Prediction Point of Fault Location on Its Campus Power Grid by using Neural Artificial Method

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Abstract The dispersed electric load connected to the power system leads to various nominal current and direction. However, to protect the plan optimally, relay settings must be updated according to its configuration. This paper investigates the prediction of fault location point for Directional Overcurrent Relay (DOCR). The system used Institut Teknologi Sepuluh Nopember (ITS) Campus electricity system connected to the grid utility. Artificial Neural Network (ANN) include data combination of power flow and short circuit as input data, can determine the appropriate fault location of the system. From the result, the data set in the master control has a smaller composition than by performing manual looking for tables. From the simulation result, 313 testing data obtained an average error of 0.002614377 so that the test results are quite close to the target data. Another advantage is that fewer data must be entered in Master control when using ANN, 136 data, compared using a lookup table, 1512 data. Through this method, the user can predict the fault location quickly and accurately.

1. Introduction
It is necessary to analyze the settings and coordination of the relay, especially in the coordination of overcurrent protection relay to improve the reliability of the protection system. Update relay setting and good relay coordination can prevent damage network and electrical equipment in the event of a fault and restrict the power supply from being cut off in other areas.

Protection coordination has a vital role in guaranteeing continuity of energy sources, so in the design of protection must be guaranteed the reliability, selectivity, flexibility, and speed of the relay operation to isolate the affected area without affecting the affected other regions. Some of the impacts can affect changes to short circuit breakdowns and errors in the termination network. Therefore, new protection scheme is carried out and calculated by considering the generator location by determining the time dial setting and the current pickup so that it can have minimum total operating time for relay. The conditions of each network topology that occur next specify the value of each relay setting related to topological terms. Coordination can be done using a hierarchical control system (hierarchical control) where there are several levels in the settlement process the problem by processing, sensing and adjusting, monitoring and supervision, using devices to find out.

One of the difficulties that occurred during the protection scheme study was the determination of the primary relay operating time and backup relay. The backup relay must work as fast as possible to back
up the central relay by taking into account the CTI (Coordination Time Interval) parameter so that the arc flash sparks interference can be minimized. This condition explains that the failure in the protection strategy is caused by the results of the operating time of the backup to the primary relay does not include the exact CTI value.

Artificial Neural Network is an algorithm that has several things to improve the optimization process as a solution to the problem of the high level of difficulty of coordinating protection in a Loop and Radial system. These are the velocity parameters and the best position exchange of each objective function.

Several methods are used to optimize some protection parameters to reduce difficulties in the study Loop and Radial systems. Optimized parameters include the TDS (Time Dial Setting) value, CTI (Coordination Time Interval), and operating time for each primary and backup relay. Some of the ways that have been done to optimize the parameters are LP (Linear Programming), Artificial Neural Network, NLPP (Nonlinear Programming Problem), GA (Genetic Algorithm), and EA (Evolutionary Algorithm). Artificial Neural Network (ANN) is an algorithm that functions to be more adaptive in detecting interference and changing combinations in a Loop and Radial system.

2. Fundamental of Power System

2.1. Fault Modelling

When an interruption occurs in a system will flow a large current leading to the point of interference. The interference current has a value higher than the maximum allowable ray current, so there is an increase in temperature on the equipment that can cause equipment damage. Disturbances that often occur in electric power systems are overload and short circuit. The three-phase short circuit is a short circuit that involves the three-phase. The two-phase short circuit is a short circuit that occurs between two-phase without being connected to the ground. One-phase short circuit affects a zero sequence impedance, and the magnitude of this short-circuit current depends on the grounding system used. The amount of each phase short circuit current above can be calculated respectively by the following equation:

\[
I_{sc\ 3\phi} = \frac{V_{LN}}{X_1} \\
I_{sc\ 2\phi} = \frac{V_{LL}}{X_1 + X_2} = \frac{\sqrt{3} \times V_{LN}}{2 \times X_1} \\
I_{sc\ 1\phi} = \frac{3 \times V_{LN}}{X_1 + X_2 + X_0 + 3 \times Z_g}
\]

Where \(V_{LN}\) is line to neutral nominal voltage, \(X_0\) is zero reactance, \(X_1\) is a positive reactance sequence while \(X_2\) is a negative reactance sequence. Overload problems occur when the electric current flowing in the power supply system is greater than the nominal current permitted through the channel (I > In). If this fault occurs, then the current passing through electrical appliances, such as transformers, generators, motors, and other electrical appliances), will exceed the current of the equipment capacity. This condition will damage the equipment.
2.2. Overcurrent Relay

The overcurrent relay is a relay that operates when the current flowing in a power system conduit exceeds the specified current value constraint. The relay will work when \( I_f > I_p \), and it will not work when \( I_f < I_p \). Where \( I_p \) represents the value of current expressed to the secondary winding \( CT \) (Current Transformer) and \( I_f \) represents the rated fault current.

The overcurrent tuning setting limit is that the releases do not work at the maximum load. Therefore, the current setting must be greater than the maximum load current. The limits of setting value is 1.05-1.3 \( I_{FL} \). In the overcurrent relay, the magnitude of the pickup flow is determined by selecting the tap value using the following equation:

\[
\text{Tap} = \frac{I_{set}}{CT \text{ primary}}
\]

(4)

Besides that, to adjust the size of the tap also requires setting the dial time. Setting the time value for each inverted relay curve can use equation (5) and Table V.

\[
t_d = \frac{k \times T}{\beta \times \left( I_{set} \right)^{\frac{1}{\alpha}} - 1}
\]

(5)

Where \( t_d \) is Time operation (second), \( T \) is Time dial, \( I \) is Current value (Ampere), \( I_{set} \) is Pickup Current (Ampere), \( k \) is inverse coefficient 1, \( \alpha \) inverse coefficient 2, and \( \beta \) is Coefficient inverse 3.

**Table 1. Coefficient of Relay Curve**
| Curve Type        | Coefficient |
|------------------|-------------|
|                  | $k$ | $\langle$ | $\circ$ |
| Standard Inverse | 0,14 | 0,02 | 2,970 |
| Very Inverse     | 13,50 | 1,00 | 1,500 |
| Extremely Inverse| 80,00 | 2,00 | 0,808 |

The overflow relay of the instant part will act if there is more current flowing beyond the allowable limit. In determining this instant pickup setting is used $I_{sc\text{ min}}$. It represents as two-phase short circuit current at minimum generation. So, the settings are set:

$$I_{set} \leq 0,8 \times I_{sc\text{ min}}$$  \hspace{1cm} (6)

Coordination of relays is performed to avoid miscoordination, such as trips simultaneously. In accordance with the IEEE 242 standard on the time difference between the primary relay and backup relay, the allowable $\Delta t$ is 0.2 - 0.5 seconds. With the following equipment specifications, CB opening time: 0.04 - 0.1s (2-5 cycles); Overtravel from Relay: 0.01 s; and Safety factor: 0.12 - 0.22 s. For the microprocessor-based relay, Overtravel time from relay can be ignored. Thus, the required time is 0.2-0.3s.

2.3. Directional Relay
Directional relay is needed where the relay current usually does not work selectively. This equipment is made just like conventional current, with the addition of direction elements that can determine the direction of the fault. Directional elements work based on the phase shift between the magnitude of the polarization and the magnitude of the operation. For forward condition, $I$ (current) lagging against $V$ (voltage), and for a reverse condition, $I$ lead to $V$.

3. Research Methodology

3.1. Campus Power Grid
In general, the campus electricity section can be described as follows. The southern ring ITS electricity network at ITS Sukolilo Campus consists of 5 Sub Stations (SS) namely SS-1 Electrical Engineering that supplies 800 kVA transformers, SS-2 Physics Engineering that supplies 630 kVA transformers, SS-3 Chemical Engineering that supplies 630 kVA transformers, SS-4 BAUK that provides 630 kVA transformers and FMIPA SS-5 that supplies 630 kVA transformers.

- Lump load 1: Sub Station 1 in Electrical Engineering Faculty with capacity 0.717 MVA,
- Lump load 2: Sub Station 2 in Engineering Physics Faculty with capacity 0.25 MVA,
- Lump load 3: Sub Station 3 in Chemical Engineering Faculty with capacity 0.329 MVA,
- Lump load 4: Sub Station 4 in General Support Division with capacity 0.225 MVA,
- Lump load 5: Sub Station 5 in Science and Statistics Faculty with capacity 0.271 MVA.
In the southern ring power network, the ring network is indeed designed, so that it is easy to maintain the electricity network and quickly solve the problem if there is damage to one of the networks or substations. However, with the aging of the electricity network, there are electrical disturbances in several substations, and the safety equipment in each Sub Station uses only the Direct Switch on the incoming Cubicle and the fuse with SF$_6$ gas in the Out Going Cubicle. After simulating the operation of the southern ring network system on the ETAP program, the values of short circuit current and Power flow are obtained. After that, several system configurations, namely: Loop and Radial systems, with various kinds of the fault where impedance 0; 0.1; 1; 10; 100 are used to represent fault type.

3.2. Artificial Neural Network

Artificial Neural Network (ANN) is a network of a group of small processing units that are modelled from human neural networks. ANN has an adaptive system so that its structure can change to solve problems based on information flowing through the network. Also called ANN is a tool to model non-linear statistical data.

This is very useful for complex modelling relationships between inputs and outputs to find data patterns. Fig.4 describes Neural Network architecture, which consists of Neurons as a basic part of
processing. The input used both during learning and in recognizing an object. Weight, the burden that always changes every time, given input as a learning process. Processing Unit, the place where an object recognition process takes place based on the loading given. Output comes from the introduction of an object.

Backpropagation is a supervised learning algorithm. They are generally used by perceptron with layers to change the weights associated with neurons. The hidden layer of the backpropagation algorithm changes the output error to change the values of the weights in the backward direction. The advance propagation stage must be done first to obtain an error. At the time of propagation forward, neurons are activated by using the activation function that can be differentiated as follow.

\[
y = f(x) = \frac{1}{1+e^{-\sigma x}}
\]  
(7)

Where

\[
f'(x) = \sigma f(x) \{1 - f(x)\}
\]  
(8)

Multiple neurons can be combined in layers to form networks, and network architecture can contain one or more layers. Given the connectivity of neurons in the network, this combination can be divided into two types: Feedforward network, Recurrent Network or Feedback Network.

The architecture used in this study is a feedforward network with new instructions, which consist of 2 layers: one input layer, one hidden layer, and one output layer. The learning process, in neural networks, is a procedure to modify the weights and biases of the network. The training algorithm forces the network to produce specific responses to specific inputs. There are two types of learning rules as Supervised Learning and Unsupervised Learning. This study uses supervised learning as a learning method. This method is monitored and provided with input-output data sets (called data training) of appropriate network behaviour. As input is applied to the network, the network output is compared to the target output. Learning rules are used to adjust network weights and biases, so that network output is closer to the target.

4. Simulation Results
The results of the calculation and modeling are the result of a combination of generation inputs that will get the value of the pickup current and time dial setting, the distribution system with the generator is divided into 2 generation topologies. Topology 1: Utility PLN electricity source, with Ring system configuration, Topology 2: Utility PLN electricity source, with Radial system configuration. The operating scheme for the transformer is varied as described follow. Scheme 1: All transformers operate, and Scheme 2 to 7, only one transformer does not operate respectively from transformer 1 to 6.

| Table 2. Power Flow Calculation in Campus Electrical System |
|------------------------------------------------------------|
| Bus Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Configura |
|-----------|---|---|---|---|---|---|---|---|---|----|---|---|---|tion      |
| 1 | 1.7 | 0.2 | -1.1 | -3 | -4.5 | -8.6 | 8.6 | 4.5 | 3 | 1.1 | -0.2 | -1.7 | 10.3 | 0 |
| 10^-5 | -1.6 | -2.9 | -4.7 | -6.2 | -10.3 | 6.2 | 4.7 | 2.9 | 1.6 | 10^-5 | 10.3 | 1 |
| 1.6 | 10^-5 | -1.3 | -3.2 | -4.6 | -8.8 | 8.8 | 4.6 | 3.2 | 1.3 | 10^-5 | 10.3 | 2 |
| 10^-5 | 10^-5 | 10^-3 | 10^-1.9 | -3.3 | -7.5 | 7.5 | 3.3 | 1.9 | 10^-5 | 10^-5 | 10^-5 | 10.3 | 3 |
| 4.7 | 3.2 | 1.9 | 10^-3 | -1.4 | -5.6 | 5.6 | 1.4 | 10^-5 | -1.9 | -3.2 | -4.7 | 10.3 | 4 |
| 6.2 | 4.6 | 2.3 | 1.4 | 10^-3 | -4.1 | 4.1 | 10^-5 | -1.4 | -2.3 | -4.6 | -6.2 | 10.3 | 5 |
The results of the Power Flow recapitulation of all system configurations at Campus Electric System is examined in the calculation, as showed in Table 2. Each relay has its own current data, which functions to secure the system. There is a target with a value of 1 to present the location of the disturbance, i.e., on Bus 1 in Table 3. Read the value of the relay short circuit currents 1 to 13 wherein the Target column is location bus disturbance. Data input into the LookUp Table for ANN training and testing process can be explained as follows. There are six channels configurations, each with a different relay current.

**Table 3. Sample Current Groupings Calculation in Power Grid**

| Relay | Target |
|-------|--------|
| 1     | 0.00   |
| 2     | 0.00   |
| 3     | 0.00   |

| Relay | Target |
|-------|--------|
| 1     | 22    |
| 2     | 22    |
| 3     | 22    |

| Relay | Target |
|-------|--------|
| 1     | -13   |
| 2     | -13   |
| 3     | -13   |

| Relay | Target |
|-------|--------|
| 1     | -6    |
| 2     | -6    |
| 3     | -6    |

| Relay | Target |
|-------|--------|
| 1     | -3    |
| 2     | -3    |
| 3     | -3    |

| Relay | Target |
|-------|--------|
| 1     | -0.001|
| 2     | -0.001|
| 3     | -0.001|

| Relay | Target |
|-------|--------|
| 1     | 270   |
| 2     | 268   |
| 3     | 256   |

**Table 4. Recapitulation of MSE Data from 15 Neurons**

| Neuron | Training | MSE      | Neuron | Training | MSE      |
|--------|----------|----------|--------|----------|----------|
| 1      | 1.1      | 0.29662  | 9      | 9.1      | 0.00099141|
| 2      | 1.2      | 0.18644  | 9.2    | 0.00032123|
|        | 1.3      | 0.48236  | 9.3    | 0.00020867|
| 3      | 2.1      | 0.13605  | 10     | 10.1     | 0.00012695|
|        | 2.2      | 0.000233 | 10.2   | 0.00034181|
|        | 2.3      | 0.000297 | 10.3   | 0.00012468|
| 4      | 3.1      | 0.000311 | 11     | 11.1     | 0.00026662|
|        | 3.2      | 0.000223 | 11.2   | 0.00015278|
|        | 3.3      | 0.000158 | 11.3   | 0.00021889|
|        | 4.1      | 0.000443 | 12     | 12.1     | 0.00030035|
| 5      | 4.2      | 0.000189 | 12.2   | 0.00025893|
|        | 4.3      | 0.000171 | 12.3   | 0.0003603|
|        | 5.1      | 0.00042  | 13     | 13.1     | 0.0041437|
|        | 5.2      | 0.00016  | 13.2   | 0.0016305|
|        | 5.3      | 0.00018  | 13.3   | 0.0086157|
| 6      | 6.1      | 0.000157 | 14     | 14.1     | 0.00021459|
|        | 6.2      | 0.00061  | 14.2   | 0.00017118|
|        | 6.3      | 0.000373 | 14.3   | 0.0003378|
| 7      | 7.1      | 0.000274 | 15     | 15.1     | 0.00031087|
|        | 7.2      | 0.000576 | 15.2   | 0.00037695|
|        | 7.3      | 0.000199 | 15.3   | 0.00022398|
The type of interphase fault is represented by an impedance of 0.1 and 1 because there are likely to be significant differences in the representation of ground fault. 0 means no fault. In this discussion there are 12 possible locations of disturbances on the bus, with details of 1 bus there are two possibilities of 2 areas of disturbance, so 6 buses multiplied by 2 fault locations. The incoming currents from relays 1 to 12 connected to the channel are entered sequentially, while relay 13 is a relay owned by PLN. The calculation of error data is grouped in tables 4.5. Each neuron trained the neuron results, experiments, and the mean square error of the training. The division of relay settings based on this source is used as an accurate calculation for all loading conditions.

Figure 5. Target results compared

Figure 6. Best Training Performance Neuron Error 9
Figures 5, 6, 7 explain the Figure of the results of training ANN Neuron 9 and Mean Square Error Neurons 9. Circle o symbolizes actual data, and (*) symbolizes the results of neural network training. The x-axis is the amount of current data processed, and the y-axis is the number of buses as many as 12 buses. The MSE value represents the mean square error. The x-axis describes the target of the training, while the y-axis describes the training output. Figure 4.19 represents. Referring to the ANN simulation, the best performance was obtained for 9 neuron data, namely 0.000099141 on the iteration of epoch 500, and the results of training calculations R = 0.99995.

5. Conclusion

Based on the simulation results and prediction analysis, Artificial Neural Network can simplify identification and accelerate the prediction fault points in the ITS electrical system. In this process, data form power flow and short circuit is trained three times, starts from the 1st neuron to the 15th neuron, to obtain the smallest error. The calculation results obtained MSE value of the smallest neuron at number 9 with trial 1. It means, the best performance was obtained for 9 neuron data, namely 0.000099141 with epoch iteration 500 and R 0.99995. The testing process is done by using 20% data, and this is done to prove the value of Weight and Bias can determine the location of the system with different data. From 313 testing data, obtained an average error 0.002614377 approaching the target data. In this advantage, Master control can use smaller amount of data to be processed. In detail, data that is needed by Master control with the Artificial Neural Network is 136 data, while lookup table is 1512 data.

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