'National Conference on Advancements in Computer Science and Engineering'
International Journal of Scientific Research in Computer Science,
Engineering and Information Technology | ISSN : 2456-3307 (www.ijsrcseit.com)

High Impendence Power Based Fault Detection in Power Plant Grids Using Deep Learning

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ABSTRACT

When there are unexpected power outages, it can cause big problems for both the people who use electricity and the people who manage the power grid. To prevent these outages, it's important to figure out what's causing them. This study focuses on a community in the Arctic where they've had a lot of outages, but they don't know why. The researchers found that by using a certain type of data analysis, they could detect outages earlier and more accurately. They came up with a way to test whether there was a problem with the power grid by comparing two sets of data. They also developed two methods to find out where the problem was happening. Both of these methods were faster and more accurate than what people were using before. Overall, this study found better ways to detect and fix problems with the power grid, which can help prevent power outages and make electricity more reliable.

I. INTRODUCTION

Transmission lines (TLs) are subjected to severe atmospheric and environmental conditions, such as aging, human activities, and a lack of preservation and care, as well as lightning strikes, icing tree interference, bird nest breakage, and hurricanes. Power systems lose efficiency as a result of faults that interrupt the flow of power. As a result, one of the primary objectives of transmission lines is to reduce the impact of faults. There are a number of sensed physical parameters in a TL that are not constant, including generator voltages, phase differences between two generators, fault resistance, fault inception angle, fault location, and length of the TL. This is necessary to provide end-users with uninterrupted electrical power. Artificial intelligence techniques must be developed to deal with TL datasets that contain all of these parameter variations in order to take into account these variations. Different lengths of TLs produce distinct impedances, which in turn produce distinct performance analysis features. Based on their length, TLs generally fall into three categories: short TLs with a maximum length of (ksm), medium TLs with a length of (km), and long TLs with a length of at least (km). For the first time, a general solution that is compatible with various transmission lines and avoids time-consuming trainings and high computational costs is proposed in this study to classify and locate faults in these three categories.

In failure detection and isolation (FDI) systems, abrupt changes in the characteristics of the signal can be easily detected; This paper focuses on power system fault analysis as one of these domains. For estimating the time-instants of sudden changes in power system fault signals recorded during disturbances in the electrical power transmission network, we propose the use of adaptive whitening filters and wavelet transforms, particularly the dyadic-orthonormal wavelet transform.A protective relay is included in every power system, ensuring improved performance while minimizing disturbance and damage. Due to their rapid, accurate, and dependable operation, digital relays have replaced solid-state devices over the past few years. In addition to the units for fault classification and localization, digital relays' fault diagnosis unit also includes a fault detector (FD) unit.

The literature on the subject of power system fault detection has recently included a number of different approaches. The phasor comparison scheme and the comparison of the values in the current samples for two cycles that are greater than the threshold value can be used to identify a fault. However, it is limited because modeling fault resistance is difficult. In order to find problems with the power system, a Kalman filter-based method has been proposed. An approach based on wavelets is used to find the sudden change in the signal. The synchronized segmentation is used to identify disturbances. Then, the adaptive whitening filter and wavelet transform were applied to the signal to find the sudden change. However, the presence of noise and harmonics as well as frequency deviations make these techniques vulnerable.

For better performance in both normal and abnormal/faulty operating conditions, modern power utilities require an effective protection scheme to safeguard the system and connected equipment. Digital relays now take the place of electromechanical relays due to their features like faster operation, accuracy, and dependability. Fault data examples whose symptoms correspond to various Severity Levels (SLs) are common in Fault Detection and Diagnosis (FDD) applications. The fault detection through digital relays and fault detector (FD) is very important for implementing any real-time solutions. The figure-1 depicts a real-world test in which errors are sorted into four distinct SLs, from SL (the smallest) to SL (the most severe). For FDD applications, it is important to be able to accurately assess the severity of faults or diseases, but it is also very difficult, especially for low-severity examples; Compared to their corresponding SL clusters, SL data clusters are significantly more similar to the normal cluster. In order to identify faults of low severity, an FDD system needs to be extremely sensitive. likewise, there shouldn't be too many false positives, which makes designing such decision systems difficult.Modern smart grid systems are more difficult to monitor and control due to their growing size and complexity. When a large number of sensors are used to precisely and comprehensively monitor infrastructures and network status information like voltage, current, temperature, humidity, and so on, these systems employ a combination of sensing and networking technologies as well as computational subsystems to enable state estimation, event detection, and optimal control. The development of detection algorithms to safeguard the system against cyberattacks or power line failures is then one of the most important tasks. In order to accomplish this, the monitoring system receives high-fidelity voltage and current measurements from high-precision microphasor measurement units (PMUs). Advanced diagnostic and control methods may be made possible by the high-resolution sensor data. However, effective and efficient methods are required to extract and analyze information from these signals due to the data's high dimensionality and complex patterns.

One of the most popular relays for protecting transmission lines are distance protection relays (Glover, Sarma, &Overbye). Distance protection relays are frequently used as backup protection for transformer busbars and distant lines, despite their primary use in transmission and distribution lines. By comparing the voltage and current values of the transmission line, distance protection relays are adjusted to operate in accordance with the impedance of the line. The impedance value is measured to determine the distance from the point where the relay is connected to the fault .As the short circuit gets closer to the line's feeding point, its impedance decreases at a certain rate, which helps pinpoint the fault's location. A crucial component of protection systems is the ability to locate the fault in transmission lines. In recent years, the significance of studies on fault location investigation has significantly increased due to the increasing complexity of power transmission systems. A fault can be quickly fixed if its location is known or can be estimated with high accuracy. Since it prevents downtime, operating costs, revenue loss, customer complaints, and system instability, prompt troubleshooting is critical. Electrical energy is typically transmitted via overhead line systems. Transmission lines that have demonstrated their operational dependability and functional use are known as overhead line systems. Additionally, overhead lines have a long useful life and low installation costs.

II. PROPOSED SYSTEM

Due to their close resemblance to normal operating conditions, faults of intermediate severity (IS) have milder symptoms than faults of severe severity. As a result, they are more challenging to identify and treat. Fault Detection and Diagnosis (FDD) methods based on Machine Learning (ML) can be seriously harmed by the lack of IS fault examples in the training data because these faults are easy to mistake for normal operating conditions. We test a novel deep learning-based method for fault detection on a data set in this paper. Our solution makes use of a novel feature extraction mechanism and a Deep Metric Learning architecture to extract features. It also makes use of a Neural Network structure to make use of current phase information for prediction. The differential currents in phases a, b, and c are analyzed for a number of time- and frequency-domain features. Three of these features are chosen to distinguish internal faults from magnetizing inrush and three more to classify transformer faults in the primary and secondary. For real-time applications, the proposed fault detector is more accurate and robust than other options because it requires less computing power. Additionally, a comparative evaluation is carried out to determine how effective the proposed approach is in comparison to the existing ones. This strategy can be used to ensure fault accuracy. For feature extraction, independent component analysis is chosen due to its reliability in locating relevant and useful features.

Benefits-

- HaveWell-Understood Formal Properties Streamlined and decoupled services
- Fast and efficient, but also as accurate as the state-of-the-art algorithms
- Reduces the resources used for processing purpose.
- Increased efficiency and speed

A. Proposed Algorithm

Deep learning (DL) is a cornerstone of many computer vision applications. It aims at learning a mapping from the input domain to an embedding space, where semantically similar objects are located nearby and dissimilar objects far from another. Ground-truth class labels are used by the user to define the target similarity on the training data. On the other hand, while the embedding space learns to replicate the user-provided similarity on the training data, it ought to also be able to generalize to novel categories that were not observed during the training process. In addition to user-provided ground truth training labels, numerous additional visual factors such as viewpoint shifts or shape variations imply various notions of object similarity, influencing the generalization of images that are not seen during training

Benefits-

- Elimination of Feature Engineering.
- Maximum Utilization of unstructured Data.
- Generate new features from limited series of features.

B. System Architecture

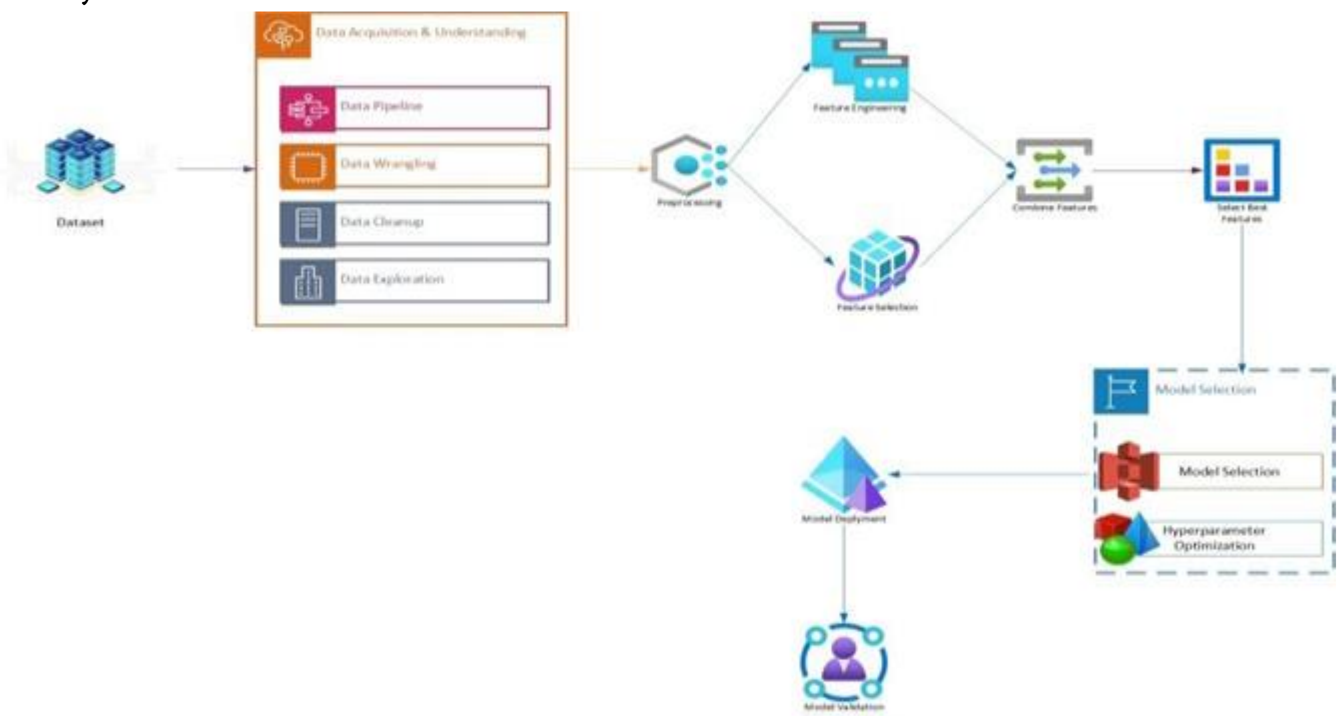

Figure 1-System Architecture

III. RELATED WORKS

In power distribution systems, particularly in sub- Saharan Africa, transient stability and supply disturbances are common but undesirable phenomena. Researchers have renewed their pursuit of cutting- edge technological solutions for fault detection and location determination at medium and low voltage levels in response to the growing demand for power delivery with greater dependability and dependability. The distribution network typically spans hundreds to thousands of kilometers in length. Power-system operators face a significant recurring challenge in this regard: managing distribution networks and locating defective segments. The challenge that is presented to network operators by the ever-expanding distribution network and regulatory demands for service reliability is daunting. However, incorporating Internet of Things (IoT) technologies into the energy distribution infrastructure would significantly accelerate fault detection and location, making the electricity delivery service more responsive, attractive, and durable. A low-cost LoRaWAN-based IoT platform for monitoring distribution networks is designed and implemented in this study.

The research was carried out in Kenya's Nakuru County on a functioning distribution network that was managed by Kenya Power Company. According to the findings of the experiments, a trigger is generated at the network monitoring center within about milliseconds of the occurrence of a fault in the distribution network, allowing for the prompt and immediate beginning of repairs. Additionally, this platform's practical evaluation has demonstrated that it is well-suited to the circumstances of developing nations, where budgetary constraints and cost restrictions prevent the transformation of the legacy grid into fully-edged smart entities. In this work, a smart fault detection and monitoring platform for the power distribution system based on LoRa is proposed as a proof-of-concept. There were three parts to the system that could use its own energy: the power harnessing and data analysis of the sensor network. A monocrystalline solar panel that powers the platform charges the batteries. The platform successfully reduces the power system operator's awareness of a distribution network de-energization from several hours to approximately ms. Because it enables the PSO to immediately begin power restoration activities, this significant reduction in the time it takes to notify the public will play a significant role in reducing the duration of blackouts.LoRaWANs should be used to monitor, detect, and locate faulted grid segments, according to our recommendation. Particularly, we recommend using the LoRa R(cid:) technology. LoRaWAN has projected itself as capable of transmitting data to far-flung and remote locations with low bandwidth, low energy consumption, and high accuracy in the LPWAN space. LoRaWAN technology is a game-changer for long-range data transmission because of its superior noise resistance. This successful LoRaWAN installation for fault- finding and monitoring of network segments in the existing legacy distribution grid demonstrates that low-cost hardware can be used to monitor networks effectively. In addition, this method provides the grid with feedback mechanisms and enables the operator of the power system to promptly address network incidents. This approach avoids the more expensive alternatives, such as one that would necessitate a complete system overhaul. Countries in the sub- Saharan African (SSA) region, where further improvements to the existing electricity network are restricted by budgetary constraints and cost restrictions, should consider this option. The study may be extended in the future to find novel methods for reducing the EEMD's current consumption to extend the battery's life. This may also necessitate tinkering with the LoRa parameters, such as the bandwidth and spreading factor of the coding rate to see how they affect power savings.

Drawbacks-

- Difficult and Less Commonly used
- Generally have high polynomial running times. Heavyweight
- Maximizes the complexity of the problem
- May take huge time and economic cost to construct.
- Approach is a bit time-consuming
- Unsuitable for large scale scenarios

IV. CONCLUSION

In the presence of noise harmonics and signal frequency change, fault detection for relaying applications is challenging. Due to their deterministic modelling, or sinusoidal current/voltage behaviour, traditional approaches are susceptible to noise. Based on the distinct parts of the current signal, a novel fault detection algorithm was proposed in this paper. In this paper, we propose a classifier that uses domain features for fault and abnormality detection in smart grids and is based on cutting-edge deep learning architectures. The proposed method does not assume sinusoidal behaviour of the current/voltage signal. As a result, we were able to incorporate deep metric learning into our model. In most performance metrics, we demonstrated that our method outperforms the available baselines. Extensive numerical results support the efficacy of our proposed method, which produces a better classification performance and compensates for the additional computational burden of learning the higher dimensional representations.

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