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ANFIS Approach for Distribution Network Reconfiguration

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Abstract

This research was conducted to optimize the distribution system using Adaptive Neuro Fuzzy Inference System (ANFIS) method. Objective functions used are to minimize active power loss, node voltage deviation, number of switches, and maintain balance of the feeder. This function is modeled in a fuzzy set to build basic characteristics. The Method has been applied to the 32 bus IEEE standard distribution system. The simulation results show that the method used can work well.

Keywords: Distribution system, reconfiguration, optimization, ANFIS.

INTRODUCTION

Efforts to minimize energy losses in power distribution systems have been an important issue in the last decade. Of all components of the power system, the distribution system is the component with the greatest losses. An example is the power system in Indonesia managed by PT PLN (Persero). Based on the energy audit until 2004, the total energy losses of PLN in Indonesia is 16.84% [1]-[4]. Of the total, distribution system losses recorded the largest losses of 14.47%, while the transmission system losses of only 2.37% [5]-[7]. The application of the Artificial Neural Network (JNA) in solving predictive problems has been successfully carried out among others [8]-[10], which proposes an artificial neural network approach to electrical load forecasts, and in [11], which modeled artificial neural networks (JNA) for weather sensitive loads forecasts.

The subsequent development of the artificial intelligence system is to integrate an artificial neural net with fuzzy logic, known as ANFIS. Adaptive Neuro Fuzzy Inference System (ANFIS) has been accepted as a reliable method and is believed to continue to grow in response to the need for intelligent systems. ANFIS is a fuzzy logic inference system that is implemented in an adaptive web system [12]-[15].

An understanding of ANFIS can be started from the basic principles of fuzzy logic system [16]-[17], artificial neural network [18]-[20], neuro fuzzy [21]-[23], to the concept of ANFIS and its application [24]-[27]. Neuro-fuzzy system is net-plated connections that realize plural basic elements and functions of the control system / traditional fuzzy logic decision. Because neuro fuzzy systems are universal approximator the neuro fuzzy control system is also a approximator universe, because of its functions constitute a form (isomorphic) with traditional fuzzy logic control system. There are several kinds of neuro-fuzzy nets including FALCON, GARIC, and other variations [28].

By utilizing the web architecture and associated learning algorithms, neuro fuzzy system has been successfully applied to a variety of purposes [29]-[31]. However, most of the neuro fuzzy systems show some major drawbacks to the decline in performance. These deficiencies result dimensionally (number of fuzzy rules) and unable to gain knowledge of a given set of training data. In [33] developed successfully developed the ANFIS method for real-time system identification that can be used for adaptive control purposes. In our research, ANFIS is used to optimize power distribution network.

ADAPTIVE NEURO-FUZZY METHOD

Adaptive neuro-fuzzy approach has been became a popular method in control area during the last three decades, especially in power system. a brief description of the adaptive neuro-fuzzy inference system (ANFIS) is given in this part [4]-[10]. The basic structure of the type of fuzzy inference system could be seen as a model that maps input characteristics to input membership functions. Then it maps input membership function to rules to a set of output characteristics. Finally it maps output characteristics to output membership functions.

ANFIS has been considered only fixed membership functions that were chosen arbitrarily. Fuzzy inference system is only applied to only modeling whose rule construction is essentially predetermined by the user's interpretation of the characteristics of the variables. On several modelling situations, it cannot be distinguish what the membership functions should look like simply from looking at data is. In such case the necessity of the ANFIS is becomes obvious.

The ANFIS learning method works similarly to that of neural networks. The learning techniques provide a method for the fuzzy modelling procedure to learn information about a data set. A network structure similar to that of a neural network can be used to interpret the input and output map so it maps inputs through input membership functions and associated parameters, and then through the output of membership functions and associated parameters to outputs. All parameters which are associated with the membership functions changes through the learning process. The computation of these parameters is facilitated by a gradient vector. The gradient vector provides a measure of how well the FIS is modelling the input and/or output data for a given set of parameters. Once the gradient vector is obtained, several optimization routines can be applied in order to adjust the parameters to reduce some error measure. This measure is usually defined by the sum of the squared difference between actual and desired outputs.

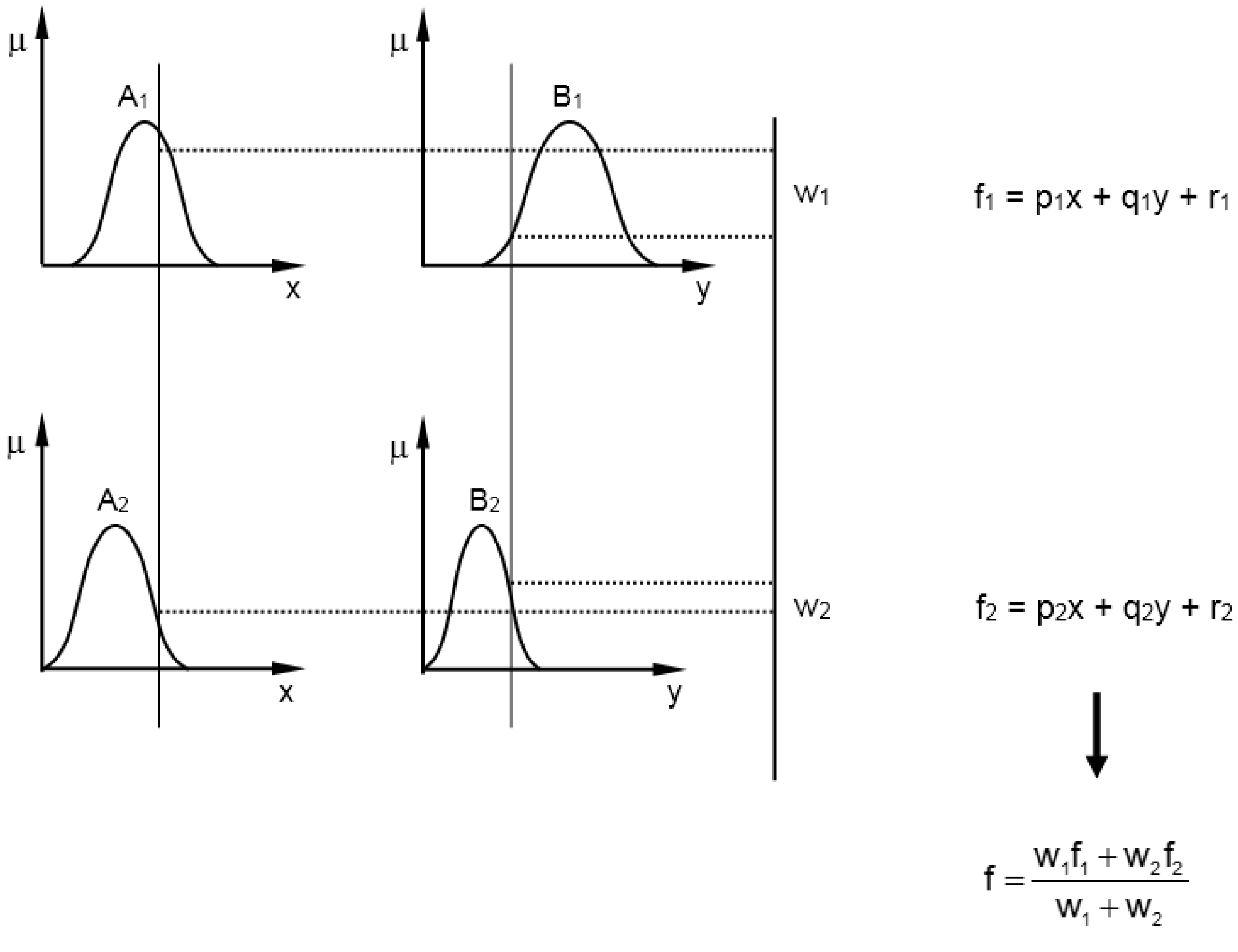

Figure 1: The model of Sugeno's fuzzy system

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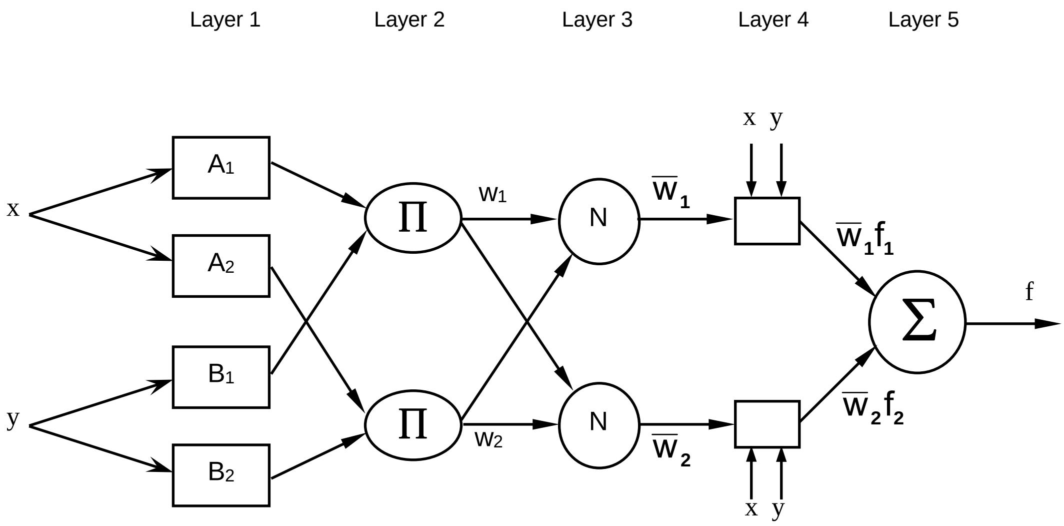

Figure 2: The typical architecture of the ANFIS

Figure 1 shows the model of Sugeno's fuzzy system while Figure 2 shows the typical architecture of the ANFIS. The network is consisting of inputs, with N neurons in the input layer and F input membership functions for each input, with F*N neurons in the fuzzification layer. In the inference and defuzzification layers, there are FN rules with FN neurons while one neuron in the output layer. In order to simplicity, it is assumed that the fuzzy inference system under consideration has two inputs x and y and one output z as shown in Figure 2. For a Sugeno fuzzy model, an appropriate rule set with two fuzzy rules is the following:

If x is A_1 and y is B_1, Then $f_1 = r_1$ (1)

If x is A_2 and y is B_2, Then $f_2 = r_2$ (2)

The output of the node i-th in layer n of ANFIS architecture is denoted as $O_{n,i}$.

Layer 1. Every node i in this layer is a square node with the function of node are:

O_i^1 = μAi(x), for i = 1, 2, (3)

or,

O_i^1 = μBi-2(y), for i = 3, 4 (4)

where x is the input of node-i, and Ai is the linguistic label which is associated with this node function. Commonly μAi(x) is chosen to be bell-shaped with maximum equal to 1 and minimum equal to 0, such as the generalized bell function below:

$$\mu_A(x) = \frac{1}{1+\left[\frac{x-c_i}{a_i}\right]^{2b_i}} \quad (5)$$

The Parameters in this layer is called as the premis parameters.

Layer 2. In this layer, every node is a circle node labeled Π which multiplies the incoming signals and sends the product out. The equation of this layer is:

O_i^2 = wi = μAi(x) x μB(y), i = 1, 2. (6)

Layer 3. In this layer, every node is a circle node labeled N. The node i-th calculates the ratio of i-th rule's firing strength to the sum of all rules firing strengths:

$$O_i^3 = \overline{w} = \frac{w_i}{w_1 + w_2}, \quad i = 1, 2. \quad (7)$$

The outputs of this layer of ANFIS will be called normalized firing strengths.

Layer 4. In this layer, every node i is a square node with a node function:

$$O_i^4 = \overline{w}_i f_i = \overline{w}_i (p_i x + q_i y + r_i) \quad (8)$$

where $\overline{w}_i$ is the layer 3 output and {pi, qi, ri} is the parameter set. The Parameters in this layer is called as the consequent parameters.

Layer 5. In this layer, the single node is a circle node labeled Σ that computes the overall output as the summation of all incoming signals. The equation of this layer is below,

$$O_i^5 = \sum \overline{w}_i f_i \quad (9)$$

RESEARCH METHODOLOGY

Most of the research activities are software system design, so the general pattern of scientific approach is realized by the steps shown in Figure 3.

The Adaptive Neuro Fuzzy Inference System (ANFIS) architecture built in the Matlab software is shown in Figure 4. A very popular neuro-fuzzy method is often known as Adaptive Neuro Fuzzy Inference System (ANFIS). ANFIS is an adaptive web based on fuzzy logic inference system [15]. Alongside the implementation of fuzzy logic inference system in adaptive nets, adaptive web properties can be used to adapt the inference system. In this case incorporated two methods to obtain the desired result is the adaptive method commonly used in artificial neural net system and fuzification commonly used on fuzzy controller. These two methods in use two different sources of information ie adaptive methods work using numerical data and fuzification methods using linguistic data. Both types of information is what can be obtained in the control system, so it is expected to create an optimal control system.

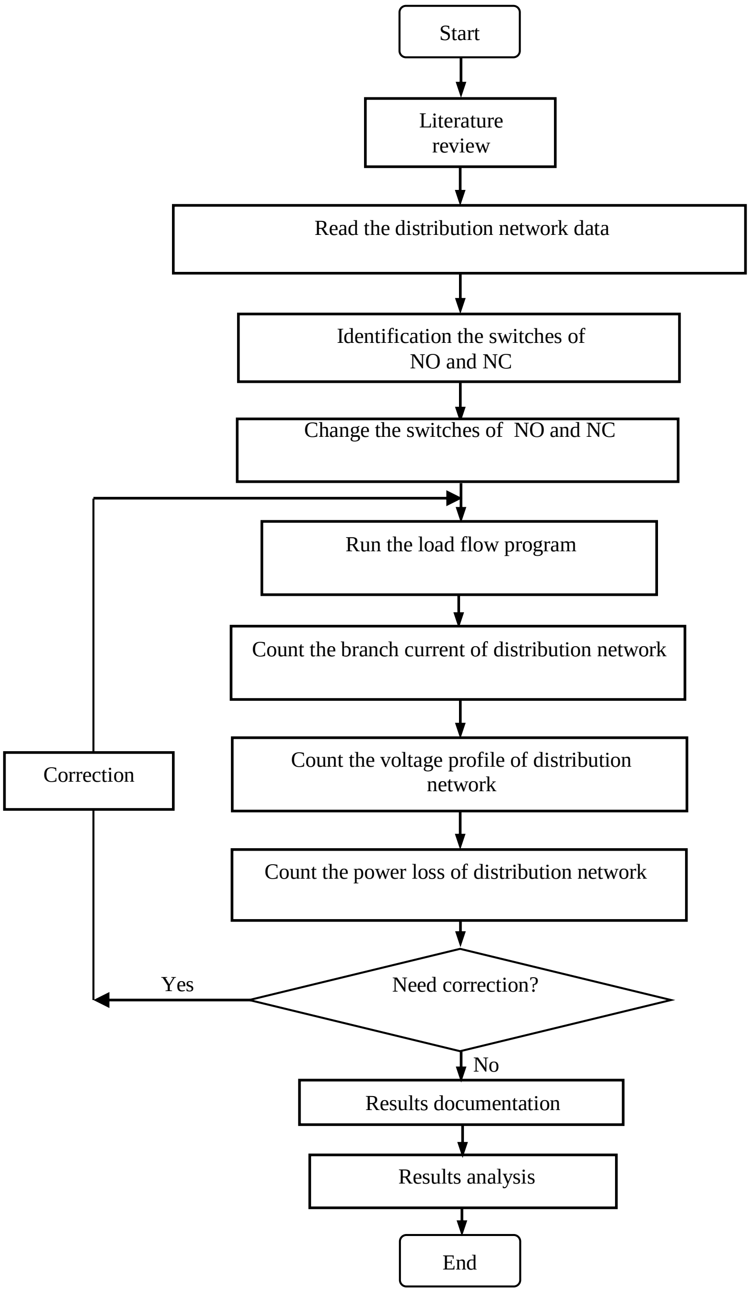

Figure 3: The steps of the research

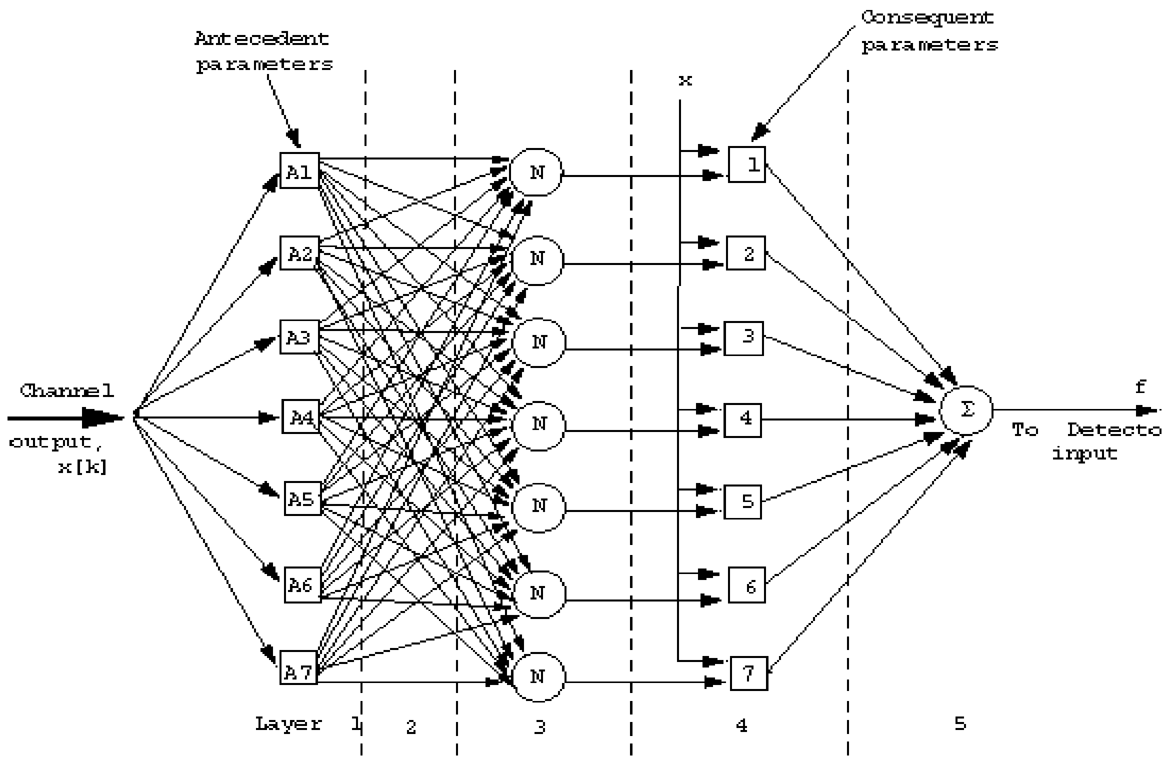

Figure 4: The Adaptive Neuro Fuzzy Inference System (ANFIS) architecture of the research

The ANFIS parameter is separated into two, namely the premise parameter (antecedent) and consequence parameter (consequent). The adaptation process is performed with the aim of obtaining these parameters in order to form an adaptive web that represents the desired inference system. The process of searching the premise parameters and consequence parameters is often known as the learning process or the training process. The training process for ANFIS used in this research is backpropagation and hybrid (combined propagation and least square estimation, LSE).

RESULTS AND DISCUSSION

This section discusses the electrical power distribution reconfiguration test consisting of four feeders, as shown in Figure 5. The four-bus distribution system is one of the IEEE standard distribution systems used by many researchers in the world to conduct research-related tests of the distribution network, i.e., distribution power flow test, distribution voltage profile test, harmonic test, and reconfiguration test. In this research, the main focus is the reconfiguration test of the electric power distribution network with the aim of reducing the power losses, keeping in mind the load balance of each feeder and the voltage level of the bus in the distribution system.

In the first step, a load flow program for a radial distribution network is run. After that, the voltage difference across the tie-switches and observed open tie-switch by keeping the maximum voltage difference is calculated. In the last step, it can be checked whether the voltage difference is greater than the value set previously.

In this study, the 30-kV radial distribution system having one substation, four feeders, and 32 bus (including sectionalizing branches and tie branches) as shown in Figure 5. Tie switches of this system are open in normal conditions. Figure 5 shows the initial configuration of distribution network.

As shown in Figure 5, there are two types of switches in the distribution nets: switches in normal circumstances are open (Normally Open Switch) and switches in normal normally closed (Normally Closed Switch) state. Based on Figure 5, it can be seen that in the IEEE standard distribution system such as the initial configuration (in Figure 5), there are still relatively large power losses, thus increasing the efficiency of higher distribution nets, hence the reconfiguration of the distribution net. Reconfiguration results that are relatively better than the initial configuration are shown in Figure 6.

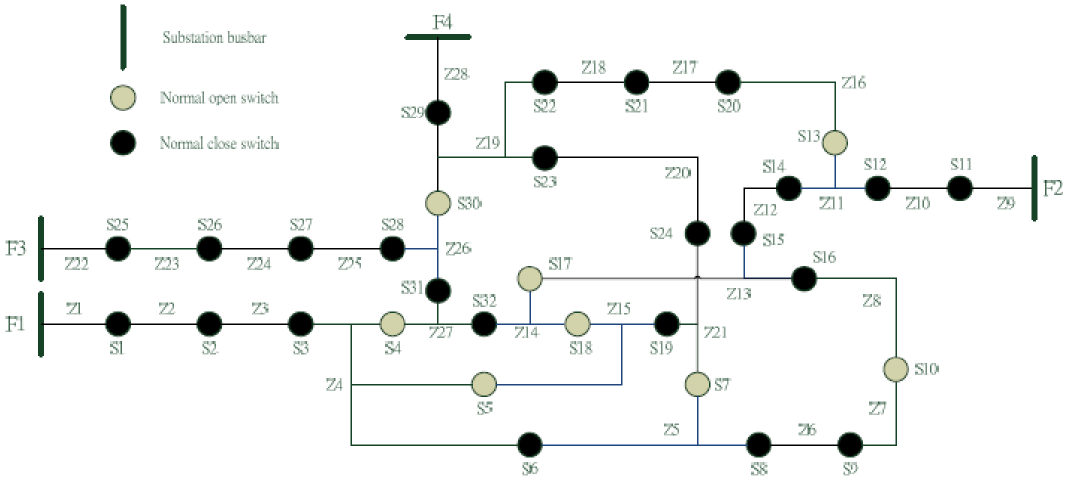

Figure 5: The IEEE standard distribution network before reconfiguration under study

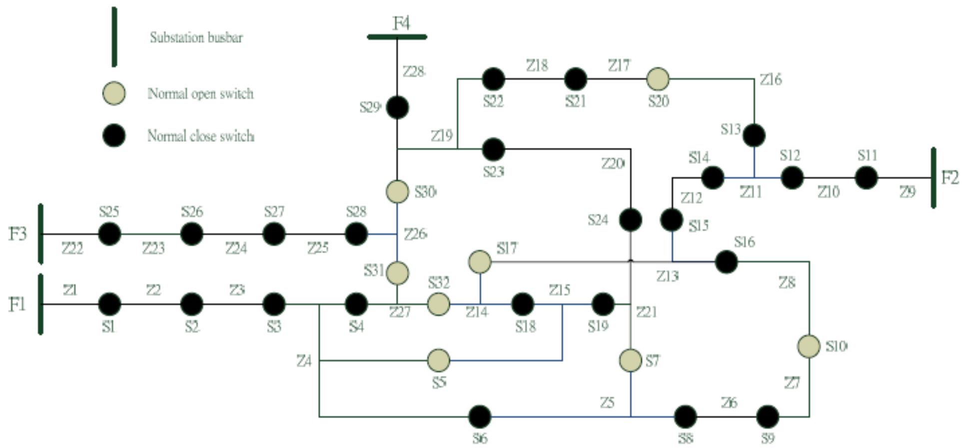

Figure 6: The IEEE standard distribution network after reconfiguration under study

Before reconfiguration the network, the total active power loss of this system is 142 kW, with the efficiency of distribution network is 92%. The minimum voltage magnitude that occurs in bus of S_{10} is 0.901 p.u. After reconfiguration, the total active power loss is 112 kW, or the other words, the efficiency of distribution network is 96%, as shown in Table 1. The minimum voltage magnitude is 0.935 p.u. that occurs in bus of S_{10}.

From the result of our case study, it can be seen from the 32 nodes radial distribution system test system that reconfiguration has the effects of loss reduction improvement over feeders in this particular case. Based on the 32 nodes radial distribution system, the ANFIS method in this paper has significant loss reduction in order to improve the efficiency of distribution system.

Table 1: The Results of Simulation of 32 Nodes Distribution Network

Test Case	**Variables of Analysis**		
	Active Power Loss (kW)	Efficiency of Distribution Network (%)	Minimum Voltage (p.u.)
Distribution network before reconfiguration	142	92	0.901 (V_{S10})
Distribution network after reconfiguration	112	96	0.935 (V_{S10})

CONCLUSION

Reconfiguring distribution nets is an effective method of minimizing active power losses in power distribution nets, while maintaining load balance in each feeder. In the reconfiguration of the distribution net, in addition to the primary purpose of obtaining optimal network reconfiguration, it is also necessary for the ANFIS algorithm of reconfiguring a distribution net with a low computational load, so that if applied to a real distribution net, it can be used online. This is due to a real distribution system, load changes can occur in a short time due to the dynamics of the system is very high.

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REFERENCES

[1] Syahputra, R., Robandi, I., Ashari, M. (2015). Reconfiguration of Distribution Network with DER Integration Using PSO Algorithm. TELKOMNIKA, 13(3). pp. 759-766.

[2] Syahputra, R., Soesanti, I., Ashari, M. (2016). Performance Enhancement of Distribution Network with DG Integration Using Modified PSO Algorithm. Journal of Electrical Systems (JES), 12(1), pp. 1-19.

[3] Syahputra, R., Robandi, I., Ashari, M., (2013), “Distribution Network Efficiency Improvement Based on Fuzzy Multi-objective Method”. International Seminar on Applied Technology, Science and Arts (APTECS). 2013; pp. 224-229.

[4] Jamal, A., Syahputra, R. (2013). UPFC Based on Adaptive Neuro-Fuzzy for Power Flow Control of Multimachine Power Systems. International Journal of Engineering Science Invention (IJESI), 2(10), pp. 05-14.

[5] Syahputra, R. (2010). Fault Distance Estimation of Two-Terminal Transmission Lines. Proceedings of International Seminar on Applied Technology, Science, and Arts (2nd APTECS), Surabaya, 21-22 Dec. 2010, pp. 419-423.

[6] Syahputra, R., Soesanti, I. (2016). Design of Automatic Electric Batik Stove for Batik Industry. Journal of Theoretical and Applied Information Technology (JATIT), 87(1), pp. 167-175.

[7] Soesanti, I., Syahputra, R. (2016). Batik Production Process Optimization Using Particle Swarm Optimization Method. Journal of Theoretical and Applied Information Technology, 86(2), pp. 272-278.

[8] Syahputra, R., Robandi, I., Ashari, M. (2015). PSO Based Multi-objective Optimization for Reconfiguration of Radial Distribution Network. International Journal of Applied Engineering Research (IJAER), 10(6), pp. 14573-14586.

[9] Jamal, A., Suripto, S., Syahputra, R. (2017). Power Flow Optimization Using UPFC Based on Neuro-Fuzzy Method for Multi-machine Power System Stability. International Journal of Applied Engineering Research (IJAER), 12(6), pp. 898-907.

[10] Jamal, A., Suripto, S., Syahputra, R. (2016). Performance Evaluation of Wind Turbine with Doubly-Fed Induction Generator. International Journal of Applied Engineering Research (IJAER), 11(7), pp. 4999-5004.

[11] Syahputra, R., Robandi, I., Ashari, M. (2015). Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm. International Review of Electrical Engineering (IREE), 10(2). pp. 293-304.

[12] Syahputra, R., Robandi, I., Ashari, M. (2014). Optimization of Distribution Network Configuration with Integration of Distributed Energy Resources Using Extended Fuzzy Multi-objective Method. International Review of Electrical Engineering (IREE), 9(3), pp. 629-639.

[13] Syahputra, R., Robandi, I., Ashari, M., (2014), “Distribution Network Efficiency Improvement Based on Fuzzy Multi-objective Method”. IPTEK Journal of Proceedings Series. 2014; 1(1): pp. 224-229.

[14] Syahputra, R., Robandi, I., Ashari, M. (2014). Performance Analysis of Wind Turbine as a Distributed Generation Unit in Distribution System. IJCSIT), Vol. 6, No. 3, pp. 39-56.

[15] Syahputra, R., (2012), “Distributed Generation: State of the Arts dalam Penyediaan Energi Listrik”, LP3M UMY, Yogyakarta, 2012.

[16] Syahputra, R., Robandi, I., Ashari, M. (2014). “Optimal Distribution Network Reconfiguration with Penetration of Distributed Energy Resources”, Proceeding of 2014 1st International Conference on

Information Technology, Computer, and Electrical Engineering (ICITACEE) 2014, UNDIP Semarang, pp. 388 - 393.

[17] Jamal, A., Syahputra, R. (2014). Power Flow Control of Power Systems Using UPFC Based on Adaptive Neuro Fuzzy. IPTEK Journal of Proceedings Series. 2014; 1(1): pp. 218-223.

[18] Soedibyo, Ashari, M., Syahputra, R. (2014). "Power loss reduction strategy of distribution network with distributed generator integration", Proceeding of 2014 1st International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE) 2014, UNDIP Semarang, pp. 404 - 408.

[19] Syahputra, R., Soesanti, I. (2016). DFIG Control Scheme of Wind Power Using ANFIS Method in Electrical Power Grid System. International Journal of Applied Engineering Research (IJAER), 11(7), pp. 5256-5262.

[20] Syahputra, R., Robandi, I., Ashari, M., (2012), "Reconfiguration of Distribution Network with DG Using Fuzzy Multi-objective Method", International Conference on Innovation, Management and Technology Research (ICIMTR), May 21-22, 2012, Melacca, Malaysia.

[21] Syahputra, R., Soesanti, I. (2015). Power System Stabilizer model based on Fuzzy-PSO for improving power system stability. 2015 International Conference on Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation (ICAMIMIA), Surabaya, 15-17 Oct. 2015 pp. 121 - 126.

[22] Syahputra, R. (2016). Application of Neuro-Fuzzy Method for Prediction of Vehicle Fuel Consumption. Journal of Theoretical and Applied Information Technology (JATIT), 86(1), pp. 138-149.

[23] Syahputra, R., (2013), "A Neuro-Fuzzy Approach For the Fault Location Estimation of Unsynchronized Two-Terminal Transmission Lines", IJCSIT, Vol. 5, No. 1, pp. 23-37.

[24] Syahputra, R., (2012), "Fuzzy Multi-Objective Approach for the Improvement of Distribution Network Efficiency by Considering DG", IJCSIT, Vol. 4, No. 2, pp. 57-68.

[25] Syahputra, R., Soesanti, I. (2015). "Control of Synchronous Generator in Wind Power Systems Using Neuro-Fuzzy Approach", Proceeding of International Conference on Vocational Education and Electrical Engineering (ICVEE) 2015, UNESA Surabaya, pp. 187-193.

[26] Jamal, A., Suripto, S., Syahputra, R. (2015). Multi-Band Power System Stabilizer Model for Power Flow Optimization in Order to Improve Power System Stability. Journal of Theoretical and Applied Information Technology (JATIT), 80(1), pp. 116-123.

[27] Syahputra, R., Wiyagi, R.O., Sudarisman. (2017). Performance Analysis of a Wind Turbine with Permanent Magnet Synchronous Generator. Journal of Theoretical and Applied Information Technology (JATIT), 95(9), pp. 1950-1957.

[28] Syahputra, R. (2017). Distribution Network Optimization Based on Genetic Algorithm. Jurnal Teknologi, Journal of Electrical Technology UMY (JET-UMY), 1(1), pp. 1-9.

[29] Syahputra, R., Robandi, I., Ashari, M., (2011), "Control of Doubly-Fed Induction Generator in Distributed Generation Units Using Adaptive Neuro-Fuzzy Approach". International Seminar on Applied Technology, Science and Arts (APTECS). 2011; pp. 493-501.

[30] Jamal, A., Syahputra, R. (2016). Heat Exchanger Control Based on Artificial Intelligence Approach. International Journal of Applied Engineering Research (IJAER), 11(16), pp. 9063-9069.

[31] Syahputra, R., Soesanti, I. (2016). An Optimal Tuning of PSS Using AIS Algorithm for Damping Oscillation of Multi-machine Power System. Journal of Theoretical and Applied Information Technology (JATIT), 94(2), pp. 312-326.

[32] Syahputra, R., Soesanti, I. (2016). Power System Stabilizer Model Using Artificial Immune System for Power System Controlling. International Journal of Applied Engineering Research (IJAER), 11(18), pp. 9269-9278.

[33] Syahputra, R., Soesanti, I. (2016). Application of Green Energy for Batik Production Process. Journal of Theoretical and Applied Information Technology (JATIT), 91(2), pp. 249-256.