

Power System Reliability Improvement Using AI

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Abstract Reliability of modern power systems is critical for maintaining a continuous and uninterrupted electricity supply. As traditional network monitoring becomes increasingly difficult for predicting faults early due to the growing size and complexity of interconnected systems, new methods have been developed specifically for these types of situations. Power systems face challenges in maintaining their reliability due to increased loading from renewable sources.

This work provides a solution using artificial intelligence-based approaches to improve the power system reliability by enabling real-time condition monitoring and predictive capabilities. Modelling an IEEE 5-bus power system as a model and simulating it using MATLAB and Simulink for analysis of the system operation during normal operation and under fault conditions. Electrical apparent power is collected together to create data sets for further analysis and modelling of these systems. Gradient boosting machine learning algorithms are employed for analyzing data sets, predicting near-overloaded transmissions via predictive modelling techniques utilizing gradient-boosted machines. Accuracy, precision, recall, and F-1 score are used as metrics for evaluating our system's predictive capabilities and effectiveness. Results clearly show that the proposed AI-based solution is significantly good for the ability to predict near-overload transmission lines to increase the reliability of systems.

Key Words: Power System Reliability, MATLAB, Simulink, Gradient Boosting, Apparent Power, IEEE Bus 5 System

1. INTRODUCTION

A power system is considered one of the most important infrastructure. It provides continuous power to the industrial, commercial, and residential consumers. Keeping a stable power system network, which is

important for continuous power flow, will prevent unnecessary power failure. With an increase in load demand and complexity of the current power system network, loading conditions in the transmission line networks could lead to abnormal conditions during disturbances or fault occurrences. Lack of prediction prior to such a condition will cause an overloaded transmission line, poor reliability of the system, and potentially a power outage for customers. It is an essential aspect in the operation of power systems to monitor the loading of transmission lines and also predict any near-overload condition of the line. Traditional analytical methods and manual monitoring can be used in determining these, but these traditional methods may not be able to determine the patterns in a huge volume of data. In recent years, the artificial intelligence (AI) and machine learning approaches have been exploited for the analysis of power systems' behavior and to increase reliability. Machine learning approaches can learn and predict certain states of the power system network. The gradient boosting method has good performance for prediction and classification tasks. In this method, the IEEE 5-bus power system network is simulated and modelled using MATLAB with the help of Simulink. Transmission line apparent power values are calculated and extracted for both normal and fault conditions. The data of the transmission line's apparent power are used in a machine learning algorithm for training. After that the algorithm predicts near-overload transmission lines when the system is under fault conditions.

A. Background

Power systems are an essential part, as they provide a continuous and stable supply of electricity to industries, commercial, and residential areas. Ensuring the reliability of these systems is very important to maintain stable operation and prevent fault occurrence in the power supply. With the increasing demand for electricity and the growing complexity of power networks, transmission lines often experience varying loading conditions. During faults, the power flow in the network changes, which can cause transmission lines to become overloaded. If such conditions are not identified at an early stage, they may lead to system instability and power outages. Traditional monitoring methods are used to analyze power system behavior, but they may not be effective in predicting complex patterns in large amounts of data. Hence, there is a need for modern technology and data-driven approaches to improve system reliability. Artificial intelligence and machine learning techniques provide an effective solution by analyzing power system data and predicting fault conditions. By applying these techniques, it becomes easy to identify near-overloaded transmission lines early and take preventive actions to ensure continuous and stable and reliable power system operation.

B. Problem Statement

Modern power systems are becoming highly complex due to the growing electricity and expansion of smart grids. During fault conditions, the distribution of power flow in transmission lines may change significantly, causing certain lines to experience higher loading levels. If these conditions are not identified early, transmission lines may occur near overload conditions, which reduce the power system reliability and make the system unstable. Traditional monitoring and analysis methods may not always be good at predicting such critical conditions because they rely mainly on traditional calculations and manual observation. Therefore, there is a need for modern and data-driven techniques that can analyze power system data and predict near-overloaded transmission lines. By predicting these conditions early, the system can take preventive methods to improve the reliability and stability of the power system.

C. Motivation

Power systems play an important role in every aspect of modern life, from small-scale use to large-scale industrial operations. Any fault or failure in the supply of electricity can lead to serious problems such as equipment damage and safety risks. As the demand for electricity continues to rise, maintaining a reliable and stable power supply has become highly challenging. Factors such as aging of equipment, increased power consumption, environmental problems, and integration of renewable energy sources make the system more complex and difficult to manage. Therefore, there is a strong need for modern techniques

that can monitor the system, predict the faulted transmission line, and take corrective actions before they cause interruptions. Artificial intelligence provides a modern and efficient solution to improve the reliability of power systems. AI can process huge amounts of real-time data, predict fault conditions, and predict upcoming faults with high accuracy. Unlike traditional methods, AI can learn from past events and continuously improve its performance. By applying AI techniques such as machine learning and neural networks, power system engineers can identify weak areas, plan maintenance effectively, and reduce the chances of blackouts. The main motivation for this project is to develop modern techniques like AI to improve reliability and ensure continuous and efficient operation.

2. METHODOLOGY

To improve power system reliability, a machine learning approach is put forward to predict the near-overloaded transmission lines. A standard power system, IEEE-5, consisting of buses, generators, loads, and transmission lines, is simulated in MATLAB/Simulink. Data is created in the case of both normal conditions and fault conditions; the apparent power values on the transmission lines are collected as features of input. The dataset is used to train different machine learning algorithms, including ANN, Naive Bayes, and Gradient Boosting; among them, Gradient Boosting is the best-performing model. Then the trained model can be used to predict near-overloaded transmission lines and take preventative action for better and stable operation of the power system.

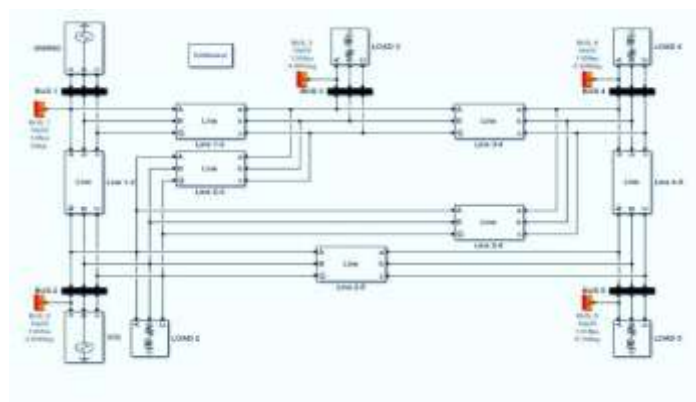


Fig.1 IEEE 5-Bus power system modelled in MATLAB

3. DATA IMPLEMENTATION

The IEEE 5-bus system is the standard model, which is used for creating of data as well as analysis of the power system. It is a typical network, which contains five buses,

connected by transmission lines and also contains generators, as well as loads. It is designed and simulated in MATLAB, Simulink for analyzing the behavior of power flow in the system in various conditions. The figure above describes the normal state of the IEEE 5-bus system where all parameters are normal. In the normal state, the system has no disturbances or faults; all the buses, generators, loads, as well as the lines are under their normal state. The power is flowing through the lines. The apparent power values in the no fault condition represent the normal power on the transmission lines.

In the fault state a fault is applied at Bus 2 of the IEEE 5-bus system. When the fault is applied, the power flow through different buses of the system gets disturbed and hence some lines may experience higher loads and go closer to near over load. The difference in apparent power values is measured using simulation during the fault situation.

All these parameters in the normal and fault condition is combined to form the dataset which represents the operating stage of the power system.

4. AI MODEL AND EXECUTION

In this paper, some ML models, such as ANN with Adam optimizer, Levenberg-Marquardt algorithm, Nave Bayes classifier and Gradient Boosting, are used to analyze the dataset created from MATLAB simulation of IEEE 5-bus system. The input data of this dataset are apparent power values of transmission lines in normal and fault condition, and output data is status of the system. The performances of models are measured by using performance metrics like accuracy, precision, recall and F1-score. Based on this gradient boosting achieves higher accuracy and is better in predicting the near overloaded transmission lines, so it used for power system reliability. The comparison of the obtained results for all models is shows in Table 1.

Algorithms	Accuracy	Precision	Recall	F1 Score
ANN (Adam)	94.2	95.2	92.5	93.8
Levenberg-Marquardt	94.8	90.8	99.7	95.0
Naïve Bayes	92.3	90.2	94.2	92.2
Gradient Boosting	97.1	97.6	96.6	97.13

Table 1. Comparison Table Of Different Algorithms

Table 1 shows that the Gradient Boosting algorithm gained the highest prediction accuracy than other algorithms. This suggests that Gradient Boosting is better able to capture the variations present in the apparent power time-series data. As a result, it provides more reliable predictions for identifying transmission lines that are close to overloading. Based on these results, Gradient Boosting is selected as the best performing model.

5. GRADIENT BOOSTING

Gradient Boosting is an advanced machine learning technique used for regression and classification problems. It works by building multiple weak learners sequentially, typically small decision trees, where each new model focuses on correcting the errors of the previous models. The process starts with a simple initial model that makes predictions, and the differences between the actual and predicted values, called residuals, are calculated. A new model is then trained to predict these residuals, and its output is combined with the previous model to improve accuracy. This process is repeated , gradually creating a strong model.

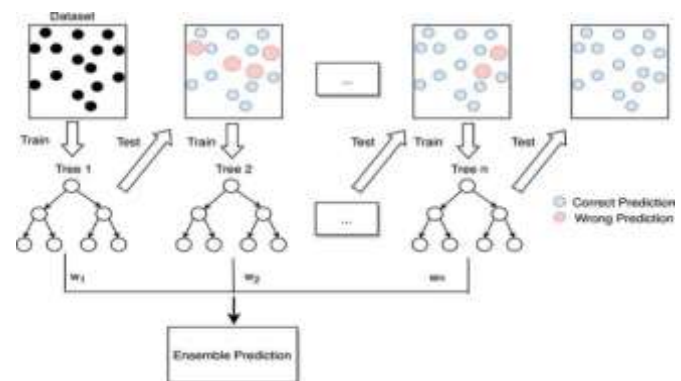


Fig.2 Model of Gradient Boosting

6 RESULT

This system was implemented to predict the near overloaded transmission lines using gradient boosting. The IEEE 5 bus system simulation was used to generate the data and to train and test the model. The performance of the trained and tested model was evaluated using performance metrics like accuracy, precision, recall and F1 score. This model provide a great accuracy for the training around 99.41 % proving that the model has learned well. It also achieved an accuracy of around

97.10% for the testing phase . The precision, recall and F1 score were high, so the model was good in identifying normal and a fault scenario with minimum error. Also sample inputs were tested and fault condition was successfully predicted along with which transmission line is near to overloaded. Hence this system is good to predict the variations of power flow and predict the fault condition in early.

7. CONCLUSION

This project used the AI based techniques for near overload transmission line prediction in the power system network. A simulated model of IEEE 5-bus system has been created in MATLAB for generating the dataset considering the conditions of system under normal and fault. Algorithms of gradient boosting were used to learn from apparent power of transmission lines. Gradient Boosting out of all models has achieved high accuracy, precision, recall and F1-score. It was found that the model had correctly learned the nature of dataset and classify the system conditions correctly. And developed system could successfully predict the fault condition and transmission line nearing to be overload. The accuracy shown by model at training and testing time is quite high and reliable. It reduces the necessity for continuous human monitoring on the system and also the probability of potential failure occurrence. Therefore the system contributes towards efficiency, reliability and stability of power system network.

8. REFERENCE

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