Investigation of High-Voltage Insulator Surface Conditions based on Machine Learning TensorFlow

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***Abstract*— The insulator plays an essential role in preventing the flow of current from the phase conductor to the earth through supporting towers so that the insulation is a significant part of the electrical energy transmission system. Generally, high-voltage insulators are widely used as external plug insulators, therefore, the performance of insulators is influenced by environmental conditions that indirectly affect the surface condition of the insulators. In this study, a diagnostic tool used in the testing surface of the insulator, which can classify mechanically whether the insulation is good or damaged. The classification method used is TensorFlow Machine learning. Machine Learning is used as a brain in the isolation classification process, while TensorFlow functions to store training data and test data in the classification process. The results obtained from this study show the accuracy of classification data is 98%.**

Keywords*— *Insulator; Image processing; Machine Learning; TensorFlow;

I. Introduction

The location of Indonesia's territory, which stretches along two-thirds the equator, is the sea area, with the population generally living in the lowlands and the coast. Almost all regions in Indonesia have tropical weather with very high climatic factors and solar irradiation times around 12 hours per day, air temperatures between 16-350 C, relative humidity around 100% at night until morning, and rainfall ranges values from of 40-500mm [1]. Besides, the publication of the Greenpeace organization states that Indonesia is the world's fourth most populated country. Such environmental conditions affect the performance of external tide insulators.

According to Mustamin (2011) [2], generally, the failure of an insulator that causing a tremendous loss is due to two aspects namely the surface aspect creating the appearance of leakage currents on the surface, and the bulk aspect which decreases the dielectric properties (ε_r and tan δ) of the insulator so that it is easy to broken (breakdown) due to lightning or switching. Moreover, the effect of humidity and high rainfall can cause the erosion of the insulator surface, while the difference in partial pressure between the material, and the atmosphere/environment allows penetration of moisture into the insulation, as well as the amount of water absorbed and the speed of the diffusion process, depending on the material itself, humidity outside air and ambient temperature. This phenomenon, according to some researchers, is called the macroscopic interface polarization effect, which will exacerbate the dielectric and electrical properties of the insulator [3]. Besides was causing a decrease in surface properties that are visible with the disappearance of the hydrophobic nature, the occurrence of cracks (tracking), and severe erosion on the surface of the insulator and an increase in surface leakage currents, thereby shortening the life of the insulation.

The traditional method for investigating surface insulator is dependent on human operations, by making direct observations on the transmission network, but because insulators generally plug outside in hard, to reach places such as methods is bulky and inefficient. The drones equipped with a high-definition camera and

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wireless transmission technology are using to check specific details of the transmission line. Utilization of digital image processing technology can be a solution in checking insulator surface conditions, whether in good condition or has damaged.

Image processing and machine vision technology are widely using in the field of transmission line inspection. Pernebayeva [4] uses Gabor and standard deviation filters with the k-NN classifier to assess the surface condition of the insulator by determining the presence of ice, snow, and water using images. It may [5] used the DAS algorithm of image processing to detect surface impurities on the insulator. Oberweger [6] suggested a method based on local gradient-based descriptors to take the isolator cap spontaneously, and then use elliptical spatial support to analyze automatically possible errors. Deep learning is part of a family of machine learning methods based on the representation of learning data and specific tasks of the algorithm. Gao [7] adopted the Convolutional Neural Network (CCN) model of deep learning to produce intelligent end-to-end detection of isolator circuits. First, the object detection method used to determine the location of the insulator, and then the isolator was extrapolated using a fully convolutional network; finally, based on the isolation damage characteristics, damage coordinates can be detected.

In this study, digital image processing used to conduct investigations quickly and efficiently on the surface of high voltage isolators using TensorFlow Machine Learning. The process begins with inputting the image of the insulator, followed by preprocessing in the form of sorting data of the damaged and broken insulation. After data is enough, do a test or training of the data and label each picture. If the training data procedure already finishes, then the data that has trained is ready to be classified or tested on new data using TensorFlow (Figure 1).

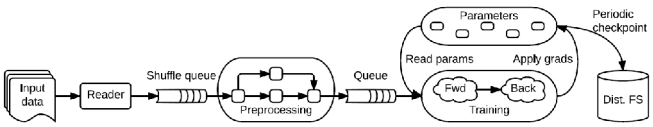

Figure 1. TensorFlow data flow graph [1]

TensorFlow is an open-source library for numerical computing using flow graphs. The nodes in the graph present multi-dimensional array data that communicate with each other. TensorFlow was developed by researchers and engineers who are members of the Google Brain Team under the division of the Google Machine Research Organization, which aims to conduct Machine Learning (ML) research and deepen research on artificial neural networks, but can also utilize in other fields. In short, TensorFlow is used for learning and increasing about ML and artificial neural networks [9].

A. Introduction to TensorFlow Imagery

Machine learning is the subdivision of artificial intelligence where the system can learn from data, identify patterns, and then make decisions without human intervention. Image recognition in TensorFlow machine learning using convolutional neural networks, also known as convents or CNN, is a famous method in computer vision applications to recognize objects from images or videos [10].

B. Inception V3

In general, the practice of image processing using network pre-training with a set of data sets is not sizeable because extensive network training takes a long time (for example, new networks require 2-3 weeks to train various GPUs on ImageNet, which contains 1.2 million images with 1000 categories).

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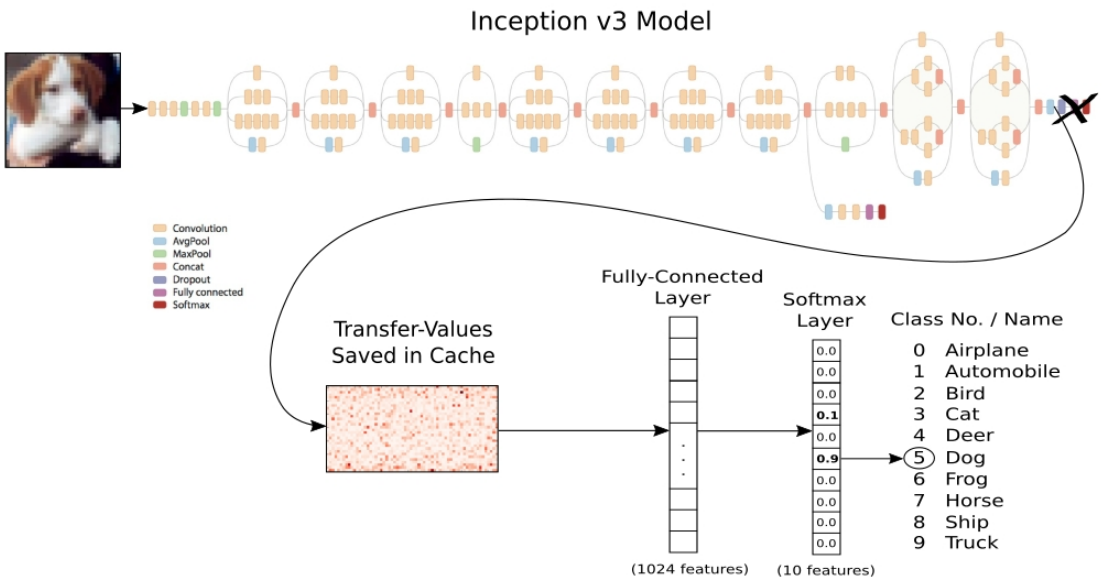

Figure 2. Model Inception –V3

The Inception Model is an ImageNet pre-training network, released by Google. The network name is the Inception module, which is a smaller model placed in a larger model, see figure 2. The same architecture use in the GoogLeNet model, which is an image recognition model released in 2014

Inception-v3 consists of two parts [11]:

1. Feature section extraction with a convolutional neural network.
2. The classification section is fully-connected and softmax layers.

C. *Tensor*

In Tensorflow, all calculations involve tensors. Tensors are n-dimensional vectors or matrices that represent all types of data. All values in tensors have identical data types with known (or partially know) forms. The shape of the data is the dimension of the matrix or array. A tensor can come from input data or calculation results. At TensorFlow, all operations carried out in a diagram. A graph is a set of calculations that occur in succession. Each activity is called an op node and is fully connected [11].

D. *Modified National Institute of Standards and Technology Dataset (MNIST Dataset)*

The MNIST dataset is one of the most commonly used datasets for image classification and can access from various sources [11]. Tensorflow and Keras allow us to import and download MNIST datasets directly from the Application Programming Interface (API). MNIST data divide into three parts: 55,000 training data points (mnist.train), 10,000 test data points (mnist.test), and 5,000 validation data points (mnist.validation) For example, an image with a size of 28 x 28 pixels produce 784 the amount of vector space to be recognized, MNIST images create a mnist.train. Images tensor of the form [55000, 784].

E. *Softmax Regression*

Softmax Regression (synonym: Multinomial Logistic, Maximum Entropy Classifier, or Multi-class Logistic Regression) is a generalization of logistical regression that can be applied for multi-class classification (assuming that the classes are mutually exclusive) [12]. Instead, the Logistic Regression model is used (standard) in binary classification tasks.

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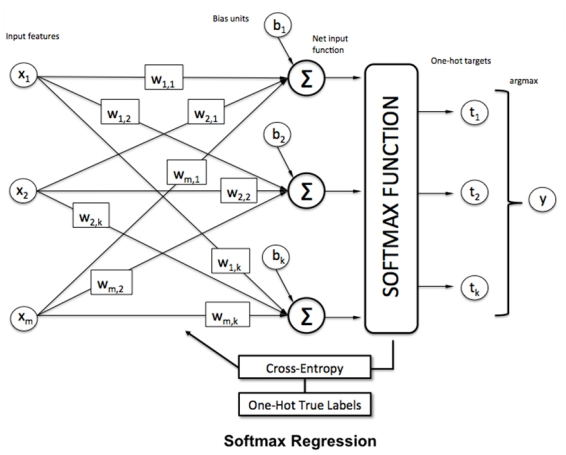

Figure 3. Softmax Regression [12]

As the name suggests, in softmax regression (SMR), the sigmoid logistic function replaces with the softmax function φ:

$$P(y = j \mid z^{(i)}) = \phi_{softmax}(z^{(i)}) = \frac{e^{z^{(i)}}}{\sum_{j=0}^{k} e^{z_k^{(i)}}}, \quad (1)$$

where input z defines as:

$$z = w_0 x_0 + w_1 x_1 + \ldots + w_m x_m = \sum_{l=0}^{m} w_l x_l = \mathbf{w}^T \mathbf{x}. \quad (2)$$

II. Research Methods

A. Insulator Classification

Inspection of the insulator carries through image analysis using a series of steps shown in Figure. 1. At the image acquisition stage, prepare a database of good and damaged image isolators. This dataset contains 300 images with two classes. The original RGB model obtained by the camera simplified by cutting a 28x28 square pixel segment to reduce computational storage complexity. Data sets are divided into train sets and tests, randomly selected to classification accuracy. Samples of both good and damaged insulators are illustrated in Figure 4.

Figure 4a. Good Condition Insulator

Figure 4b Broken Insulator

Figure 5 shows that the system designed requires machine learning that makes as a brain in the isolation classification process. A connection between TensorFlow and computer software is also required. TensorFlow functions to store training data and test data needed in the isolator classification process

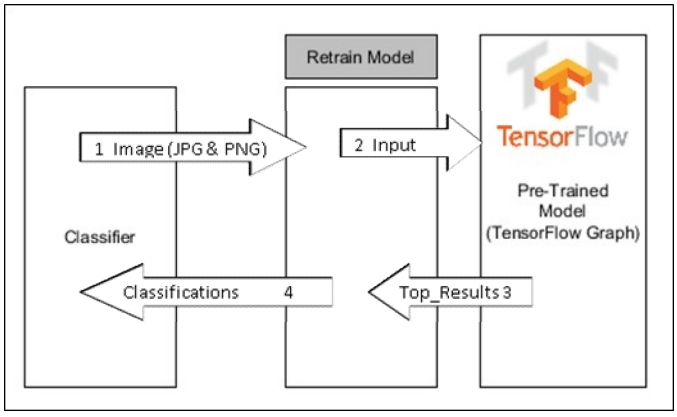

Figure 5. Classification System

B. Flow Chart of the TensorFlow System

Figure 6 illustrates the system flow that makes, where the first process is to sort between insulator data that is good and damaged. If the data taken is sufficient, conduct training or training on the data that has been collected and label each image. If the data training process has been completed, then the data that creates is

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ready to be classified or tested with new data using TensorFlow

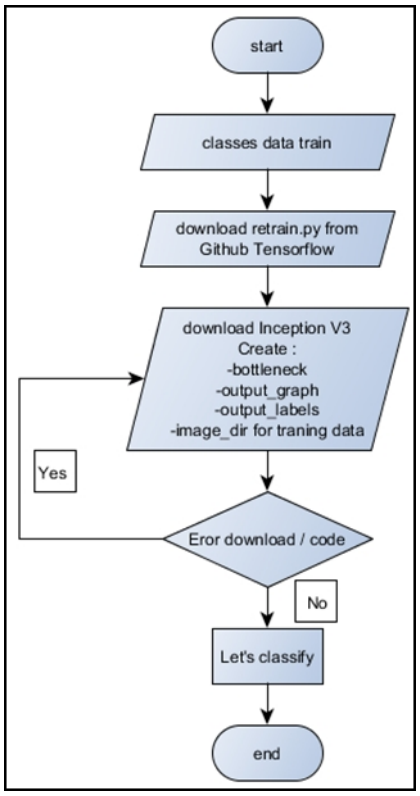

Figure 6. TensorFlow System Flow Chart

III. Results and Discussion

Digital Image Processing System Using ML TensorFlow to investigate the surface condition of high-voltage insulators is a simulation application to determine the good or damage of an insulator, especially those extreme tides. First, the user will make the file selection until the GUI system, and the GUI system limits the range of files to only the Joint Photographic Group / Joint Photographic Experts Group (JPG / JPEG) and Portable Network Graphics (PNG) then the GUI system will record and display the image files. If the image is following what the user intended, the user can classify by pressing the classification button, and if otherwise, the user can re-select the intended image file. The classification button sent to the TensorFlow system by bringing the file name that has been previously recorded by the GUI system and immediately conducts a classification analysis. The results of the TensorFlow classification analysis send back to the GUI system for display so that users can see the accuracy of the TensorFlow system. If the user wants to reclassify, he can re-select the image to be categorized ad and vice versa can press the exit button, and the system will end the process.

The system will run and automatically determine the condition of an insulator. Users only take pictures and enter the system. The system will send back the results then a conclusion will be drawn that the insulation is of good or damaged category

A. Pre-Classification Display

The testing process begins with pre-classify the isolator that will test after that do the training, the variables used in the training process are (100 x 100) pixel images, 500 training steps, then select images from the test data and continue with image recognition for know the accuracy of the classification process as shown in Figures 7 and 8.

Figure 7. Pre-classification of Damaged Isolators

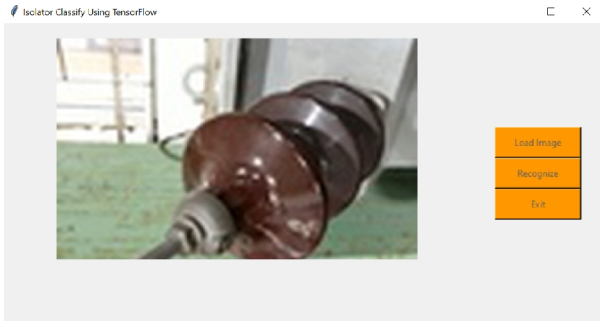

Figure 8. Pre-classification of Good Insulators

Figure 7 shows the pre-classification process on the damage isolator and Figure 8 on the good insulator.

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B. Display Classification Results

After the image recognition process, the application will display the results of the classification (Figures 9 and 10). It can be seen in Figure 9; the accuracy of the classification results is 0.99478 (damaged) and 0.000522 (Good); this value indicates that the insulators tested are insulators have been damaged, while figure 10 obtained the classification results are worth 0.99303 (good) and 0.00697 (damaged), it concludes that the isolator tested was good.

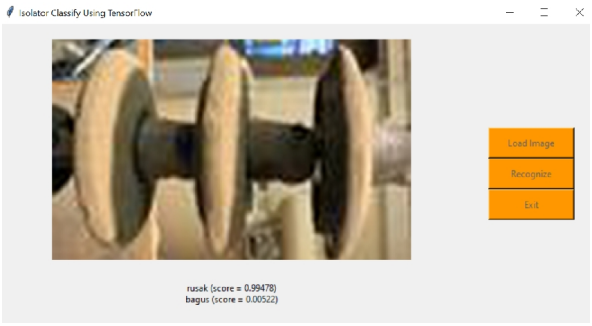

Figure 9. Classification of Damaged Isolator

Figure 10. Classification of Good Isolator Results

C. TensorFLow Accuracy Analysis

The following is some presentations of the accuracy value of the TensorFlow system that runs on the isolation classification GUI application.

akurasi hasil klasifikasi seseuai dengan fakta lapangan dengan rata-rata nilai akurasi sekitar 98%.

Measurement of accuracy values aims to find out how valid the results of the classification. The highest amount of accuracy is 100%, but the value rarely found due to a bias in reading the image, especially on small pixel images. The highest accuracy value obtained is 99.47% Figure 10. The accuracy level of the classification results shows in table 1. Results from classification and hypothesis show the accuracy of the classification results is by the facts of the field with an average accuracy value of approximately 98%.

Table 1. Results of Data Accuracy Measurement at 500 Training steps

No.	Data Test	Hypothesis	Train Score Accuracy TensorFlow	
			Good	Damage
1.		Damage	0,01603	0.98397
2.		Damage	0.02431	0,98397
3.		Good	0,97186	0,02814
4.		Good	0.96036	0,03964
5.		Good	0,9861	0.01389

D. Comparative Testing of Accuracy Against Image Size

Image size is very influential on the accuracy of the TensorFlow classification results. Figure 11 shows the test pixel size of the image. The results obtained show that pictures with pixels below 28 x 28 are unsuitable for use because their accuracy is below 50%. The largest pixel size of the image is the higher the accuracy value of the TensorFlow classification.

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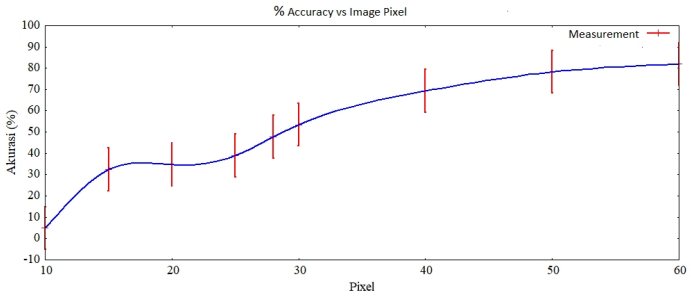

Figure 11. Comparison between the accuracy value and image size

IV. Conclusion

High-voltage insulators are mostly external pairs, so they are very susceptible to exposure to pollution, which can cause insulators to be damaged. Investigation of the surface condition of the insulation can be using image processing with the TensorFlow machine learning, where the system can automatically classify the state of the insulator is good or damaged. There are four stages carried out in this investigation application, namely: data input, pre-processing, training, and image recognition. The results of this study indicate the level of accuracy in the isolator classification of 98%, with the image size must be greater than 28 x 28 pixels.

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