USE AI RELAY PROTECTION FOR TRANSFORMER PROTECTION

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Abstract: *Transformer protection is a critical component of modern electrical power systems, ensuring operational safety and reliability. This paper explores the use of artificial intelligence (AI)-based relays in transformer protection systems. The study demonstrates how AI relays improve fault detection accuracy, reduce response time, and enhance the overall performance of power systems. Experimental results show significant improvements in protection efficiency compared to traditional relay systems.*

Introduction

Power transformers are essential in electricity transmission and distribution networks. They are subject to various types of faults, including overcurrent, overvoltage, short circuits, and insulation failures. Traditional protective relays, which operate based on predefined settings and thresholds, can sometimes fail to accurately identify complex or evolving fault conditions.

AI-based relays, leveraging advanced machine learning algorithms, have the potential to revolutionize transformer protection. These relays are capable of learning from historical data and adapting to changing system conditions, thus offering superior protection capabilities. This paper investigates the design, implementation, and benefits of AI relays in transformer protection.

Methods

System design

The AI relay system was designed using supervised machine learning models. The primary components of the system include:

1. Data acquisition module the data acquisition module is responsible for gathering real-time operational data from the transformer. This includes:

- Voltage and Current Measurements: Accurate voltage and current readings are essential for detecting overcurrent, under-voltage, and short-circuit faults.
- Temperature Monitoring: Internal and ambient temperature data are collected to identify overheating issues that may indicate insulation failure or excessive load.
- Environmental Factors: External parameters such as humidity and atmospheric pressure may also be recorded, as they can affect transformer performance.

The module interfaces with sensors installed on the transformer and transmits the collected data to the feature extraction module. High-frequency sampling ensures that transient faults and fast-evolving conditions are captured.

2. Feature extraction module this module processes the raw data collected by the Data Acquisition Module and extracts relevant features that are critical for fault detection. The main tasks include:

- Signal Processing: Filtering and denoising the signals to remove noise and irrelevant variations.

- Harmonic Analysis: Identifying harmonic distortions, which can indicate load imbalance or non-linear loads affecting transformer performance.
- Load Variation Patterns: Analyzing load fluctuations over time to detect abnormal patterns.
- Thermal Trends: Tracking temperature changes and identifying potential overheating conditions.

Feature extraction is crucial for ensuring that the AI model receives high-quality input data, which directly impacts the accuracy of fault detection.

3. AI Model The AI Model is the core component of the system, responsible for analyzing the extracted features and making protection decisions. The key aspects of the AI model are:

- Neural Network Architecture: A multi-layer neural network was used, with layers optimized for time-series data analysis. The input layer receives the extracted features, while hidden layers process the data to detect patterns indicative of faults.
- Training Process: The model was trained using a large dataset of historical fault and normal operation scenarios. Supervised learning techniques were employed, with labeled data representing different fault types.
- Fault Classification: The model classifies inputs into various fault categories, such as short circuit, overcurrent, and thermal overload. Additionally, it can distinguish between transient and permanent faults, enabling more precise protection actions.
- Adaptive Learning: The model is designed to continuously learn from new data, allowing it to improve over time and adapt to evolving operational conditions.

Data collection.

Historical data from 50 power transformers over a period of five years was collected. The data included:

- Normal operating conditions

- Different fault scenarios (e.g., short circuit, overcurrent)
- Environmental conditions (e.g., ambient temperature)

Model training.

The collected data was divided into training (80%) and testing (20%) datasets. The neural network model was trained using backpropagation and stochastic gradient descent (SGD) algorithms. Cross-validation was employed to prevent overfitting.

Results

The AI relay system was tested in a laboratory environment simulating various fault conditions. Key findings include:

1. Improved Fault Detection Accuracy: The AI relay achieved a fault detection accuracy of 98.7%, compared to 92% for traditional relays.
2. Reduced Response Time: The average response time of the AI relay was 20 ms, compared to 35 ms for traditional systems.
3. Adaptability: The AI relay demonstrated an ability to adapt to new fault scenarios by retraining on updated data.

Discussion

The experimental results highlight the significant advantages of AI relays in transformer protection. The higher fault detection accuracy reduces the risk of transformer damage and unplanned outages. Additionally, the reduced response time ensures faster isolation of faults, minimizing the impact on the rest of the power system.

However, some challenges remain. The implementation of AI relays requires significant investment in data collection and model training infrastructure. Furthermore, the reliability of AI relays in real-world scenarios needs to be tested over extended periods.

Conclusion

AI-based relays offer a promising solution for improving transformer protection. By leveraging machine learning algorithms, these relays provide superior fault detection, faster response times, and greater adaptability compared to traditional systems. Future work will focus on real-world deployment and long-term performance evaluation of AI relay systems.

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