Transient Stability Prediction Using algorithm Backpropagation

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Abstract. Current electricity needs are increasing along with the use of electricity in household appliances, offices and so on, so that electricity supply must increase. Request Electricity that continues to increase will result in changes in the condition of the system which is usually caused by a short circuit in the electrical power system. As a result of changes in this condition of system, the system will be change from the old to the new. The short period between the two conditions is called the transitional or transient period. This study aims to determine whether the system is stable or unstable in the event of a disturbance, so an Artificial Neural Network (ANN) is needed to determine the predictions of transient stability. The ANN used in this study uses backpropagation. Backpropagation algorithm is used to compare the performance of each NN system that has a number of hidden layers and different neurons used in performance. Performance can be assessed with several types of parameters, one of them is MSE (Mean Square Error). From several experiments training at random data in backpropagation, the smallest errors were found in 7 hidden layers and each hidden layer had 10 neurons. The data used is data that has never been used in the training phase, the results obtained in this test are prediction targets of transient stability to determine whether the system is stable or unstable in the event of a disturbance 3 phase. Testing is used there 25%, 50%, 75%, and 100% from 61 data, so that accuracy in testing data shows that backpropagation has achieved good and accurate that is 100%.

Key words : Transient Stability, Artificial Neural Networks (ANN), Backpropagation, and MSE (Mean Square Error)

1. Introduction

Current electricity needs are increasing along with the use of electricity in household appliances, offices and so on, so that electricity supply continues to increase. Increased electricity supply will result in changes in system conditions that usually occur due to short circuit in the electric power system and sudden release or the addition of large loads. As a result of changes in working conditions on the system, the state of the system will change from the old state to the new state. The short period between these two conditions is called the transition or transient period. Stability of the power system is the ability of the electric power system with its initial operating conditions, so it can stabilize again after experiencing interference, with certain variable limits so that the system continues to operate normally [1]-[2]. The factors that occur are caused by the development of the electric power system this result in the weakness system performance when experience of the disturbance [3]. According to the IEEE in power system vol. 19, No. 2, May 2004 [4] stability is divided into three classifications namely is stability of rotor angle, frequency stability, and voltage stability. In this research more to focused in stability rotor angle to prediction system stable or unstable.

Referring to the previous research [5]-[8] there is have researched to prediction generator stability. The research [5] used input active power, reactive power, terminal voltage, and electrical torque input, the target is obtained by predicting transient stability. The plant used is a modification of 39 New England buses. Neural network is used by Recurrent Neural Network (RNN). The research [6] used input voltage input phasor measurement and maximum value rotor angle in generator, the target obtained is predicted transient stability. The plant is used to modify 10 New England machine systems. Neural
network is used by Recurrent Neural Network (RNN). The research [7] used input normally load inputs, short circuits, and different load capacities, the target obtained is prediction load, bus, and line faults. Plant used IEEE 14 bus modification. The neural network is used by the Decision Tree. The research [8] used input pre-fault, during fault, post-fault bus voltage magnitude, and targets that were obtained is security and insecurity prediction in bus system. The plant used modification diagram of 127-bus WSCC (Western States Coordinating Council) power system. The neural network is used by the Multiple Layer Perceptron (MLP).

In this research used input active power, reactive power and location of disturbance, the target is obtained is stable and unstable in generator system if happened short circuit 3 phase. Plant used modification IEEE 9 bus. The neural network is used by backpropagation. Backpropagation is a method of ANN (Neural Network) that can be applied by training networks to gain network capabilities that recognize targets during the training process. After process training in backpropagation finishing, then will be get MSE value (mean square error). The MSE is to get an error value, if the smaller value obtained means that the error is decreasing. Then after to get the smallest MSE value, the system specified in the training process on the network is said to be trained and the results of the obtained curve are convergent. The results of this training process will be used as test inputs to determine whether the system is stable or unstable after happened disturbance in bus.

2. Simulation setup

2.1 Plant

This research uses a modification IEEE 9 bus. The modification consists of adding line and buses. An addition of line for actual conditions adjusted for impedance and admittance. While the addition of buses used to simulate short circuit on the line. There are 12 points of fault, location points fault on buses is 1, 4, 7, 10, 11, 13, 14, 16, 17, 19, and 20. Detail figure are shown in figure 1.

![Figure 1. Single line diagram (SLD) IEEE 9 bus modification](image-url)
2.2 Scenario research

1. Scheme 1: Generator 1 (G1) on the modified IEEE 9 bus system is set to the swing generator operation mode.
2. Scheme 2: The swing generator used in this scheme is Generator (G2) while in the G1 and G3 as voltage control.
3. Scheme 3: The swing generator used in this scheme is Generator (G3) while in G1 and G2 as voltage control.

2.3 How to obtain data

1. In this research the IEEE 9 bus simulation was modified using ETAP software. Data simulation is given disturbance 1 second, this disturbance is short circuit 3 phase. CB is open at the specified time. For other cases there are only 1,1 and 1,2 second. Detail table are shown in table 1.

| Generation | Time CB open (second) |
|------------|-----------------------|
| Case study for example in bus 1 | 1,1 |
| | 1,2 |
| | 1,3 |

2. The result in table 1 obtained graph is active power, reactive power and response rotor angle. The graph obtained when sampling data takes 0 until 3 seconds. 0 until 3 seconds is the duration of simulation. Figure 2, 3, and 4 these is total 61 the case from research, detail figure are shown in figure 2, 3, and 4.

![Figure 2. The example of data active power](image1)

![Figure 3. The example of data reactive power](image2)
According to ANSI / IEEE 399-1980 standards [9], the generator response rotor angle if more than 180 degrees the system is unstable and if generator response rotor angle less than 180 degrees the system is stable. Detail figure are shown in figure 4.

After the sampling process then obtained numerical data. Numerical data obtained when given 1 second of disturbance short circuit 3 phase to simulation analysis rotor angle stability. Analysis rotor angle done by the way If CB open at 1,1 seconds stills stable, then tried again until the value response rotor angle unstable. So, the numerical data obtained 61 event. 61 event obtained from example case study in buses 1. Buses 1 given disturbance short circuit 3 phase in 1 second and CB open 1,1. The result given disturbance short circuit 3 phase is active, reactive and response rotor angle. After that the graph in sampling in time 0 until 3 seconds. So that 0 till 3 second obtained 303 data. One event consists of active, reactive and response rotor angle so that get 1819 data. Table from 2, 3, and 4 these is a unity, detail table are shown in table 2, 3, and 4.

Table 2. Input data active and reactive power generation 1 (part 1 from 3 parts)

| Number | Input 1 Location of the disturbance | Input 2 – Input 304 Active power generation 1 | Input 305 – Input 608 Reactive power generation |
|--------|-----------------------------------|-----------------------------------------------|------------------------------------------------|
|        |                                   | Input 2 | Input 3 | ........ | Input 304 | Input 305 | Input 306 | ........ | Input 608 |
| 1      | 1                                 | 73,9    | 73,9    |         | 54,76     | 163      | 162,9    |         | 84,9     |
| 2      | 1                                 | 73,9    | 73,9    |         | 73,6     | 163      | 163      |         | 84,9     |
| 3      | 4                                 | 73,9    | 73,9    |         | 78,3     | 163      | 162,9    |         | 84,9     |
| 4      | 4                                 | 73,9    | 73,9    |         | 136,3    | 163      | 162,9    |         | 84,9     |
| ...    | ...                               | ...     | ...     |         | ...      | ...      | ...      |         | ...      |
| 60     | 20                                | 73,9    | 73,9    |         | 36,6     | 163      | 162,9    |         | 84,9     |
| 61     | 20                                | 0,0025  | 0,0018  |         | 49,9     | 163      | 163      |         | 160,003  |

Figure 4. The example data response rotor stable (a) and response rotor angle unstable (b).
### Table 3. Input data active and reactive power generation 2 (part 2 from 3 parts)

| Number | Input 1 Location of the disturbance | Input 609 – Input 911 Active power generation 2 | Input 912 – Input 1214 Active power generation 2 |
|--------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|
|        |                                     | Input 609 | Input 610 | Input 911 | Input 912 | Input 913 | Input 1214 |
| 1      | 1                                   | 84,9      | 84,9      | 30,6     | 30,6     | 30,6     | 0,09      |
| 2      | 1                                   | 84,9      | 84,9      | 30,6     | 30,6     | 30,6     | 0,09      |
| 3      | 4                                   | 84,9      | 84,9      | 30,6     | 30,6     | 30,6     | 0,09      |
| 4      | 4                                   | 84,9      | 84,9      | 30,6     | 30,6     | 30,6     | 0,09      |
|        |                                     |           |           |           |           |           |           |
| 60     | 20                                  | 84,9      | 84,9      | 30,6     | 30,6     | 30,6     | 0,09      |
| 61     | 20                                  | 160,005   | 160,005   | 48,2     | 48,2     | 48,2     | 3,9       |

### Table 4. Input data active and reactive power generation 3 (part 3 from 3 parts)

| Number | Input 1 Location of the disturbance | Input 1215– Input 1517 Active power generation 3 | Input 1518 – Input 1819 Active power generation 3 |
|--------|-------------------------------------|-----------------------------------------------|-----------------------------------------------|
|        |                                     | Input 1215 | Input 1216 | Input 1517 | Input 1518 | Input 1519 | Input 1819 |
| 1      | 1                                   | 0,093     | 0,093     | 12,8      | 12,8      | 12,8      | 6,5       |
| 2      | 1                                   | 0,093     | 0,093     | 12,8      | 12,8      | 12,8      | 10,4      |
| 3      | 4                                   | 0,093     | 0,093     | 12,8      | 12,8      | 12,8      | 11,2      |
| 4      | 4                                   | 0,093     | 0,093     | 12,8      | 12,8      | 12,8      | 6,09      |
|        |                                     |           |           |           |           |           |           |
| 60     | 20                                  | 0,093     | 0,093     | 12,8      | 12,8      | 12,8      | 67,7      |
| 61     | 20                                  | 3,9       | 3,9       | 5,2       | 12,8      | 12,8      | 41,8      |

2.4 Artificial Neural Network (ANN) architecture uses backpropagation

The ANN in research have 2 parts, these is training and testing. The result of training in 3.1 and The result of testing in 3.2. The result of was used as a clarification transient stability whether the system is stable or unstable when given a disturbance short circuit 3 phase. The steps used to design stability clarification using backpropagation are as follows:

1. Input variable
   - The ANN in research have 2 parts, these is training and testing. The result of training in 3.1 and The result of testing in 3.2. The result of was used as a clarification transient stability whether the system is stable or unstable when given a disturbance short circuit 3 phase. The steps used to design stability clarification using backpropagation are as follows:

   1. Input variable
      - Location of Disturbance (LD)
      - Active and reactive (P and Q) power in generator 1, 2 and 3

2. Target Variable
   - Stable
   - Unstable

   Detail figure are shown in figure 5.
Figure 5. Architecture neural network uses backpropagation

3. Result and Discussion

3.1 The result of training

Artificial neural networks (ANN) are neural networks that resemble cells of the human brain. ANN have a potential to overcome difficulties in processing data [10]. This training starts with reading the input for calculates the error value. This process repeated until the network generated which can be good performance. The performance is indicated by the MSE value. If the MSE value is small then the network is said to be trained. In this research value MSE the smallest in layer 7 hidden with each layer has 10 neurons. Detail figure are shown in figure 6.
3.2 The result of testing

This network testing to determine which the network can be used to obtained transient stability prediction targets. The way to get output at the testing stage is to implement the backpropagation method that is the same as the training stage. In testing, the data to be used 50% from 61 data. Total 61 data were obtained from ETAP simulations when given 1 second disturbance on each bus has been discussed earlier. 50% from 61 is 30 data, 30 data from random data. Detail figure are shown in table 5.

| Testing Data | Amount of test data input | Data during testing | Percent testing data | Accuracy (%) |
|--------------|---------------------------|---------------------|----------------------|--------------|
| 30 data      | 8                         | 25 %                | 100                  |
|              | 15                        | 50 %                | 100                  |
|              | 23                        | 75 %                | 100                  |
|              | 30                        | 100 %               | 100                  |

4. Conclusion

From several experiments training at random data in backpropagation, the smallest errors were found in 7 hidden layers and each hidden layer had 10 neurons. The data used is data that has never been used in the training phase, the results obtained in this test are prediction targets of transient stability to determine whether the system is stable or unstable in the event of a disturbance short circuit 3 phase. Testing is used there 25%, 50%, 75%, and 100% from 61 data, so that accuracy in testing data shows that backpropagation has achieved good and accurate that is 100%.
5. REFERENCES

[1] A.H. El-Abiad and K. Nagappan, “Transient stability regions for multi-machine power systems,” IEEE Trans. on Power Apparatus and Systems, Vol. PAS-85, Feb., 1966, pp.169-179.
[2] Athey, T., Podmore, R., and Virmani, S., “A Practical Method for Direct Analysis of Transient Stability”, IEEE Trans. Power Apparatus and Systems, 1979, vol. PAS-98, pp. 573-584.
[3] Ms. Chitra Thakur and Mr. Saurabh Sahu, “Analysis Of Voltage Stability And Transfer Capability Enhancement Of Transmission System Using Facts Controllers,” Current Trends in Technology and Science ISSN : 2279-0535, Volume II, Issue VI, 2013
[4] P. Kundur et al., “Definition and Classification of Power System Stability,” IEEE Trans. Power Syst., vol. 19, no. 3, pp. 1387–1401, 2004.
[5] Olulope Paul Kehinde, “Transient Stability of Hybrid Distributed Generation Using Computational Intelligent Approaches”, Thesis University of Cape Town, 2014.
[6] J. J. Q. Yu, D. J. Hill, A. Y. S. Lam, J. Gu, and V. O. K. Li, ”Intelligent Time-Adaptive Transient Stability Assessment System,” IEEE Transactions on Power Systems, vol. PP, pp. 1-1, 2016.
[7] Pannell Zachary, Ramachandran Dr. Bhuvaneswari, Snider Dr. Dalla,“Machine Learning Apporach to Solving the Transient Stability Assessment Problem”,IEEE, 2017.
[8] Mahdi Mohammed, Genc V.M. Istemihan,“Artificial Neural Network Based Algorithm for Early Prediction of Transient Stability Using Wide Area Measurement”, IEEE 978-1-5090-5938-6/17, 2017.
[9] ANSI/IEEE Std 399-1990, “IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis”, (IEEE Brown Book).
[10] El-Amin Ibrahim M, Al-shams Abdul-Aziz M, “Transient Stability Assessment Using Artificial Neural Network”, Journal Elsevier “Electric Power System Research”, (Vol.40, no 7-16), 1997.