Bangladesh University of Engineering and Technology

Department of Electrical and Electronic Engineering

Course No: EEE 306

Course Title: Power System I Laboratory

Project Report

Electrical Fault Generation and Classification in the Northern Region of Bangladesh Using Deep Learning

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Introduction:

Power system is a complex design built to transfer power using transmission lines covering a vast area. It is easy to succumb into some faults among this complex design. Each kind of fault is different than the others, and they also have different correction measurement. In this project, we intend to detect the fault and classify it into different classes based on the instantaneous voltage and current of three phase line. We will cover the transmission system of whole Northern region of Bangladesh as our sample region. We will use Simulink to model the power system and generate the fault data and will use Machine Learning and Deep Learning to classify the faults.

Theory:

A fault in a circuit is any failure which interferes with the normal flow of current. Transmission line faults can be classified into four distinct types:

1) Triple Line Fault (LLL)
2) Line-to-Line Fault (LL)
3) Line-to-Ground Fault (LG)
4) Double Line-to-Ground Fault (LLG)

The LLL fault causes all three lines of the system to be shorted and symmetrical current flows through the system. The LL fault happens when any to line becomes shorted and a huge current flows through that two lines. The LG fault is situation generated when one of the lines tear down to the ground. This is the most common type of fault faced by the power system. The LLG fault is a phenomenon where any two lines are shorted and connected to the ground. Whichever the fault type might be, the system faces a flow of magnificent current which may hamper the power system by destroying the transmission line and associated electrical drives.

Description of Simulink Model:

We are using the power system model of PGCB of the Northern part of Bangladesh (According to June, 2020 model of PGCB).

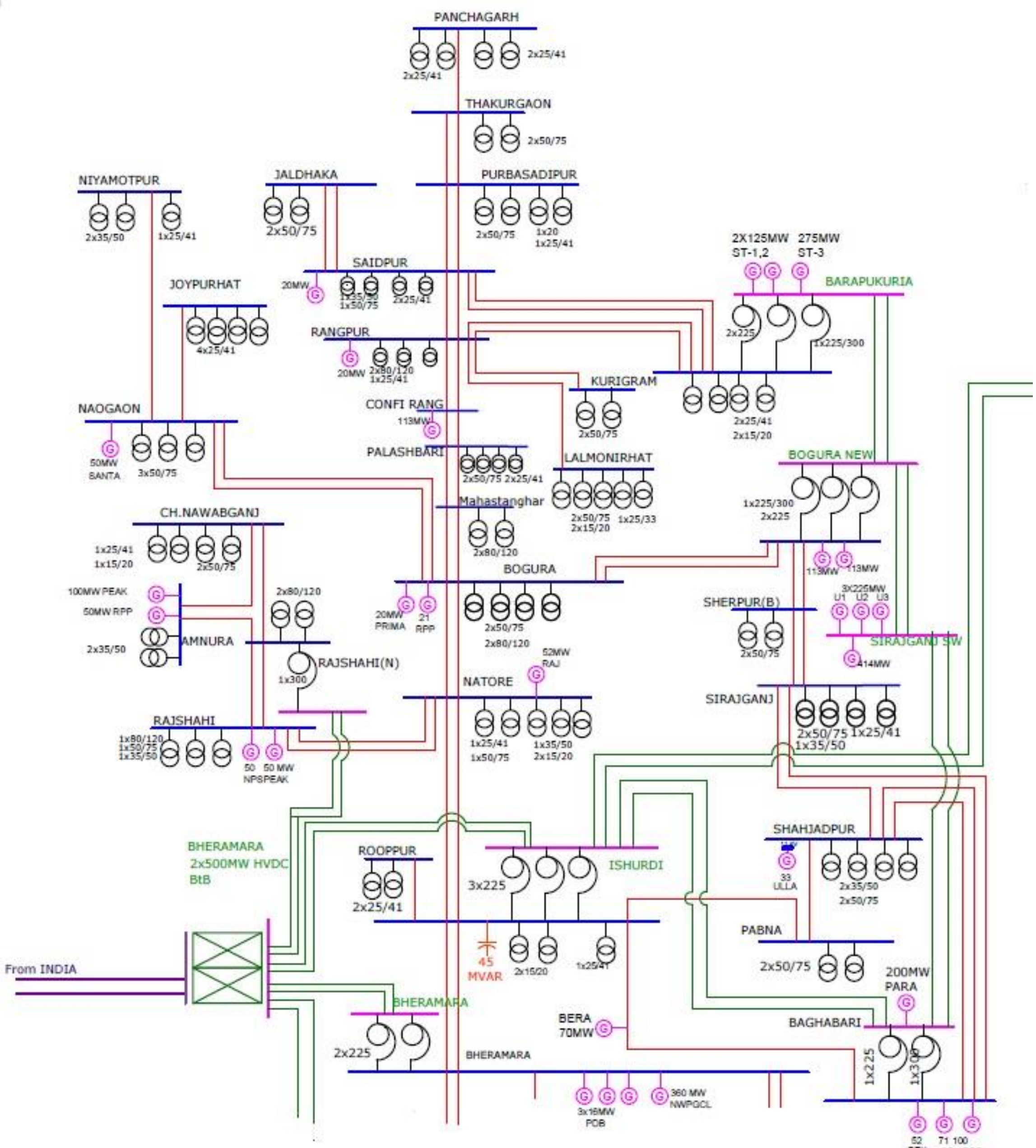


Fig: PGCB model of the power system of the project

It is to be mentioned that we have excluded Bheramara HVDC substation that interconnects power with India for reducing the complexity of the model. We have built the model of the power system in the Simulink.

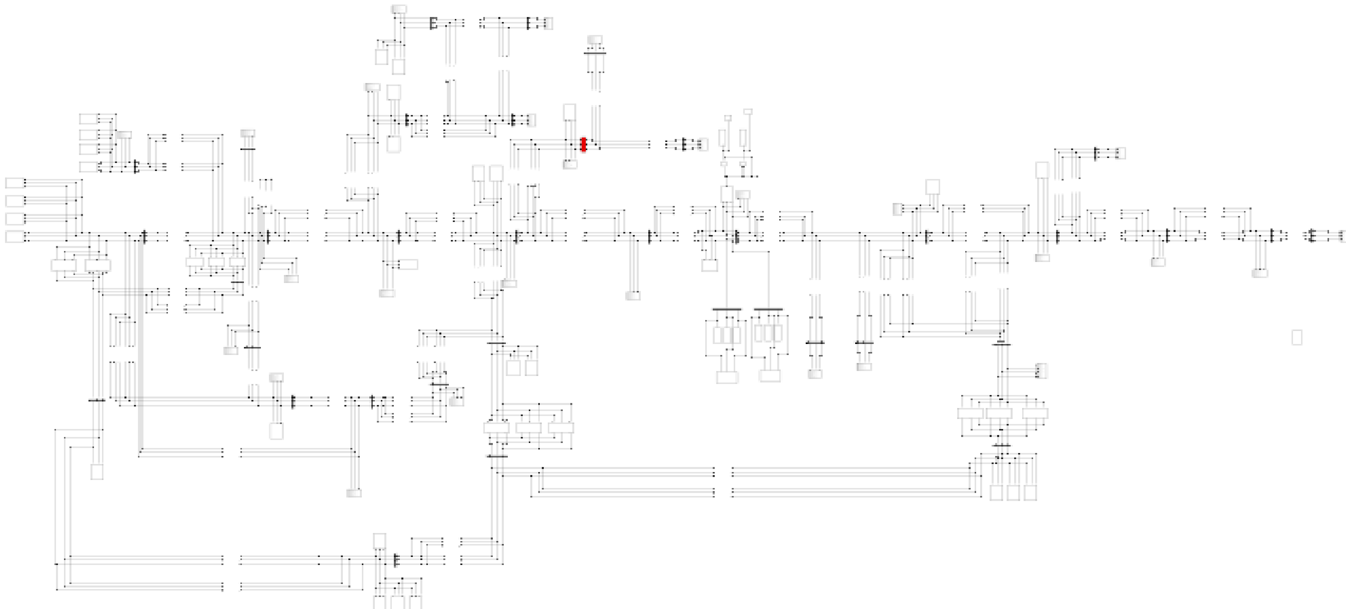


Fig: Simulink model of the power system

The model includes 35 substations of the Northern part of Bangladesh, some notable of them are Bheramara, Baghabari, Barapukuria, Ishwardi, Rajshahi, Bogura, Sirajganj etc. The red marked one is the Naogaon substation which we are considering as slack bus for our system.

We have used distributed line parameter instead of equivalent π model to achieve better accuracy of the result. We have collected all the necessary data like generated power, substation capability and transmission line length from PGCB website. As the load demand is a confidential information for PGCB, we have used load demand of 0.8 lagging pf associated to each substation.

All four types of fault and no fault situation was generated at all the substations and at different lengths of transmission line and acquired the data of all the three lines current and line-to-line voltages to see how the system response to the fault. This data is later on used to classify the fault into different types using Machine Learning and Deep Learning.

An Overview of the Data:

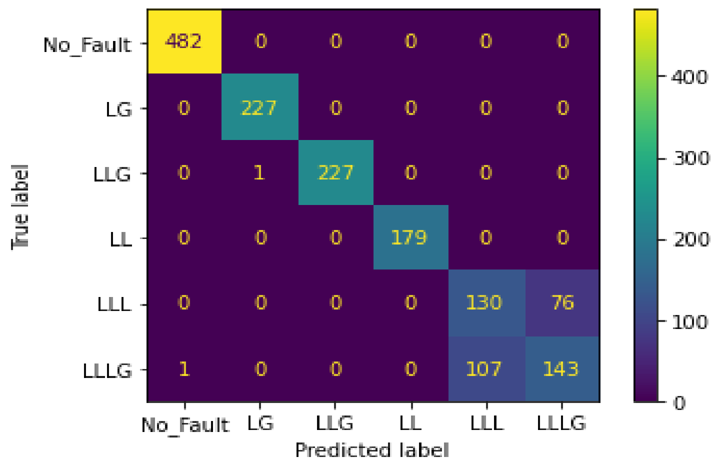
Index	I_a	I_b	I_c	V_a	V_b	V_c	Fault Type
6363	21.718519	– 28.646567	3.616817	0.567205	–0.121645	–0.445560	0
2655	36.575172	228.274870	–262.133531	0.501190	0.039542	–0.540732	3
1186	–742.784641	51.029811	– 29.571785	–0.031443	0.351300	–0.319858	2
6029	54.319537	2.429480	– 60.168155	0.133928	0.455813	–0.589741	0
7375	– 48.364436	94.097385	– 48.737306	–0.551469	0.047974	–0.503495	0

From the Simulink model, we generate the time series data for each phase of current and each phase of voltages. Now our goal is the extract features from these time series data and feed train a deep learning model with this data. Also we can use machine learning algorithms with these data to classify the faults.

Machine Learning Approach:

With machine learning approach, we've used the generated data as it is without any kind of special feature extraction. We've used Decision Tree Classifier and fed the time series data directly to the model. As the generated data is time series hence it has some inherent pattern and due to this inherent pattern the machine learning model just learns the pattern for that specific fault.

Performance of Machine Learning Model:



Accuracy of the Training dataset is : 100.0 %
Accuracy of the validation dataset is : 88.239033%

As we can see that the performance of the machine learning model is quite good. But the problem is that as we trained the machine learning model with the time series data directly hence our model has learnt to only fit our training data. To make our prediction more generalized for any we should use feature extraction to get some kind of internal meaning of the data for each kind of fault.

Feature Extraction:

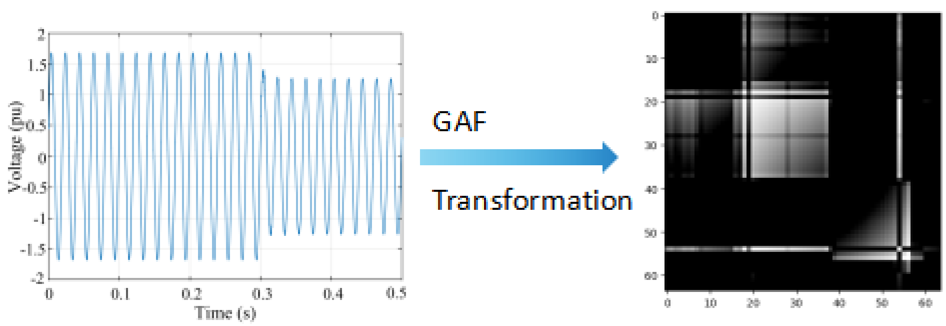
To extract the features from the time series data, we've used the Gramian Angular Field (GAF) Transformation method. This method converts one dimensional time series data to an image or a 2 dimensional data.

$$X = \{x_1, x_2, ..., x_n\}$$

$$\begin{pmatrix} \langle \tilde{x}_1, \tilde{x}_1 \rangle & \dots & \langle \tilde{x}_1, \tilde{x}_n \rangle \\ \langle \tilde{x}_2, \tilde{x}_1 \rangle & \dots & \langle \tilde{x}_2, \tilde{x}_n \rangle \\ \vdots & \ddots & \vdots \\ \langle \tilde{x}_n, \tilde{x}_1 \rangle & \dots & \langle \tilde{x}_n, \tilde{x}_n \rangle \end{pmatrix}$$

$$x, y >= x \cdot y - \sqrt{1 - x^2} \cdot \sqrt{1 - y^2}$$

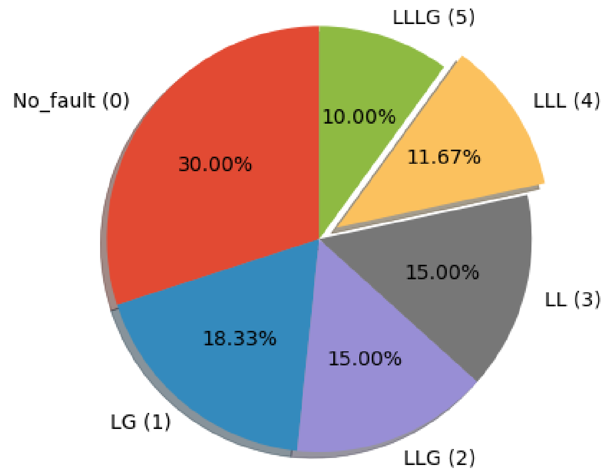
$$\tilde{x}_i = \frac{(x_i - \max(T_{va})) + (x_i - \min(T_{va}))}{\max(T_{va}) - \min(T_{va})}$$



This GAF transformation is applied to each phase Voltages and each phase currents for each fault sample. For each sample’s phase Voltage or current we took 100 time stamps data and then converted it to an image through GAF transformation.

Transformed Data:

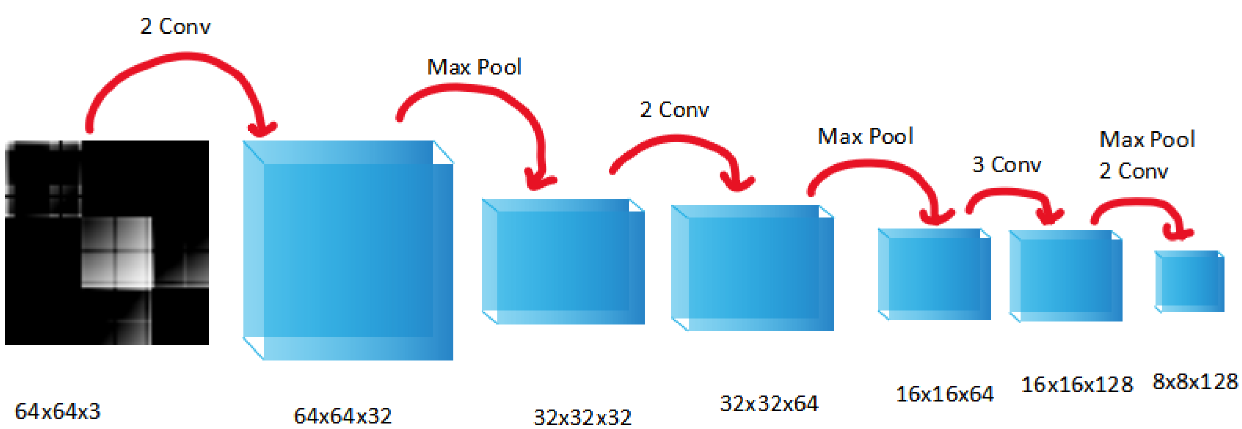
Total Data Generated: 76
Each Sample: 6 time series data with 100 samples



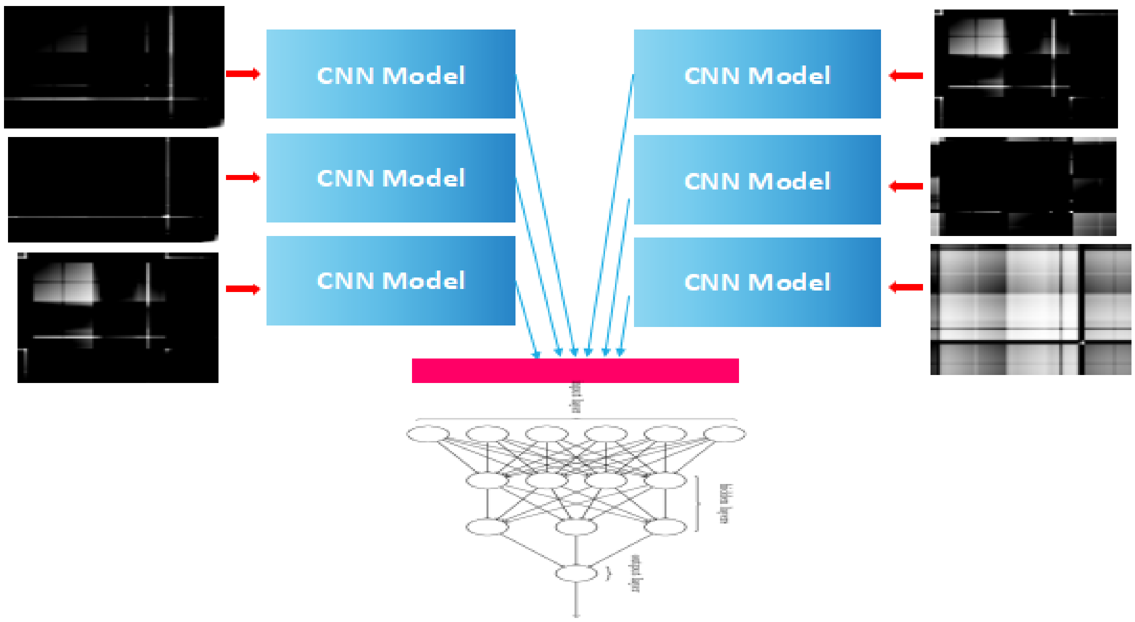
Description of the Deep Learning Model:

After this transformation, we used convolutional neural network to extract features. Initially, we used the VGG16 model architecture and fed each six of the phase voltages and currents and concatenate them at the end and then it is flattened before feeding it through some Linear Feed Forward layers and at the last a Softmax layer is applied.

CNN Architecture:



Model Architecture:



Results and Confusion Matrix:

Validation loss is 2.087895393371582
Accuracy of the validation data is 18.75%

The accuracy is very poor this is because we had only 76 sets of sample data to work with and out of them 16 were used for validation and the rest of the 60 were used for training.

Future Development:

In addition to our current project, we may include to receive the exact location of fault along with the fault type. We can include the feature of the necessary steps that is required for the detected fault types making the whole system automated.

Conclusion:

This project is of huge value to PGCB. Using this project, we can readily classify the fault type and take necessary steps to solve the problem. The project only uses software and voltage and current measuring instruments. So, it is a very cost effective project. Moreover, the project covers the entire Northern region of Bangladesh. So, a huge part of the population of Bangladesh can have the benefits of this project. The manpower required to utilize this project is very low. All being said, we may expect this project to come in handy for the greater benefits of the people of the Northern part of Bangladesh.

References:

1) https://pgcb.gov.bd/site/page/05a258ae-2288-44d5-95c1-4e30b35eb7ec/-
2) https://www.sciencedirect.com/science/article/pii/S037877962030242X
3) https://www.kaggle.com/datasets/esathyaprakash/electrical-fault-detection-and-classification