CAPSTONE PROJECT

POWER SYSTEM FAULT DETECTION AND CLASSIFICATION

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OUTLINE

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PROBLEM STATEMENT

Power distribution systems play a critical role in delivering electricity safely and efficiently to end-users. However, these systems are vulnerable to a range of electrical faults caused by equipment failures, weather disturbances, or line interference. Such faults can disrupt supply, damage infrastructure, and pose serious safety risks. As power networks become more dynamic and interconnected, manually identifying and classifying these faults is no longer practical. The increasing complexity of the grid demands intelligent systems capable of monitoring real-time data and detecting abnormalities with speed and precision. Ensuring grid reliability hinges on the ability to recognize and respond to faults promptly.

PROPOSED SOLUTION

To address the growing challenge of detecting and classifying faults in power distribution systems, the proposed solution leverages machine learning and cloud-based deployment for real-time fault recognition. The approach is structured as follows:

- **Data Collection:**
  - **Gather labeled datasets containing electrical parameters such as voltage and current phasors under various operating conditions.**
  - **Include both normal scenarios and fault conditions (line-to-ground, line-to-line, three-phase faults) for balanced learning.**
- **Data Preprocessing:**
  - **Clean the dataset to handle missing readings, noise, and anomalies in the measurement data.**
  - **Perform feature engineering by extracting relevant attributes like phase differences, current imbalances, and voltage dips that may indicate specific faults.**
- **Machine Learning Algorithm:**
  - **Implement a classification model, such as a Random Forest Classifier, to distinguish between different fault types.**
  - **Evaluate other models (e.g., Decision Tree, SVM) and compare performance. Train the model using historical fault data and validate using test sets to ensure generalization.**
- **Deployment:**
  - **Deploy the trained model using IBM Watsonx.ai within IBM Cloud Lite. Create a public/private API endpoint for accessing the fault classification service via real-time data streams or batch input.**
  - **Ensure scalability and low-latency response to support real-time applications.**
- **Evaluation:**
  - **Measure the model's accuracy, precision, recall, and confusion matrix across fault categories.**
  - **Monitor and log prediction outcomes to identify misclassifications and retrain as needed. Fine-tune hyperparameters and improve the model iteratively for better classification performance.**
  - Result: Successfully deployed a machine learning model on IBM Cloud that accurately detects and classifies multiple power system faults in real time.

SYSTEM APPROACH

This section describes the overall methodology and tools used to build and deploy the power system fault detection and classification model.

- **System requirements**

Hardware Requirements:

- **Processor: Intel Core i5 or above**
- **RAM: Minimum 8 GB**
- **Storage: At least 500 MB free disk space**

Software Requirements:

- **OS: Windows / Linux / macOS**
- **IBM Cloud (for model deployment using Watsonx.ai)**
- **Web Browser (for accessing IBM Cloud dashboard)**
- **Git (for version control and deployment)**

- **Library required to build the model**

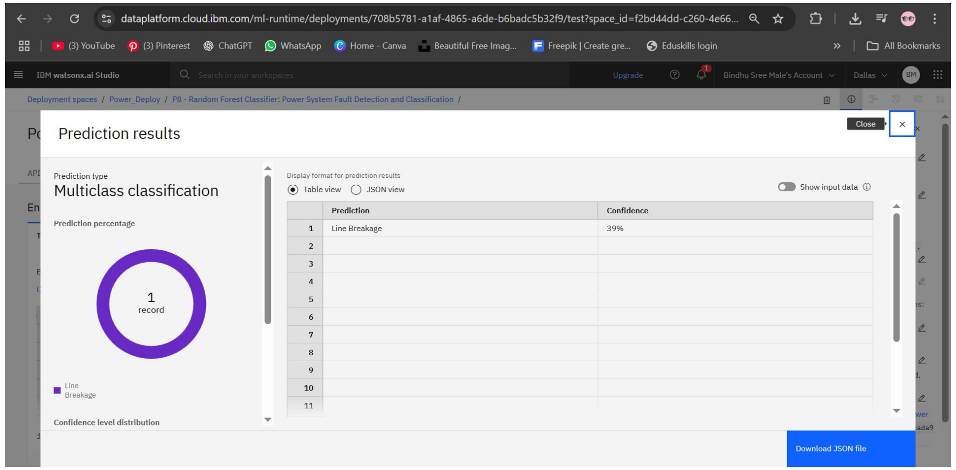
The following Python libraries were used in the project:

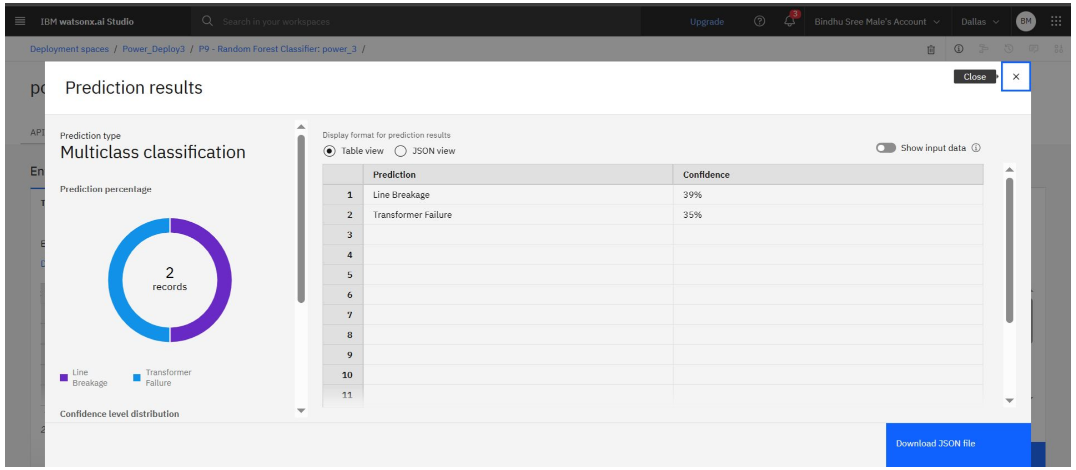
- **pandas – For data loading, cleaning, and manipulation**
- **numpy – For handling missing values and numerical operations**
- **sklearn (scikit-learn) –**
  - **RandomForestClassifier for fault type classification**
  - **train_test_split, accuracy_score, confusion_matrix for model training and evaluation**
- **matplotlib.pyplot / seaborn – For visualizing model performance**
- **ibm-watson-machine-learning – To deploy the trained model on IBM Cloud using Watsonx.ai**

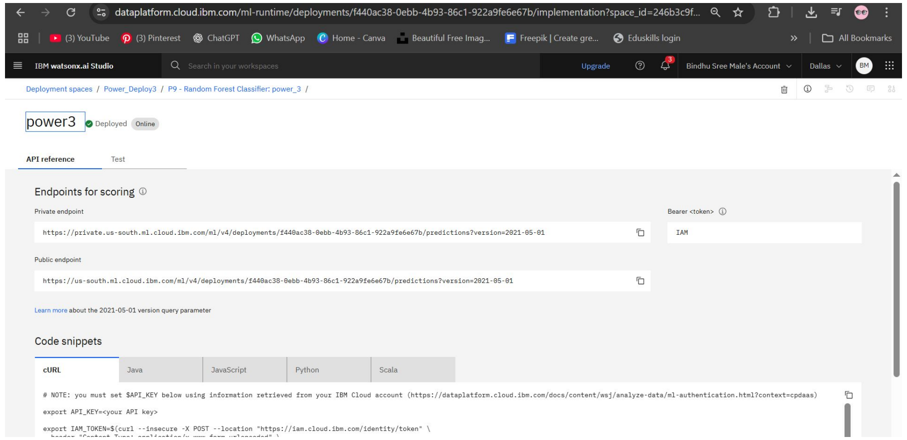
ALGORITHM & DEPLOYMENT

- **Algorithm Selection:**
  - The system uses the Random Forest Classifier to detect and classify different types of faults in a power distribution system. This algorithm is highly effective for multiclass classification tasks and performs well with structured numerical data like voltage and current measurements, making it suitable for fault detection applications.
- **Data Input:**
  - Input features include voltage and current phasors under different load and fault conditions. These features are directly extracted from the dataset and represent real-time electrical parameters essential for accurately identifying power system faults.
- **Training Process:**
  - The dataset is preprocessed to handle missing values and ensure balanced class representation. It is then split into training and testing sets. The Random Forest model is trained on this data, and the trained model is exported along with relevant metadata for cloud deployment.
- **Prediction Process:**
  - The trained model is deployed on IBM Watsonx.ai and accessed via API. It takes electrical input parameters and classifies the system state (e.g., line-to-ground, line-to-line, three-phase fault, or normal). The output includes the predicted fault type along with confidence scores for each class.

RESULT







- **Github link**

https://github.com/bindhu0404/IBM_SkillsBuild-AI-Cloud-Technologies

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CONCLUSION

- The machine learning model successfully classified different types of power system faults with high accuracy using Random Forest, based on electrical measurement data.
- Deployment on IBM Watsonx.ai enabled real-time predictions through cloud-hosted API endpoints, supporting scalable and accessible fault detection.

- Key challenges included handling imbalanced fault classes, preprocessing complex phasor data, and configuring deployment in the IBM Cloud environment.

- Potential improvements include incorporating real-time smart grid data, exploring deep learning models for enhanced performance, and integrating explainable AI techniques.

- Accurate and timely fault detection is essential for maintaining power grid stability, reducing downtime, and improving the reliability of electrical distribution systems.

FUTURE SCOPE

- Integration of Real-Time Smart Grid Data: Enhance the model by incorporating live data from smart meters, IoT-based sensors, and SCADA systems to improve the system's responsiveness and accuracy.
- Use of Advanced Machine Learning Techniques: Explore deep learning models like LSTM or CNN to capture complex temporal patterns and improve fault classification performance, especially in noisy or overlapping fault scenarios.
- Edge Computing for Low-Latency Detection: Deploy the model on edge devices located at substations or grid nodes to enable real-time fault detection with minimal delay and reduced reliance on cloud connectivity.
- Scalability Across Regions and Grid Types: Expand the system to monitor power faults across different regions or city grids, adapting to diverse electrical infrastructures and environmental conditions.

REFERENCES

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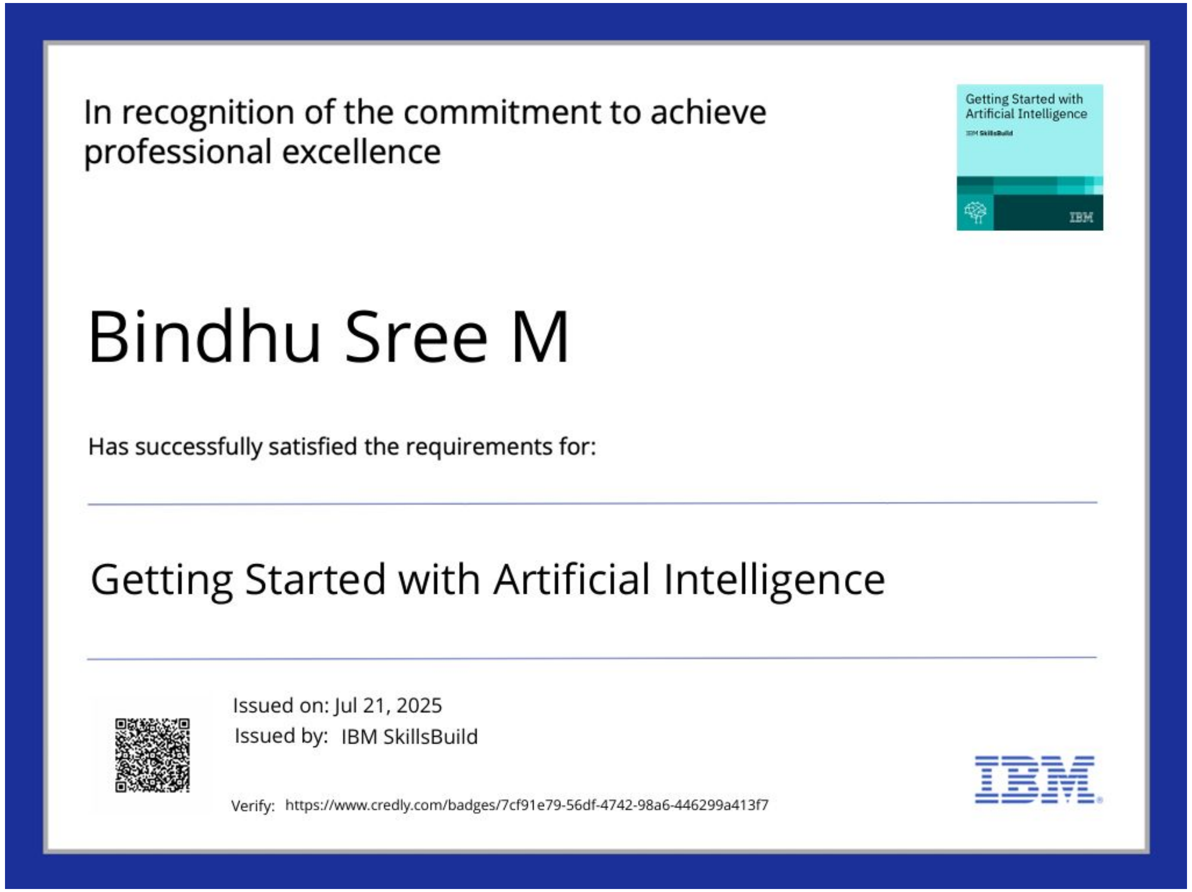
IBM CERTIFICATIONS

- Screenshot/ credly certificate(getting started with AI)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IBM CERTIFICATIONS

- Screenshot/ credly certificate(Journey to Cloud)

IBM CERTIFICATIONS

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