Parallel transmission lines protection using creative Cos-Sin protection

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1 - Abstract

This research addresses the critical challenges in protecting double-circuit transmission lines through an innovative approach utilizing a Cos-Sin function methodology, operating independently of communication channels. The proposed design represents a significant advancement in addressing conventional protection limitations

2 - Introduction

To overcome such drawbacks, this article introduces an innovative Cos-Sin function to protect double-circuit transmission lines without communication channels. The proposed design extracts a set of information from a creative Cos-Sin variational relay signal. This information is the size and polarity of the innovative Cos-Sin changing relay signal. In the proposed design, we measured the current signal only at the relay position. Apply a simple formula to combine three-phase power signals into one to reduce computational burden. In this study, we use ATP software to generate failure cases and MATLAB to implement the proposed design. Furthermore, this paper validates the simplicity of the experimental implementation of the proposed Cos-Sin variation for signal propagation using physical data. The software used to record physical data is his LABVIEW software. This paper also compares the proposed method with conventional methods and new existing methods. The results show that the proposed design is successful in overcoming these difficulties and its experimental setup is simple. Furthermore, this article documents the success of the proposed method under various transmission line lengths and system voltages. The results show that the proposed design is sensitive, selective, safe, reliable and dependable for the protection of dual-circuit transmission lines.

Power systems have widely installed parallel transmission lines due to their advantages of increasing power system capacity and reliability and reducing construction costs [1] [2] . Therefore, it is important to consider parallel transmission line protection. The transmission line plays an important role, and errors in the transmission line account for about 50% of the total errors [2] [1]. Moreover, malfunctions of its protection technologies cause dangerous stability problems such as cascading failures, isolation of interconnected subsystems, and large-scale power outages [3].

Protection relays used in parallel lines are more complex than those used in a single transmission line due to the mutual coupling between the dual circuits and the initial conditions for faults [4].

Transmission path protection measures include those that use communication channels and those that do not use communication channels. The reliability of communication links influences the reliability of communication-based protection [5].

Many recent research papers have proposed various protection schemes for parallel transmission lines. Longitudinal differential protection is now widely used in parallel ultra-high voltage transmission lines. However, this depends on the communication channel and is subject to capacity. Directional comparison pilot protection also depends on the communication channel, and mutual zero inductance affects the communication channel [2]. As a result, communication-based relays are typically costly and require high-accuracy synchronization between the two final measurements [6].

Current mutual differential protection is independent of the communication channel. However, if an abnormality occurs in the transmission line connection, it cannot be detected by remote side protection. The range of consecutive operating zones depends on the system conditions and is affected by the equivalent power supply resistance [2]. Cross differential relays only require information from one terminal. However, it is not possible to distinguish between the transient components that occur in the case of a fault and those that occur due to the opening of a circuit breaker [3].

There are two ways to resolve this issue. The first method involves impedance-based relays, but because they require a voltage signal, they are subject to the transient response of transformers with coupling capacitors. The second method is the analysis of traveling waves induced by far-end circuit breaker opening-based relays [7].

Smart industries must be developed (Iqbal et al. 2020) and technology transfer must be ethical (Vargas-Elizondo 2020). Reference (Jung et al. 2020) presents a part alignment evaluation method for further industrialization.

My recent work goals are:

1. Develop speed of transmission line protection like

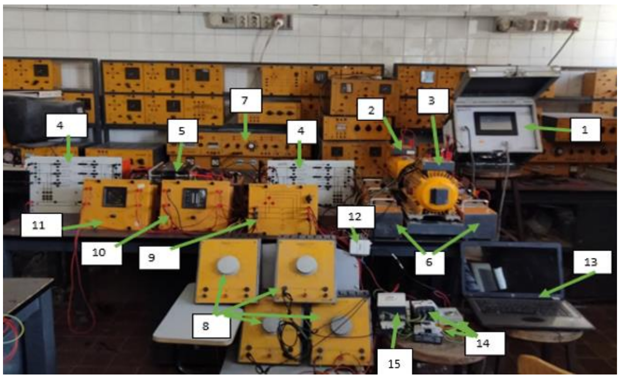


Figure1 Laboratory model of a wind turbine system it consists of

1-constant current source	9-Faults circuit
2-DC motor	10-Laptop
3-Synchronous generator	11-NI USB 6009 CARD
4-electric transmission line	12 -circuit breaker
5-transformer	13 -synchronization switch
6-current transformer	14-Frequency meter
7-electrical Grid	15-Voltage meter
8-resistors	

(Chen et al. in press-a).

2. Avoid unnecessary interruptions due to CT saturation due to out-of-zone errors such as: B. [8].

3. Provide an algorithm that is variant-insensitive under error conditions [9].

4. Improve protection techniques to prevent fault tolerance that can lead to malfunctions [10].

5. Maintain independent timing information technology to avoid the risk of losing data synchronization (Chen et al. in press-b).

All the above goals are benefits achieved with this work. The proposed technology is a new ultra-fast online digital design for protecting parallel transmission lines. The function of this design is to detect faults, distinguish between in-zone and out-of-zone faults, and select faulty circuits. Combine three-phase power signals into one signal using a simple formula. Therefore, calculations are reduced, and the speed of new transfer signal performance is increased.

The proposed design uses a set of information (size and polarity). Extract them from innovative Cos-Sin relay signals. It is independent of the communication channel and is independent of capacitance, mutual coupling of parallel lines, system configuration, line length and system voltage, and even compensation of series capacitors. The proposed relay is simple and does not use voltage measurements. Therefore, the transient response of the voltage converter does not affect this. The experimental implementation capability of the suggested relaying signal is confirmed.

The structure of this paper includes nine sections. The simulation model is presented in Sect. 2, followed by the proposed Cos-Sin signal in Part 3. Then, Sect. Figure 4 shows the proposed protection. Furthermore, Section 5 explains the simulation results and discussion. Section 6 presents the possibilities for experimental design, followed by the advantages of the proposed method over traditional algorithms in Section 6. Then, Section 8 presents a comparison of the new and existing methods. Section 9 provides the conclusions.

3 Simulation Model

Laboratory model of a wind turbine system

Figure 2 to connect the protection program in the computer and the laboratory model, an interface card, USB 6009, produced by National Instruments, was used.

The 6009 card receives signals and sends them to the computer

The card 6009 receives the disconnect signal in the event of an faults within the protection area and sends it to the circuit breaker

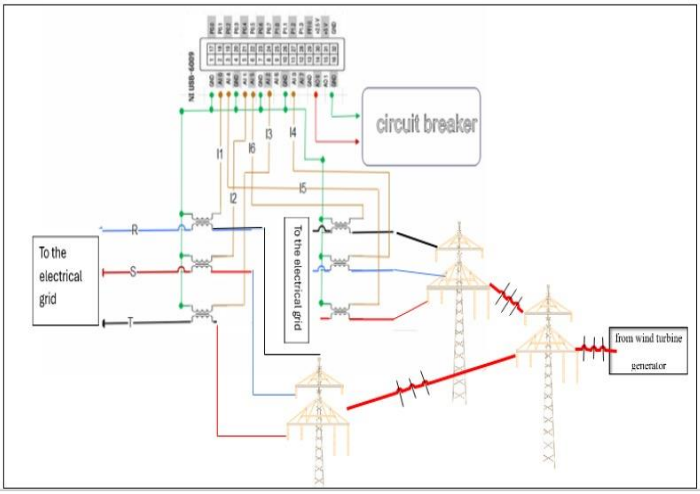


Figure 3 Scheme of laboratory of Simulation Model system

4 Proposed Cos-Sin Relaying Signal

The Cos-Sin transform is a mathematical tool to properly handle unsteady transient signals. Reference [11] shows the following Cos-Sin transformation: Reference

[11] presents the Cog-Sin transform and its complement to obtain the unity signal under

conditions and the deviation from unity under poor conditions. References [11] maintains a complementary signal artificially. These illustrate the general concept of Cos-Sin

Equation I. 2 and 3 represent the voltage or current of a sinusoidal signal at any time as 7(fl and its complement) χa(t).

X(t)= XmaxCos(wt + &)

Xa(t)= XmaxCos(wt + & – 90)

Xa(t)= XmaxSin(wt + &)

XCS = X 2(t)+ X2(t)

XCS = X2

Signal Processing Innovation: We present an innovative Cos-Sin transformation operation designed to detect and extract abrupt changes in signals. Unlike previous approaches, such as reference [11] which relies on artificially calculated complement signals, our methodology eliminates the need for artificial signal acquisition.

Cos-Sin Signal Calculation: The Cos-Sin signal (χCS) is computed using a moving window methodology. Key characteristics of this approach include:

1. Moving Window Parameters:
   - Window duration: One-quarter cycle time
   - Time interval: Equivalent to the separation between cosine and sine signals (90°)
2. Mathematical Foundation: The proposed Cos-Sin signal (χCS) is mathematically defined as: $XCS(n) = X^2(m) + X^2(m - mq)$

Where:

- χ(n) represents the original sine signal
- m denotes the number of samples
- mq indicates the number of samples in a quarter cycle

Signal Behavior Analysis:

1. Healthy Sinusoidal Signal Conditions:
   - When the moving window spans a quarter cycle
   - The transformed signal value equals X^2max
   - Maintains constant value under normal operating conditions
2. Distorted Signal Characteristics (Fault Conditions):
   - The transformed signal deviates from the X^2max value
   - Provides clear indication of system anomalies
   - Enables fault detection through value variation

Implementation Advantages: This mathematical foundation facilitates the development of a straightforward protection scheme based on two key properties:

- Constant X^2max value during normal operation
- Distinct deviation from X^2max during signal distortion

Signal Enhancement: The research proposes additional processing operations to modify the Cos-Sin signal, further improving its effectiveness in protection applications. This enhancement builds upon the fundamental transformation while maintaining the method's inherent simplicity.

This approach represents a significant advancement in signal processing for protection systems, offering both mathematical elegance and practical utility.

Would you like me to elaborate on any specific aspect of the signal processing methodology or its implementation?

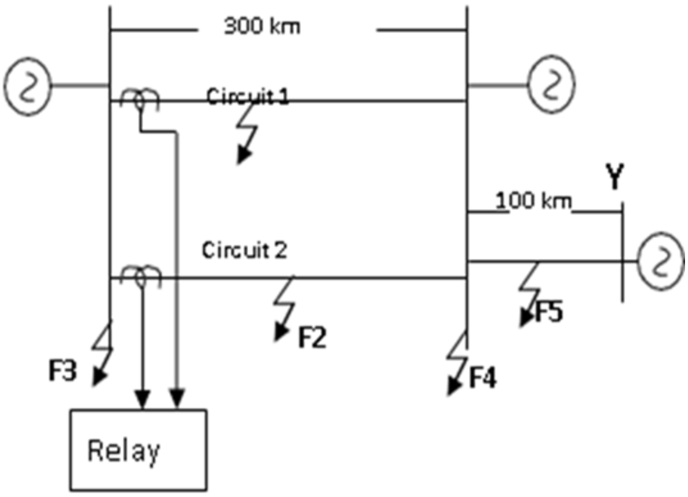


Figure 4 The tested transmission system

Proposed Signal Modification: The signal modification process introduces a novel relaying signal with distinct characteristics:

- Zero value during healthy system conditions
- Non-zero value during distorted signal conditions

Signal Processing Methodology:

1. Subtraction Process: The Cos-Sin variation signal (XCSV) is obtained through a subtraction process applied to the Cos-Sin signal. This process is mathematically represented as:

$$XCSV(k) = XCS(k) - XCS(k-1)$$

Where:

- k represents the sample number of the Cos-Sin signal
- The process window spans two consecutive samples

2. Sample Management: The implementation requires specific sample handling:

- Total required samples: Quarter cycle plus two samples
- Implementation of a sliding window mechanism
- Real-time sample processing where:
  - New samples enter the processing window
  - Oldest samples exit simultaneously
  - This approach minimizes relay response time

3. Processing Window Characteristics:

- Dynamic window operation
- Continuous sample updating
- Efficient memory utilization
- Optimized for real-time protection applications

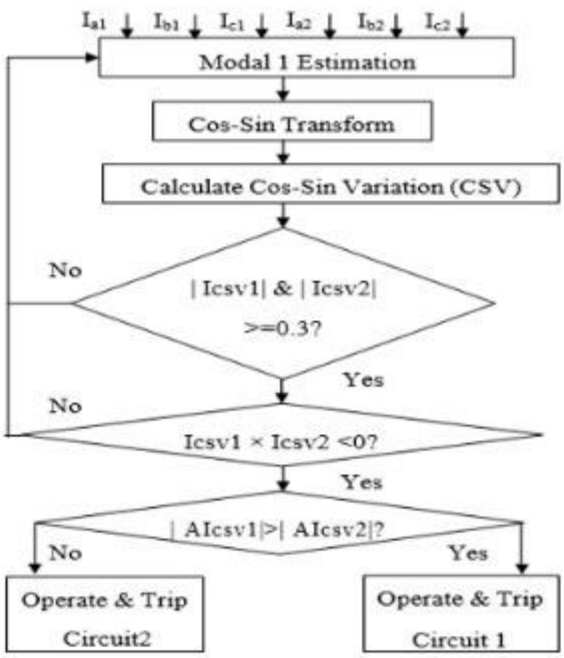
4. Time Optimization: The design specifically addresses relay timing considerations:

- Immediate sample processing
- No accumulation of processing delay
- Maintenance of protection system responsiveness

This enhanced signal processing methodology provides a robust foundation for protection system applications, offering:

- Clear distinction between normal and fault conditions
- Efficient computational implementation
- Real-time operation capability
- Minimal processing delay

The modification represents a significant advancement in protection system signal processing, combining mathematical precision with practical implementation considerations.



Figur5 shows a flow chart of the protection technology used

In the previous section of the research, the steps of the arithmetic and logical operations of the algorithm were shown and explained in the flow chart shown in Figure5

The order of the steps is as follows: -

System Design and Implementation: This research introduces a groundbreaking Cos-Sin function that enables the development of a robust single-ended digital relay system specifically designed for double circuit line protection. The implementation leverages the Cos-Sin feature through a novel methodology that consolidates three-phase currents into a unified current signal, resulting in:

- Reduced computational complexity
- Enhanced response speed
- Simplified decision-making based on Cos-Sin signal polarity and magnitude

Key Advantages:

1. Single-Terminal Operation:

- Information acquisition from a single terminal
- Elimination of communication requirements
- No synchronization equipment needed

2. Voltage Independence:

- Operation independent of voltage measurements
- Immunity to transformer transient voltage responses
- Elimination of redundant circuit breaker requirements

3. Robust Performance Under Challenging Conditions:

- Effective operation during CT saturation
- Reliable response to distant faults
- Accurate handling of high fault resistance
- Precise detection of proximal faults
- Appropriate response to short-duration faults

4. System Compatibility:

- Adaptable to various system voltages
- Flexible under different loading conditions
- Compatible with diverse system configurations
- Accommodates varying line lengths
- Unaffected by parallel circuit mutual coupling
- Resistant to switching capacitance effects

5. Enhanced Protection Features:

- Ultra-fast response characteristics
- Suitability for long-distance transmission lines
- Adaptability to various operational scenarios

Practical Implementation: The Cos-Sin methodology demonstrates exceptional practicality in real-world applications, featuring:

- Straightforward construction requirements
- Simple implementation process
- Reliable operation under diverse conditions
- Minimal maintenance needs

This innovative protection system represents a significant advancement in transmission line protection technology, offering a comprehensive solution that combines operational excellence with practical implementation simplicity. (5).

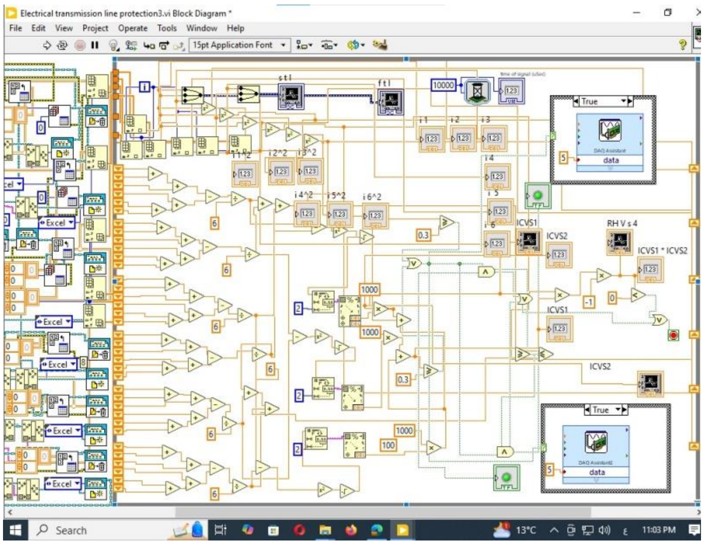


Figure6 shows the protection program designed on the LabView package

Possible operating conditions

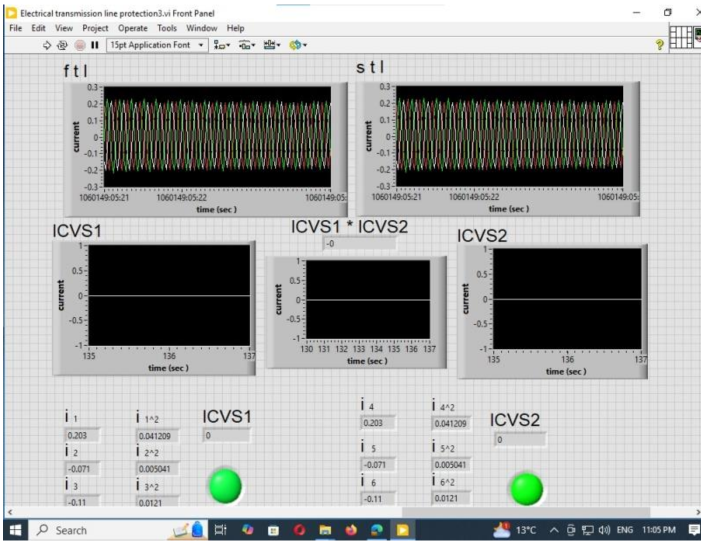


Figure 7 shows the waves of two parallel lines in the normal state

From the shape of the signals, it is clear that the waves are three-phase sine waves and that there are no errors of any kind

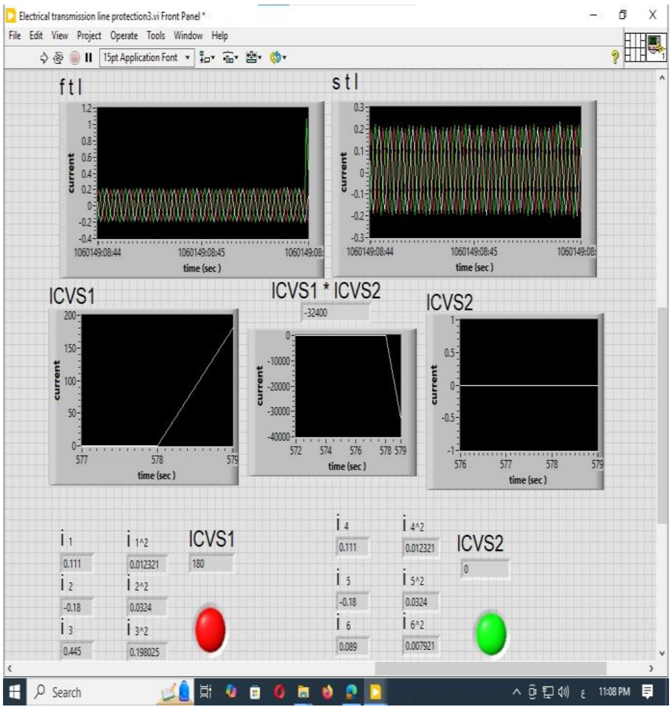


Figure8 shows the waves for two parallel lines in the event of a fault on the first line

From the shape of the signals, it is clear that there is an increase in the current of the second line, and this evidence indicates that the fault is internal. Based on this, the line with the fault was disconnected.

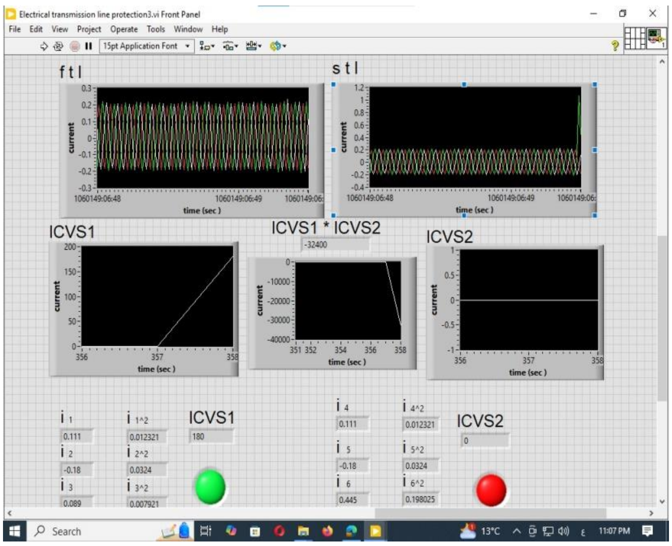


Figure9 shows the waves of two parallel lines in the event of a fault on the second line

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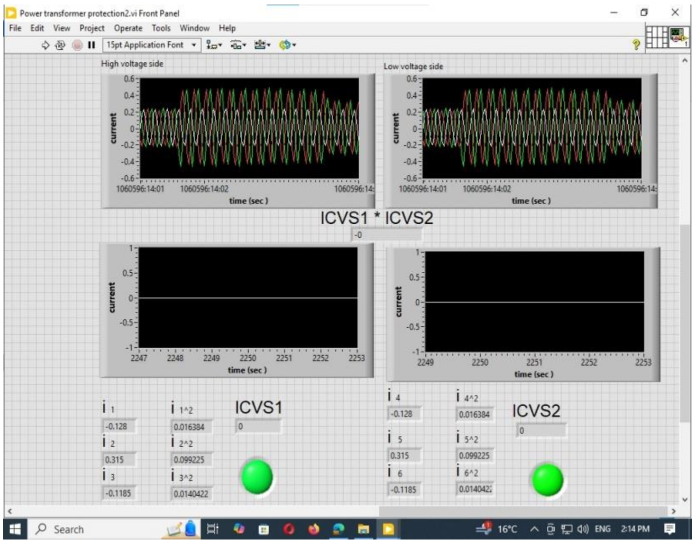

Figure 10 shows the waves of two parallel lines in the event of an external fault

From the shape of the signals, it is clear that there is an increase in the current of the first and second lines together. This is evidence that the fault is external.

Based on this, the protection did not take a decision to disconnect either of the two lines.

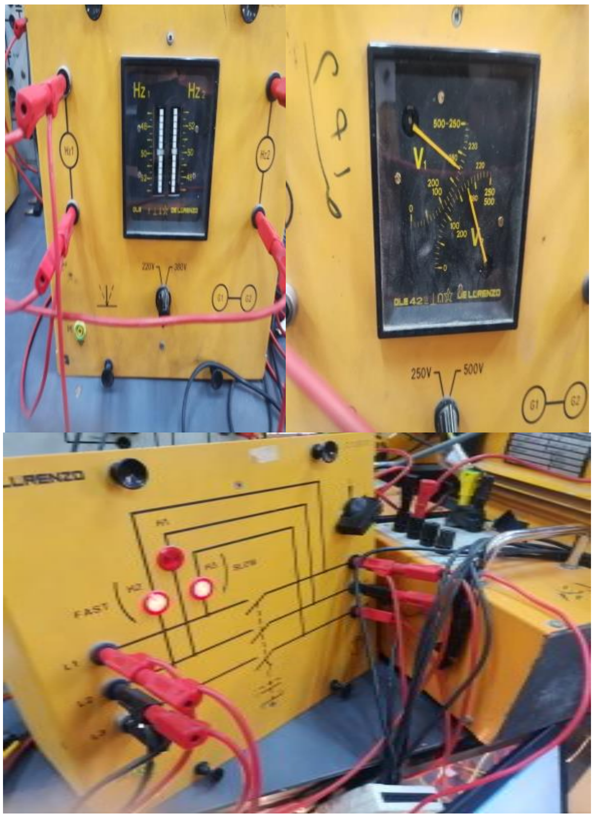

Figure11 shows the synchronization

After connecting and adjusting the voltage and frequency values, and following the phases, the laboratory system is connected to the local network

5 Conclusion

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