CAPSTONE PROJECT

POWER SYSTEM FAULT DETECTION & CLASSIFICATION VIA MACHINE LEARNING

Presented By:

1. Sanat-National Institute of Technology, Srina gar-Electrical Engineering

OUTLINE

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PROBLEM STATEMENT

- Design a machine learning model to detect and classify different types of faults in a power distribution system. Using electrical measurement data (e.g., voltage and current phasors), the model should be able to distinguish between normal operating conditions and various fault conditions (such as line-to-ground, line-to-line, or three-phase faults). The objective is to enable rapid and accurate fault identification, which is crucial for maintaining power grid stability and reliability.

PROPOSED SOLUTION

- Data Collection:
  - Gather voltage and current phasor data during normal and fault conditions.
  - Label data with fault types (e.g., line-to-ground, line-to-line, three-phase).
- Data Preprocessing:
  - Clean and normalize data using watsonx.ai Studio tools.
  - Extract features (e.g., RMS, frequency data, symmetrical components).
- Model Training:
  - Use watsonx.ai Studio AutoAI for feature selection and model training (Random Forest, LSTM, CNN).
  - Set up a multi-class classifier to identify fault types and normal states.
- Deployment:
  - Deploy the model as a REST API using watsonx.ai for real-time fault detection.
  - Integrate with dashboards for instant alerts.
- Evaluation & Improvement:
  - Monitor accuracy and retrain with new data.
  - Use feedback to reduce false positives and improve the system

SYSTEM APPROACH

1.System Requirements

- IBM Cloud account with provisioned watsonx.ai Studio service.
- Access to IBM Cloud Object Storage for dataset and model storage.
- Internet-enabled browser for working in watsonx.ai Studio workspace.
- Sufficient cloud compute resources (CPU/GPU) for model training and deployment.

2. Libraries & Tools Required (Available in watsonx.ai Studio)

- Data Handling: pandas, numpy
- Visualization: matplotlib, seaborn
- Time-Series & ML Modeling: scikit-learn, statsmodels, prophet, tensorflow, keras, pytorch
- Automation & Optimization: IBM AutoAI for automated feature engineering and model tuning
- Deployment & MLOps: watsonx.ai deployment spaces for REST API hosting, MLOps tools for model lifecycle management

ALGORITHM & DEPLOYMENT

Algorithmic Approach

- We take synchronized phasor readings (currents Ia, Ib, Ic and voltages Va, Vb, Vc) and compute key features like magnitudes, angles, and sequence components. We also use simple signal analysis-via wavelet or Fourier methods to spot the quick changes caused by faults. These features feed into machine learning models (like SVM, decision trees, k-NN, or random forest), where parameters are tuned smartly to make them accurate and reliable. Studies show SVM is great at handling tricky nonlinear patterns, while combining wavelets with a random forest often gives very high accuracy for distinguishing different fault types

Deployment Strategy

- Once the model works well, it gets deployed in the cloud as a REST API service. We use tools like IBM Watson Studio, secure object storage, and Watson Machine Learning or Cloud Functions. Incoming phasor data streams are processed in real time, and the model returns a fault detection result in milliseconds. Integration with SCADA or WAMS systems enables fast protective action or alerts, making the system practical for live grid protection workflows.

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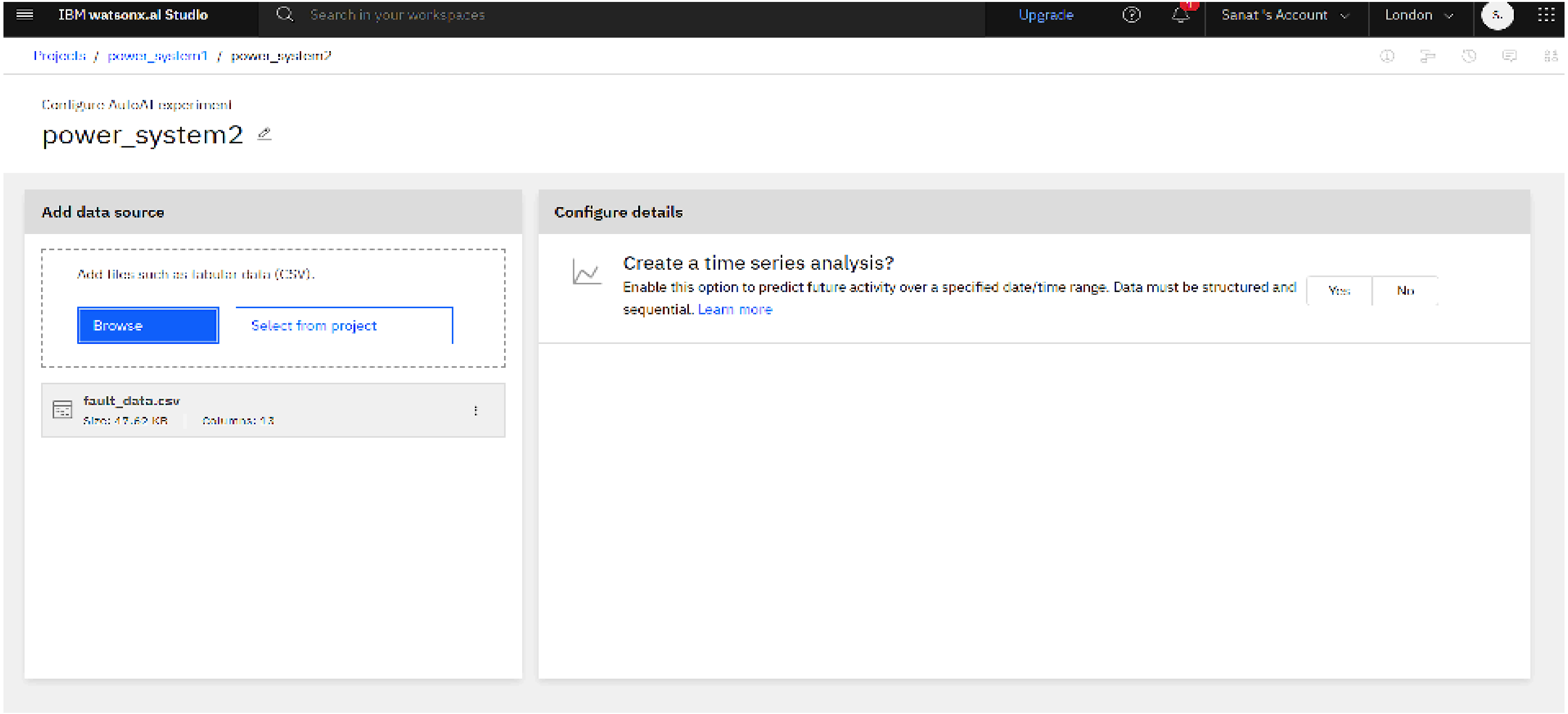
RESULT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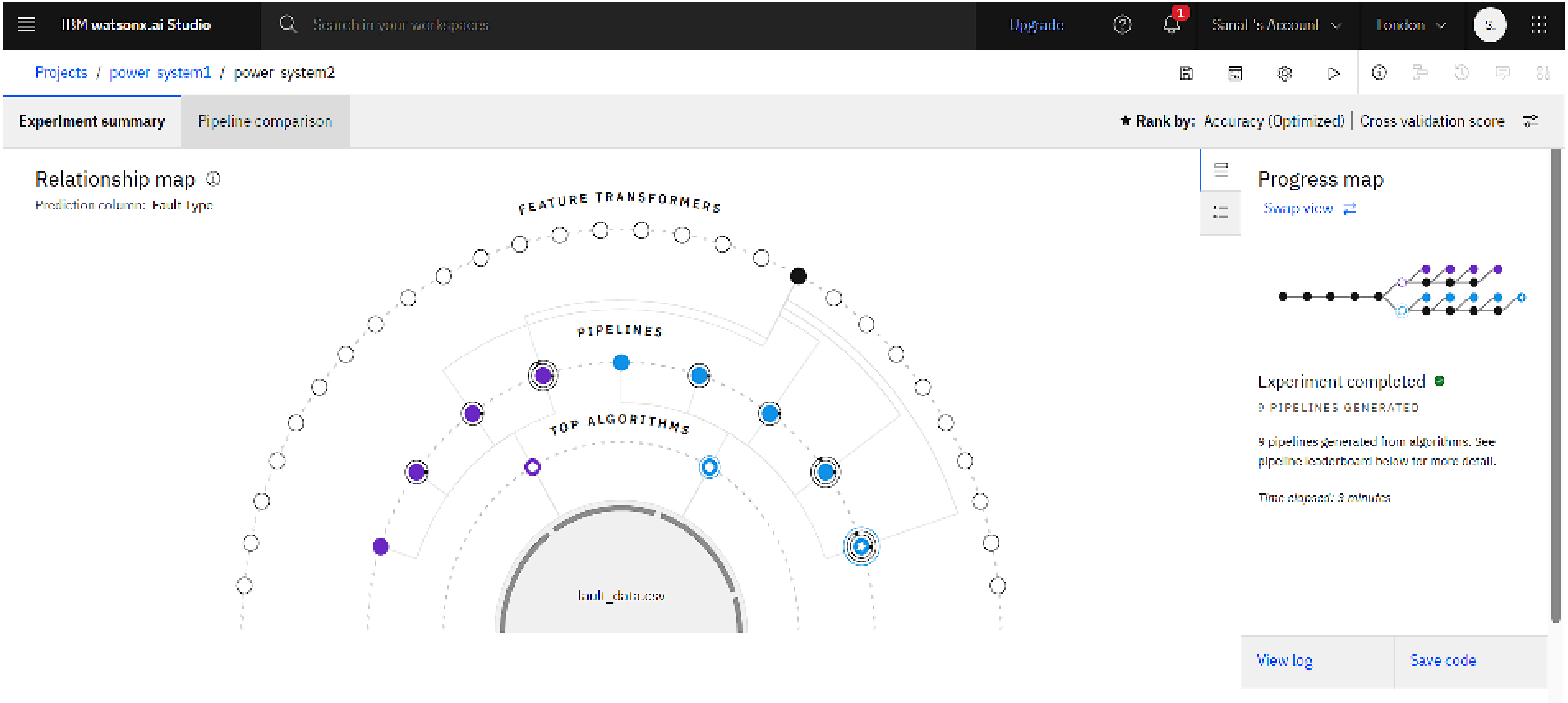
Search in your workspaces
Upgrade
Sanat 's Account
London
Projects / power_system1 / power_system2
Configure AutoAI experiment
power_system2
Add data source
Add files such as tabular data (CSV).
Browse
Select from project
fault_data.csv
Configure details
Create a time series analysis?
Enable this option to predict future activity over a specified date/time range. Data must be structured and sequential. Learn more
Yes
No

RESULT



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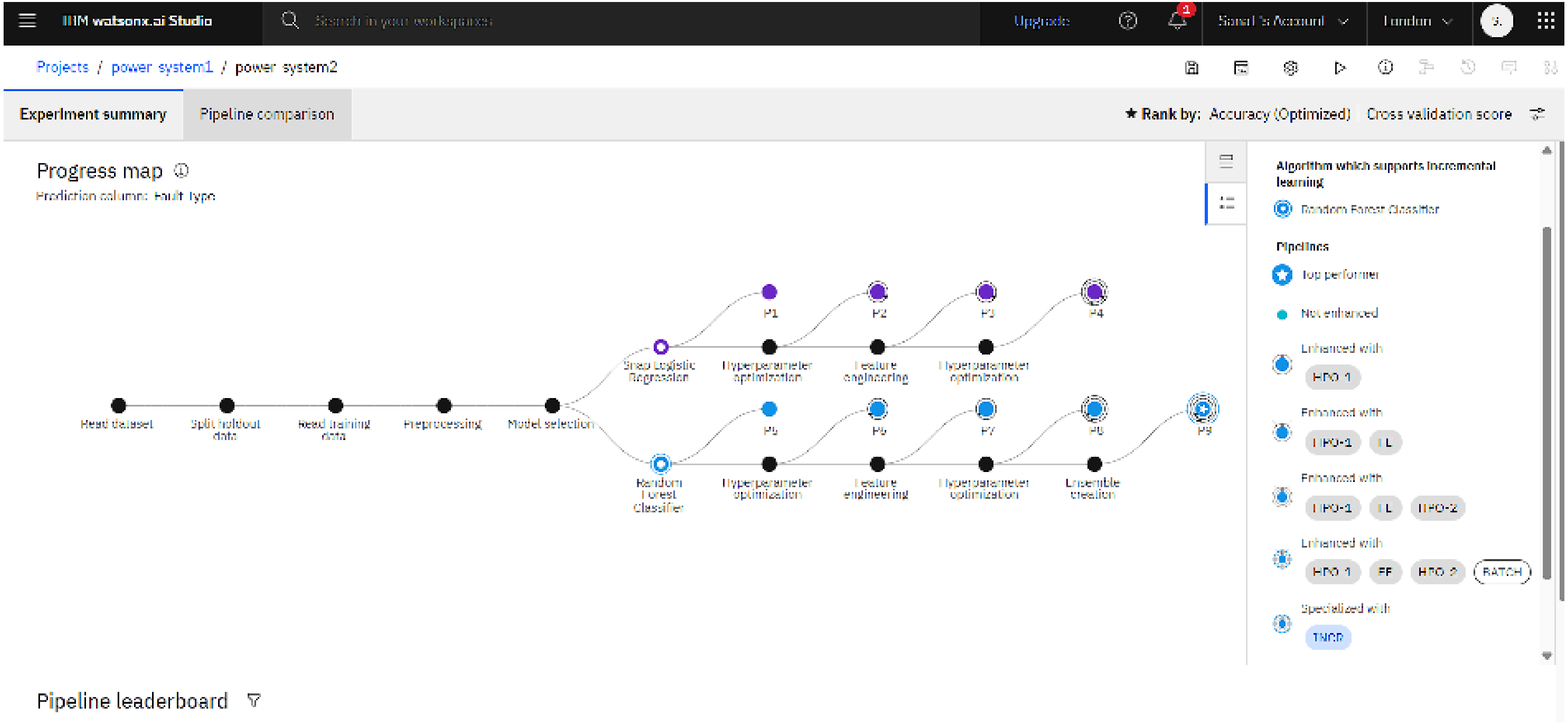
RESULT



IBM watsonx.ai Studio
Upgrade
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Projects / power system1 / power system2
Experiment summary
Pipeline comparison
★ Rank by: Accuracy (Optimized) Cross validation score
Progress map
Prediction column: Fault type
Read dataset
Split holdout data
Read training data
Preprocessing
Model selection
Snap Logistic Regression
Random Forest Classifier
Hyperparameter optimization
Feature engineering
Ensemble creation
P1
P2
P3
P4
P5
P6
P7
P8
P9
Algorithm which supports incremental learning
Random Forest Classifier
Pipelines
Top performer
Not enhanced
Enhanced with
HPO-1
FE
HPO-2
BATCH
Specialized with
INCR
Pipeline leaderboard

RESULT

- In recent studies, ensemble models like Random Forest combined with LSTM have achieved fault classification accuracy up to ~99.96%, with cross-validation scores around 99.7%, showing top-tier reliability in distinguishing fault types .

CONCLUSION

- In summary, this work demonstrates that combining time-frequency signal analysis—such as wavelet transforms or discrete Fourier transforms—with machine learning models like SVMs and Random Forests reliably identifies and classifies faults in three-phase power systems. Through simulations, the hybrid approach shows high accuracy, fast detection within a cycle or less, and robustness across varying fault conditions and noise levels. These strengths make the method practical and effective for real-time grid protection and fault diagnostics in smart or traditional networks.

FUTURE SCOPE

- Integrate renewable energy sources like solar and wind into fault detection systems — handling variability in inverter-dominated grids is increasingly important .
- Explore physics-informed machine learning, which couples physical grid models with data-driven tools to improve accuracy and trust.
- Develop real-time, wide-area monitoring using PMUs or μ-PMUs for faster, network-wide fault detection across smart grids

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REFERENCES

- IBM Cloud Documentation – https://cloud.ibm.com/docs
- IBM Machine Learning Services – https://www.ibm.com/cloud/machine-learning

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Learning hours: 20 mins

THANK YOU