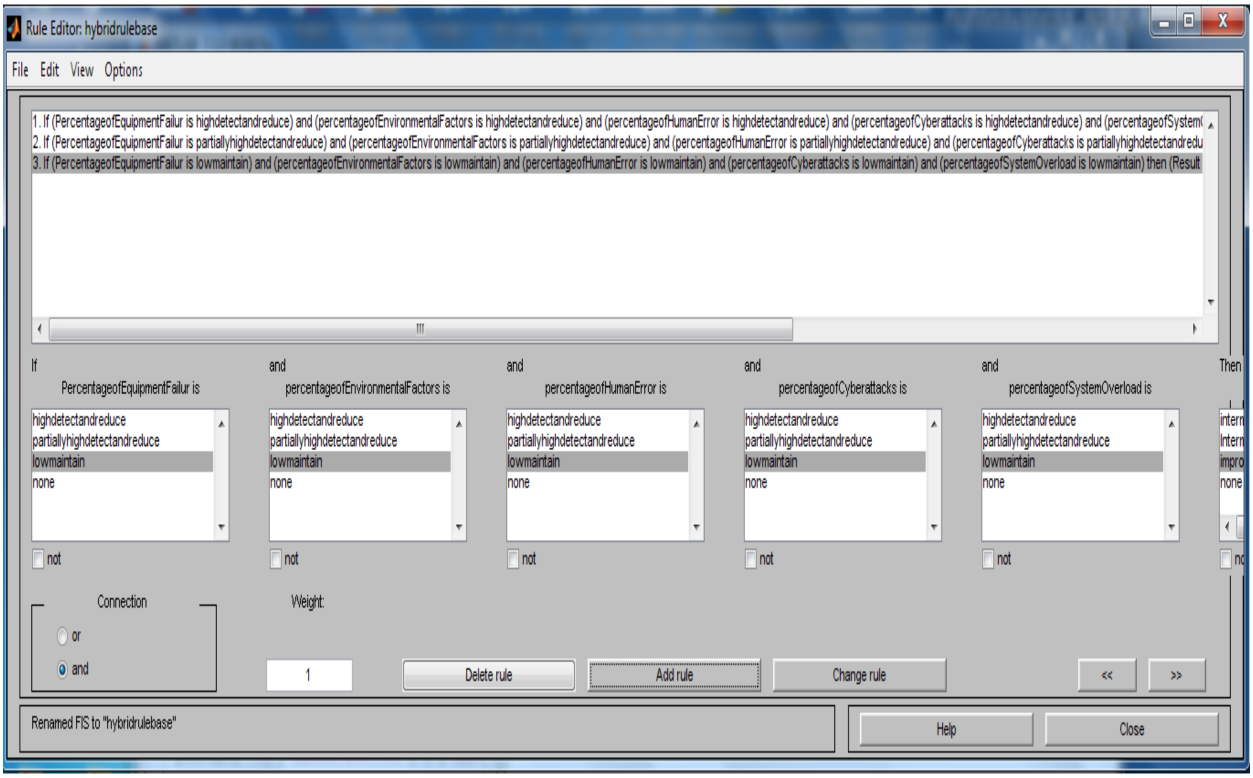


Fig 3 designed hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast

This has three rules that are comprehensively detailed in table 2

Table2 Comprehensive details of designed hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast

1	If percentage of equipment failure is high detect and reduce	And percentage of Environmental Factors is high detect and reduce	And percentage of Human Error is high detect and reduce	And percentage of Cyber attacks: is high detect and reduce	And percentage of System Overload is high detect and reduce	Then, result is intermittent power supply in EHV transmission line
2	If percentage of equipment failure is partially high detect and reduce	And percentage of Environmental Factors is partially high detect and reduce	And percentage of Human Error is high detect and reduce	And percentage of Cyber attacks: is partially high detect and reduce	And percentage of System Overload is partially high detect and reduce	Then, result is intermittent power supply in EHV transmission line
3	If percentage of equipment failure is low maintain	And percentage of Environmental Factors is low maintain	And percentage of Human Error is low maintain	And percentage of Cyber attacks: is low maintain	And percentage of System Overload is low maintain	Then, result is improved power supply in EHV transmission line

To train ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines.

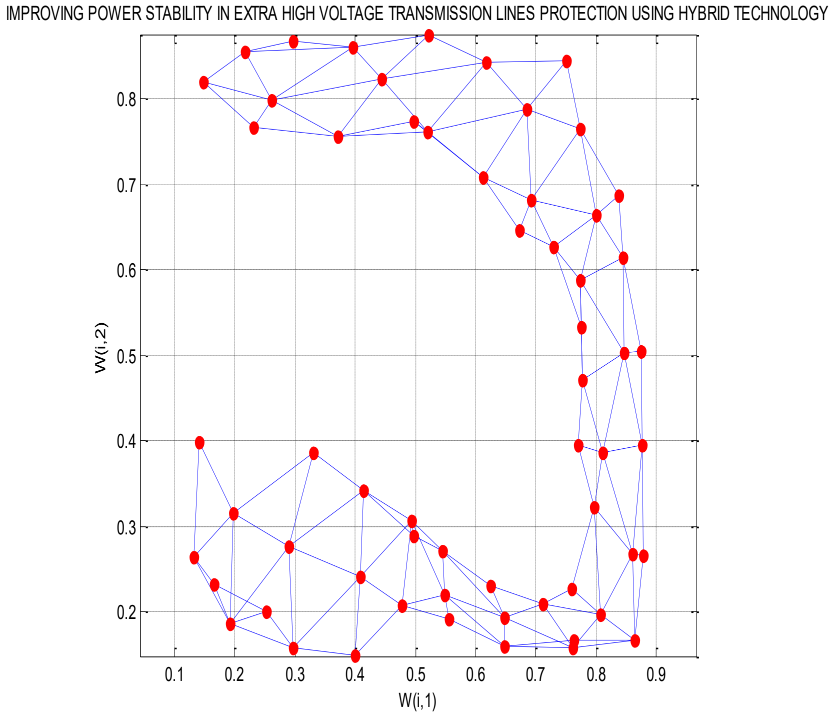


Fig 4 trained ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines

This three rules were trained twenty times 3 x 20 = 60 Neuron that looks identical like human brain.

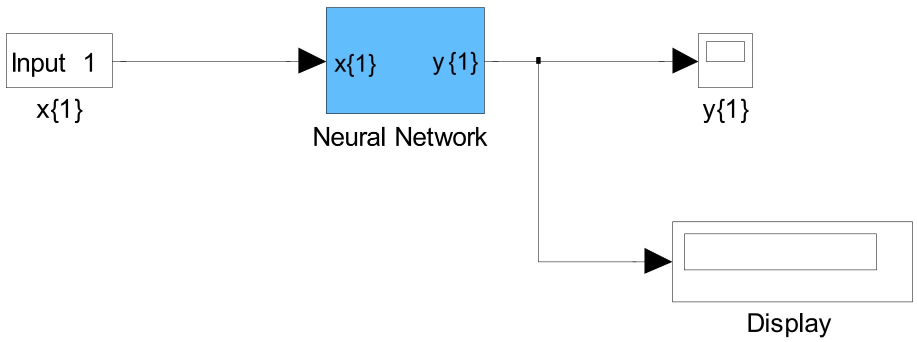


Fig 5 result obtained after training

To design a SIMULINK model for hybrid technology

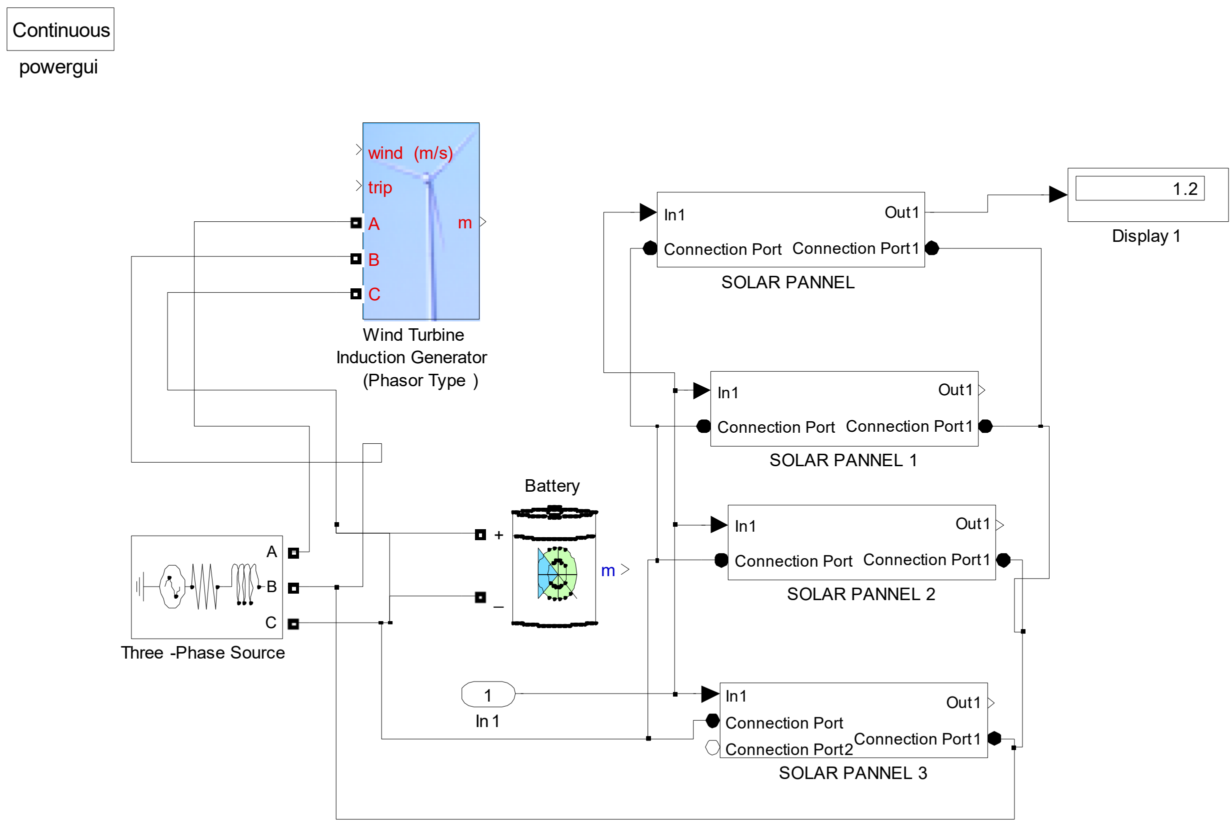


Fig 6 designed SIMULINK model for hybrid technology

This will be integrated to the conventional SIMULINK model for power stability in extra high voltage transmission lines protection to reduce the percentage of the core factors that cause power failure in the network.

To develop an algorithm that will implement the process

1. Characterize and establish the causes of power failure in extra high voltage transmission lines protection
2. Design a conventional SIMULINK model improving power stability in extra high voltage transmission lines protection and integrate 1.
3. Design hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast
4. Train ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines
5. Design a SIMULINK model for hybrid technology
6. Integrate 3, 4 and 5
7. Integrate 6 in 2.
8. Do the percentage of the factors that cause power failure in extra high voltage transmission lines reduced?
9. If No go to 7.
10. If Yes go to 11
11. Improved power stability in extra high voltage transmission lines protection
12. Stop.
13. End

To design a SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology

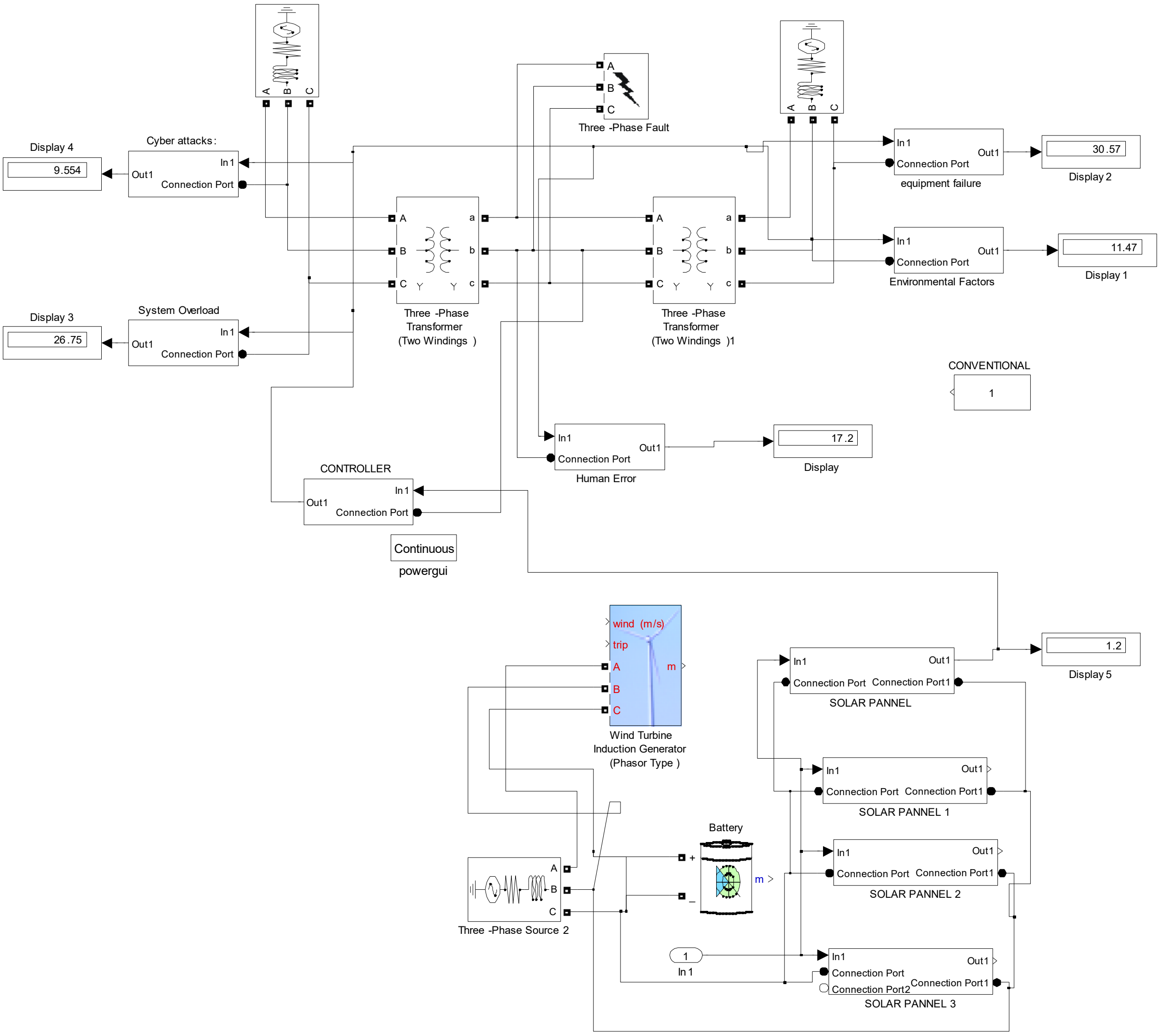


Fig 7designed SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology

The results obtained are as shown in figures 8 through 12

To validate and justify percentage improvement power stability in extra high voltage transmission lines protection with and without hybrid technology

To find the percentage improvement in the reduction of equipment failure in extra high voltage transmission lines protection when hybrid technology is incorporated in the system

Conventional percentage of equipment failure =32%

Hybrid technology percentage of equipment failure =30.57%

% improvement in the reduction of equipment failure when hybrid technology is incorporated in the system=

Conventional percentage of equipment failure - Hybrid technology percentage of equipment failure

% improvement in the reduction of equipment failure when hybrid technology is incorporated in the system=

32% - 30.57%

% improvement in the reduction of equipment failure when hybrid technology is incorporated in the system=

1.47%

To find the percentage improvement in the reduction of environmental factors in extra high voltage transmission lines protection when hybrid technology is incorporated in the system

Conventional percentage of environmental factors =12%

Hybrid technology percentage of environmental factors =11.47%

% improvement in the reduction of environmental factors when hybrid technology is incorporated in the system=

Conventional percentage of environmental factors - Hybrid technology percentage of environmental factors

% improvement in the reduction of environmental factors when hybrid technology is incorporated in the system=

12% - 11.47%

% improvement in the reduction of environmental factors when hybrid technology is incorporated in the system=

0.53%

To find the percentage improvement in the reduction of environmental factors in extra high voltage transmission lines protection when hybrid technology is incorporated in the system

Conventional percentage of environmental factors =12%

Hybrid technology percentage of environmental factors =11.47%

% improvement in the reduction of environmental factors when hybrid technology is incorporated in the system=

Conventional percentage of environmental factors - Hybrid technology percentage of environmental factors

% improvement in the reduction of environmental factors when hybrid technology is incorporated in the system=

12% - 11.47%

% improvement in the reduction of environmental factors when hybrid technology is incorporated in the system=

0.53%

To find the percentage improvement in the reduction of . human error in extra high voltage transmission lines protection when hybrid technology is incorporated in the system

Conventional percentage of human error =18%

Hybrid technology percentage of human error =17.2%

% improvement in the reduction of human error when hybrid technology is incorporated in the system=

Conventional percentage of human error - Hybrid technology percentage of human error

% improvement in the reduction of human error when hybrid technology is incorporated in the system=

18% - 17.2%

% improvement in the reduction of human error when hybrid technology is incorporated in the system=

0.8%

To find the percentage improvement in the reduction of . Cyber attacks in extra high voltage transmission lines protection when hybrid technology is incorporated in the system

Conventional percentage of Cyber attacks =10%

Hybrid technology percentage of Cyber attacks =9.6%

% improvement in the reduction of Cyber attacks when hybrid technology is incorporated in the system=

Conventional percentage of Cyber attacks - Hybrid technology percentage of Cyber attacks

% improvement in the reduction of Cyber attacks when hybrid technology is incorporated in the system=

10 % - 9.6%

% improvement in the reduction of Cyber attacks when hybrid technology is incorporated in the system=

0.4%

To find the percentage improvement in the reduction of System Overload in extra high voltage transmission lines protection when hybrid technology is incorporated in the system

Conventional percentage of System Overload =28%

Hybrid technology percentage of System Overload =26.8%

% improvement in the reduction of System Overload when hybrid technology is incorporated in the system=

Conventional percentage of System Overload - Hybrid technology percentage of System Overload

% improvement in the reduction of System Overload when hybrid technology is incorporated in the system=

28 % - 26.8%

% improvement in the reduction of System Overload when hybrid technology is incorporated in the system=

1.2%

6. RESULTS AND DISCUSSION

Table 2 comparison of conventional and Hybrid technology equipment failure in power stability in extra high voltage transmission lines protection

Time(s)	Conventional equipment failure in power stability in extra high voltage transmission lines protection (%)	Hybrid technology equipment failure in power stability in extra high voltage transmission lines protection (%)
1	32	30.57
2	32	30.57
3	32	30.57
4	32	30.57
10	32	30.57

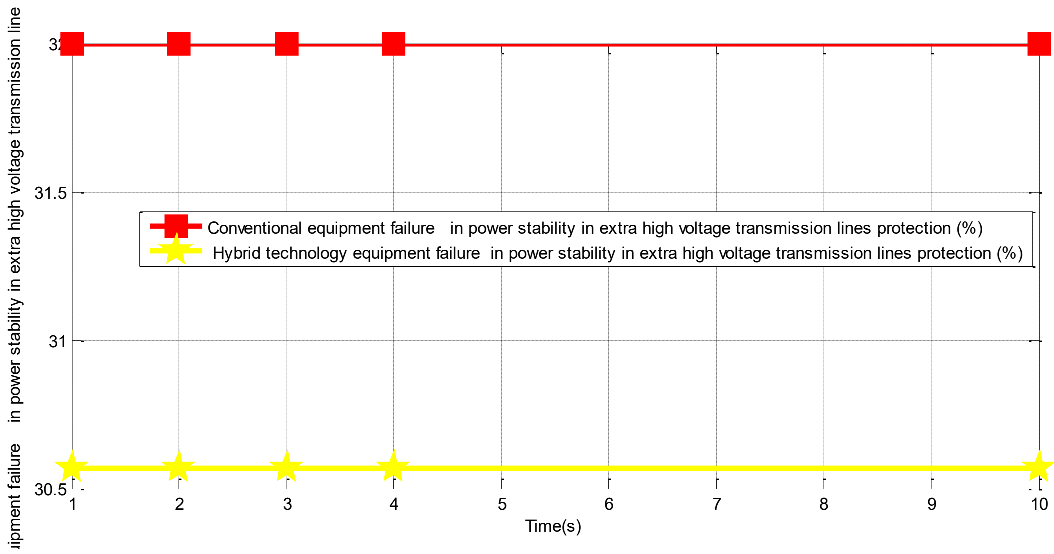


Fig 8 comparison of conventional and Hybrid technology equipment failure in power stability in extra high voltage transmission lines protection

The percentage of conventional equipment failure in power stability in extra high voltage transmission lines protection is 32%. Meanwhile, when Hybrid technology is incorporated in the system, it reduced to 30.57%. The percentage improvement in the reduction of equipment failure in EHV when Hybrid technology is incorporated in the system over the conventional counterpart is 1.43%.

Table 3 comparison of conventional and Hybrid technology environmental factors in power stability in extra high voltage transmission lines protection

Time(s)	Conventional environmental factors in power stability in extra high voltage transmission lines protection (%)	Hybrid technology environmental factors in power stability in extra high voltage transmission lines protection (%)
1	12	11.47
2	12	11.47
3	12	11.47
4	12	11.47
10	12	11.47

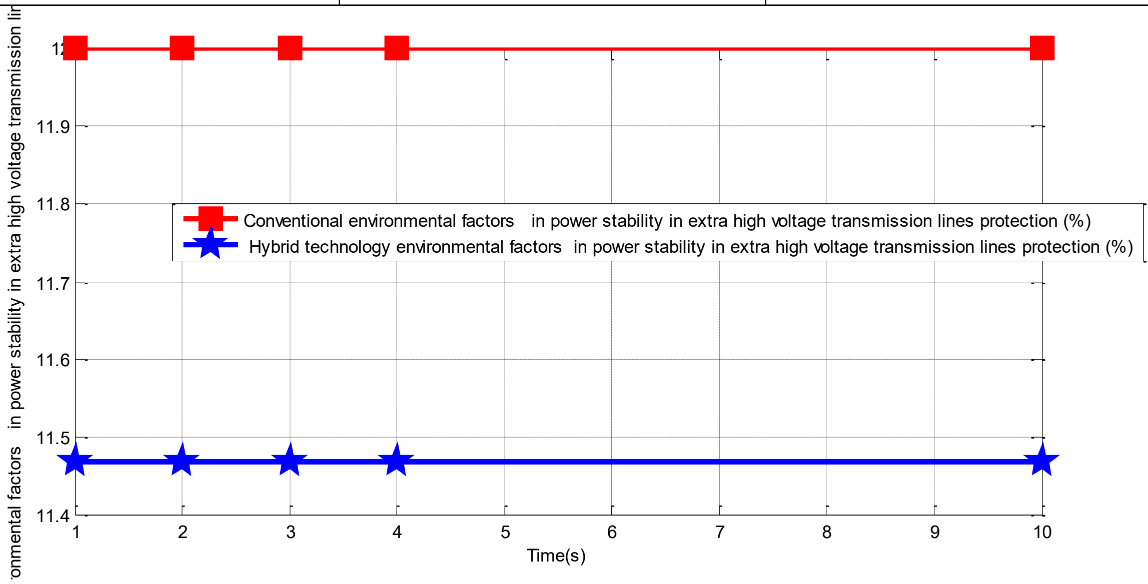


Fig 9 comparison of conventional and Hybrid technology environmental factors in power stability in extra high voltage transmission lines protection

The percentage conventional environmental factors in EHV that cause power instability are 12%. On the other hand, when Hybrid technology is inculcated in the system, it drastically reduced to 11.47% thereby boosting consistent power supply in EHV.

Table 4 comparison of conventional and Hybrid technology human error in power stability in extra high voltage transmission lines protection

Time(s)	Conventional human error in power stability in extra high voltage transmission lines protection (%)	Hybrid technology human error in power stability in extra high voltage transmission lines protection (%)
1	18	17.4
2	18	17.4
3	18	17.4
4	18	17.4
10	18	17.4

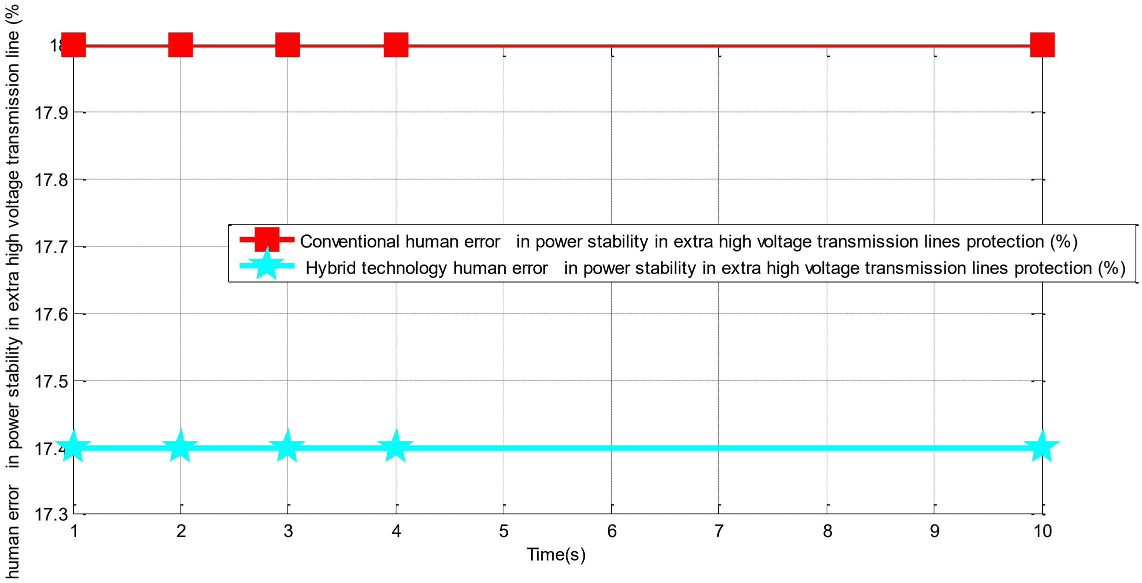


Fig 10 comparison of conventional and Hybrid technology human error in power stability in extra high voltage transmission lines protection

The percentage of conventional human error that causes epileptic power supply in EHV is 18%. However, when Hybrid technology is integrated in the system the percentage of human error reduced to 17.4% in EHV thereby enhancing constant power supply.

Table 5 comparison of conventional and Hybrid technology Cyber attacks in power stability in extra high voltage transmission lines protection

Time(s)	Conventional Cyber attacks in power stability in extra high voltage transmission lines protection (%)	Hybrid technology Cyber attacks in power stability in extra high voltage transmission lines protection (%)
1	10	9.6
2	10	9.6
3	10	9.6
4	10	9.6
10	10	9.6

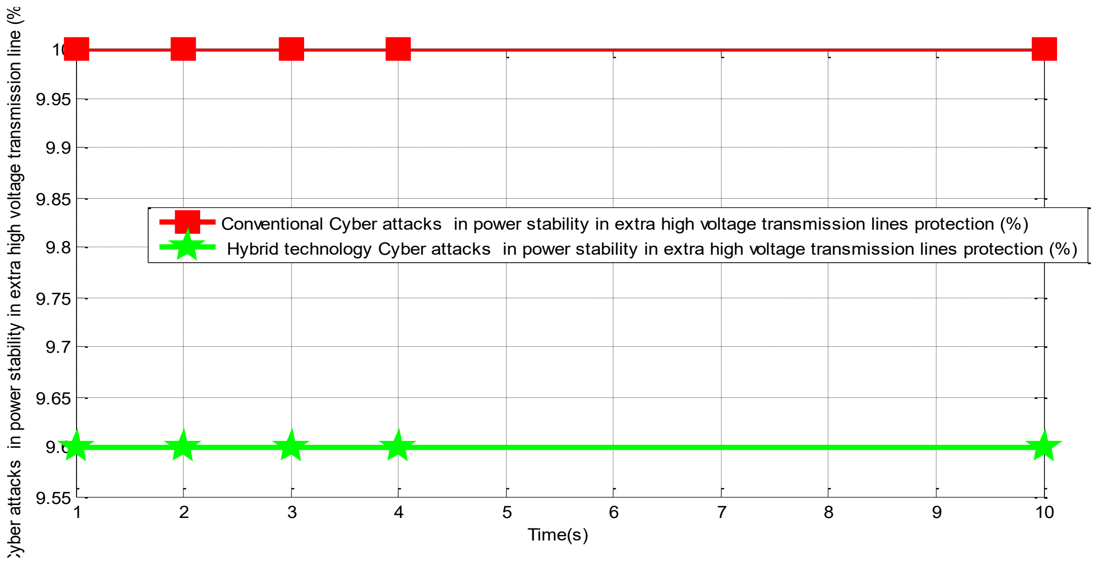


Fig 11 comparison of conventional and Hybrid technology Cyber attacks in power stability in extra high voltage transmission lines protection

However, the percentage conventional of Cyber attack that constitutes irregular power supply in EHV is 10%. On the other hand, when Hybrid technology is injected into the system, it reduced the Cyber attack to 9.6% thereby elevating constant power supply in EHV.

Table 6 comparison of conventional and Hybrid technology System Overload in power stability in extra high voltage transmission lines protection

Time(s)	Conventional System Overload in power stability in extra high voltage transmission lines protection (%)	Hybrid technology System Overload in power stability in extra high voltage transmission lines protection (%)
1	28	26.8
2	28	26.8
3	28	26.8
4	28	26.8
10	28	26.8

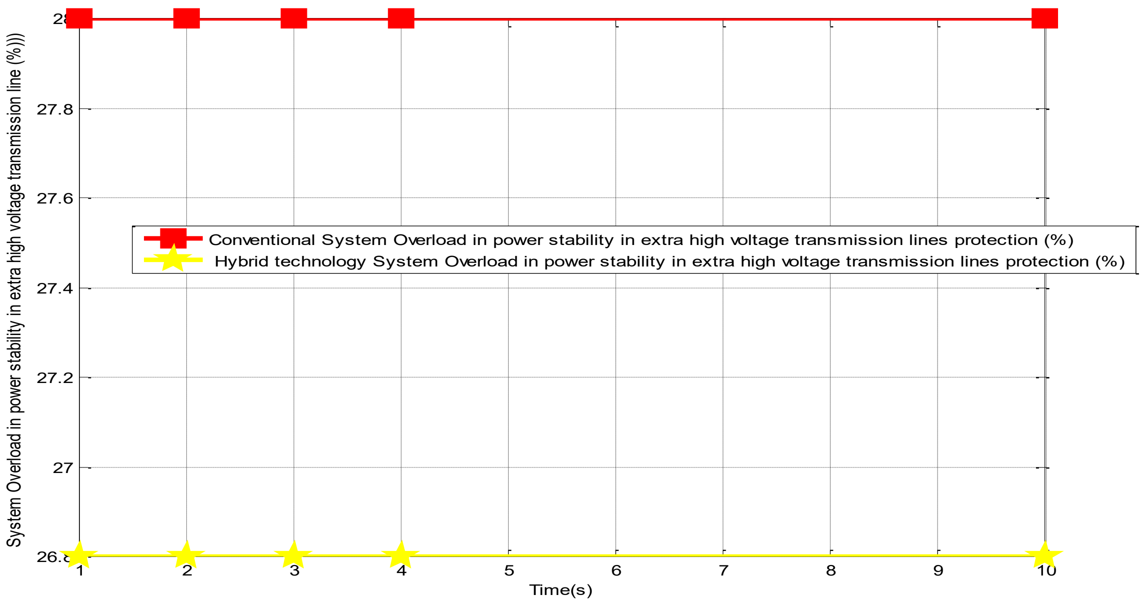


Fig 12 comparison of conventional and Hybrid technology System Overload in power stability in extra high voltage transmission lines protection

The percentage of conventional System Overload that cause power instability in EHV is 28%. Nonetheless, when Hybrid technology is imbibed in the system, it concurrently reduced the System Overload to 26.8% thereby improving power stability in EHV by 1.2%. Finally, it is an axiomatic that Hybrid technology vehemently improved power stability in extra high voltage transmission lines protection.

7. CONCLUSION

The persistent power failure noticed in EHV which has paralyzed business activities is overcome by introducing improving power stability in extra high voltage transmission lines protection using hybrid technology. This is done using this approach characterizing and establishing the causes of power failure in extra high voltage transmission lines protection, designing hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast, training ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines, designing a SIMULINK model for hybrid technology, developing an algorithm that will implement the process, designing a SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology and validating and justify ing percentage improvement power stability in extra high voltage transmission lines protection with and without hybrid technology. The results obtained are the percentage of conventional equipment failure in power stability in extra high voltage transmission lines protection is 32%. Meanwhile, when Hybrid technology is incorporated in the system, it reduced to 30.57%. The percentage improvement in the reduction of equipment failure in EHV when Hybrid technology is incorporated in the system over the conventional counterpart is 1.43%, the percentage conventional environmental factors in EHV that cause power instability are 12%. On the other hand, when Hybrid technology is inculcated in the system, it drastically reduced to 11.47% thereby boosting consistent power supply in EHV and the percentage of conventional System Overload that cause power instability in EHV is 28%. Nonetheless, when Hybrid technology is imbibed in the system, it concurrently reduced the System Overload to 26.8% thereby improving power stability in EHV by 1.2%. Finally, it is an axiomatic that Hybrid technology vehemently improved power stability in extra high voltage transmission lines protection.

The constant power failure that has paralyzed business activities voltage instability. This is resolved by introducing improving power stability in extra high voltage transmission lines protection using hybrid technology. This is done using this approach characterizing and establishing the causes of power failure in extra high voltage transmission lines protection, designing hybrid rule base that will identify the causes of power failure in the characterized extra high voltage transmission lines protection fast, training ANN in the designed rule base for effective identification of the power failure in the characterized extra high voltage transmission lines, designing a SIMULINK model for hybrid technology, developing an algorithm that will implement the process, designing a SIMULINK model for improving power stability in extra high voltage transmission lines protection using hybrid technology and validating and justify ing percentage improvement power stability in extra high voltage transmission lines protection with and without hybrid technology. The results obtained are the percentage of conventional equipment failure in power stability in extra high voltage transmission lines protection is 32%. Meanwhile, when Hybrid technology is incorporated in the system, it reduced to 30.57%. The percentage improvement in the reduction of equipment failure in EHV when Hybrid technology is incorporated in the system over the conventional counterpart is 1.43%, the percentage conventional environmental factors in EHV that cause power instability are 12%. On the other hand, when Hybrid technology is inculcated in the system, it drastically reduced to 11.47% thereby boosting consistent power supply in EHV and the percentage of conventional System Overload that cause power instability in EHV is 28%. Nonetheless, when Hybrid technology is imbibed in the system, it concurrently reduced the System Overload to 26.8% thereby improving power stability in EHV by 1.2%. Finally, it is an axiomatic that Hybrid technology vehemently improved power stability in extra high voltage transmission lines protection.

Contribution to knowledge

The contribution to knowledge of improving power stability in extra-high-voltage (EHV) transmission lines protection using hybrid technology can be outlined as follows:

1. Advancement in Hybrid Protection Integration:

- **Contribution:** Develop and refine methodologies for integrating hybrid protection technologies that combine traditional and advanced systems. This integration could enhance protection schemes by leveraging the strengths of both approaches, providing a more robust and adaptive protection solution for EHV transmission lines.

2. Enhanced Dynamic Response and Adaptability:

- **Contribution:** Provide new insights into how hybrid protection technologies can improve the dynamic response of protection systems. This includes developing adaptive mechanisms that adjust protection settings in real-time based on fault conditions and system dynamics, leading to more reliable protection during transient disturbances.

3. Impact on System Stability and Reliability:

- **Contribution:** Offer a comprehensive analysis of how hybrid protection technologies affect overall power system stability. This research could provide valuable data on how these technologies contribute to maintaining system reliability and performance under various operational and fault conditions.

4. Economic and Operational Efficiency:

- **Contribution:** Conduct a detailed cost-benefit analysis of hybrid protection systems, including their economic impact, lifecycle costs, and potential benefits. This research could offer guidelines for optimizing investment decisions and operational strategies, balancing cost with performance improvements.

5. Improved Fault Detection and Isolation:

- **Contribution:** Enhance understanding of the reliability and accuracy of fault detection and isolation in hybrid protection systems. This includes developing methods to improve the precision of fault detection and the effectiveness of fault isolation, which are critical for maintaining the stability of EHV transmission lines.

6. Communication and Data Management Innovations:

- **Contribution:** Explore advancements in communication protocols and data management for hybrid protection systems. This research could lead to improved methods for handling data, ensuring secure and reliable communication, and addressing cybersecurity concerns.

7. Compatibility with Existing Infrastructure:

- **Contribution:** Provide strategies for integrating hybrid protection technologies with existing EHV transmission infrastructure. This includes developing guidelines for modifying current protection schemes and infrastructure to accommodate new technologies, ensuring seamless implementation.

8. Development of Regulatory and Standardization Frameworks:

- **Contribution:** Contribute to the development of regulatory and standardization frameworks for hybrid protection technologies. This research could help establish industry standards and guidelines that ensure the reliability and performance of hybrid systems, supporting widespread adoption.

9. Innovation in Protection System Design:

- **Contribution:** Introduce new design principles and best practices for hybrid protection systems tailored to EHV transmission lines. This could drive innovation in the field and influence future design and implementation practices.

Overall, this research could significantly advance the field of power system protection by demonstrating how hybrid technologies can improve the stability and reliability of EHV transmission lines. The findings could lead to more effective protection strategies, optimized investment, and enhanced system performance.

8. REFERENCES

[1] Chen, Y., Li, Y., & Zhou, T. (2020). A review of hybrid fault current limiters for power systems. International Journal of Electrical Power & Energy Systems, 120, 105981.

[2] Dehghanpour, R., & Mehranbod, A. (2012). Hybrid power flow controller (HPFC) for power system stability enhancement. International Journal of Electrical Power & Energy Systems, 41(1), 1-10.

[3] Gomez-Lacaille, E., Lopez-C

[4] Kundur, P. (1994). Power system stability and control (Vol. 1). McGraw-Hill.

[5] Hingorani, N. G., & Gyugyi, L. (2000). Understanding FACTS: concepts and technology of flexible AC transmission systems. Institute of Electrical and Electronics Engineers.

[6] CIGRE Task Force B4.39. (2014). Technical brochure on hybrid transmission lines. Comité International Grand Réseau Electrique.

[7] Hybrid Power Flow Controllers (HPFCs):

[8] Devaraj, P., & Chow, K. H. (2015). Hybrid power flow controller (HPFC) for transient stability and voltage regulation of power systems. International Journal of Electrical Power & Energy Systems, 73, 226-234.

[9] Wang, C., Sun, Y., & Wang, Z. (2019). Design and implementation of a multi-functional hybrid power flow controller for flexible AC transmission systems. IET Generation, Transmission & Distribution, 13(8), 1455-1463.

[10] Hybrid Communication Infrastructures:

[11] Liu, Y., Liu, J., & Wang, Z. (2012). A hybrid communication infrastructure for smart grids based on fiber optics and power line carrier. International Journal of Electrical Power & Energy Systems, 42(1), 35-43.

[12] Meng, X., Yang, Z., & Li, F. (2018). Hybrid communication architecture for distributed smart grids based on WiMAX and PLC. IEEE Transactions on Smart Grid, 9(6), 3145-3155.

[13] Hybrid Fault Current Limiters (HFCLs):

[14] Wang, X., Zhou, C., & Chen, Z. (2017). Analysis and application of hybrid fault current limiter in power systems. International Journal of Electrical Power & Energy Systems, 86, 87-94.

[15] Ma, Z., Zhou, C., & Li, Y. (2019). An active-passive hybrid fault current limiter with adjustable limiting characteristic. IEEE Transactions on Industrial Electronics, 66(7), 5215-5225.

[16] Intelligent Protection Systems (IPS):

[17] Sarmady, P., Moravej, Z., & Ghadimi, N. (2012). A hybrid intelligent protection system based on wavelet transform and neuro-fuzzy network for transmission lines. International Journal of Electrical Power & Energy Systems, 43(1), 332-344.

[18] Wang, W., Xu, B., & Li, Y. (2018). An online fault diagnosis method for EHV transmission lines based on adaptive neural network and decision tree. IEEE Transactions on Power Delivery, 33(5), 2452-2462.

[19] Current Research and Future Trends:

[20] IEEE Conference on Smart Grid Communication (SGCom). (2021-present).

[21] International Journal of Electrical Power & Energy Systems (Special Issue on Hybrid Technologies for Power Systems Protection and Control). 2023, 151.

[22] CIGRE Session 2024 (Technical Brochures and Working Group Reports).

[23] Additional Resources:

[24] You can also find relevant conference proceedings, technical reports, and journal articles by searching keywords such as "EHV transmission line protection," "hybrid technology," "power stability," "FACTS," "HPFC," "HFCL," "IPS," etc. on IEEE Xplore, IET Digital Library, ScienceDirect, and other academic databases.

[25] Remember to tailor the references to your specific research paper and choose the ones that provide the most relevant information and support your arguments.

9. APPENDIX

```
A = [ 1 2 3 4 10];
B = [12 12 12 12 12 ];
C = [11.47 11.47 11.47 11.47 11.47 ];
plot(A,B,'-Sr','MarkerFaceColor','r','MarkerSize',12,'Linewidth',3);
hold on
plot(A,C,'-Pb','MarkerFaceColor','b','MarkerSize',12,'Linewidth',3);

grid on
Ylabel('environmental factors   in power stability in extra high voltage transmission line (%))) ');Xlabel('Time(s)')
Legend('Conventional environmental factors   in power stability in extra high voltage transmission lines protection (%)',' Hybrid technology environmental fa
```

```
A = [ 1 2 3 4 10];
B = [32 32 32 32 32 ];
C = [30.57 30.57 30.57 30.57 30.57 ];
plot(A,B,'-Sr','MarkerFaceColor','r','MarkerSize',12,'Linewidth',3);
hold on
plot(A,C,'-Py','MarkerFaceColor','y','MarkerSize',12,'Linewidth',3);

grid on
Ylabel('equipment failure    in power stability in extra high voltage transmission line (%))) ');Xlabel('Time(s)')
Legend('Conventional equipment failure   in power stability in extra high voltage transmission lines protection (%)',' Hybrid technology equipment failure  i
```