How neural networks can improve the performance of electrical power systems?

Qinyi Xu

WenZheng College of Suchow University, China

Abstract. As a new technology, artificial neural network is applied in more and more fields. It is not only popular in the computer field, but also in the traditional energy system. Artificial neural network can solve the problem that which traditional methods used in power system are having difficulty about speed, accuracy and efficiency. This paper will introduce the types of artificial neural networks and its application in power system to analyze how artificial neural networks improve the efficiency of power system. Artificial neural networks have been studied since the 1980s with the rise of artificial intelligence and are dedicated to using nonlinear adaptive information processing capabilities to handle information that cannot be processed by traditional methods. Additionally, applicability of artificial neural network to the collection of clean electricity such as wind energy, solar energy, and tidal energy is discussed. And how ANN can help people choose the right location to build power stations under the interference of complex natural environmental factors. Finally, the defects in the current power system and the possible future development direction of artificial neural networks is explained.

Keywords: Artificial Neural Network, Solar Power System, Wind Power System, Tidal Power System, Applications in Power System.

1. Introduction

A power system is a consumer system consisting of a power plant, transmission and transformation lines, power supply and distribution plants, and electricity consumption links, and the basic requirement of a modern power system is to provide consumers with high quality electricity. In the initial power system network, the system network needs to be modified by the power engineer to adjust the input data of the program in order to meet the power demand of the consumers. The design of the power system requires analysis and accounting of the electric load and power levels, regional distribution, composition and its load characteristics for the design period. A power and electricity analysis is performed to justify a reasonable range of power supply for the system. The generation of electricity also requires a large amount of fuel, which requires a study of the regional fuel balance and then calculating the fuel requirements for the power plant. Because of the huge amount of calculations a number of problems arise: for example, the calculation of the solution takes too long to meet the time requirements of the design task, or the task of designing a characteristic with statistical requirements, or a part of the system is not easy to determine: for example, voltage control [1]. For these difficult problems, artificial neural networks offer a possible solution. ANN(artificial neural network) is a powerful pattern recognition technology, so when ANN can be valuable when computers are interact to real life. ANN's research stems from the fact that the human brain is superior to computers in some areas: for example, when processing visual information, one-year-old babies can recognize faces and objects better than the most advanced AI in the world today. And the very small size of the brain means that it dissipates very little power [1]. And when faced with a simple but large computation, the computer shows its strengths, which is why artificial neural networks are studied.

In this study, we show that Artificial neural network computation can replace the traditional programming instruction computation to complete the design of electrical power systems.

2. Types of Artificial Neural Network

Firstly, types of ANN are explained. ANNs are mainly divided into feed-forward networks and feedback networks, where there are two different types of feed-forward networks, single-layer and multi-layer perceptron.

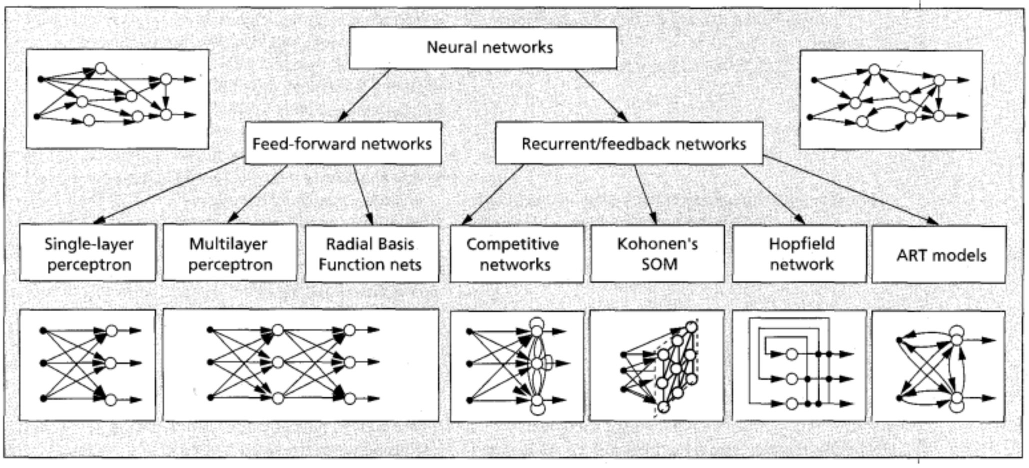

Figure 1. A taxonomy of feed-forward and recurrent/feedback network architectures.[6]

Secondly, the difference between feed-forward networks and feedback networks is that feed-forward networks do not generate loops, while feedback networks generate loops due to the presence of feedback links [6]. Lastly, comparative analysis has been made between the single-layer perceptron and the multi-layer perceptron. The single-layer perceptron was developed by engineers because it can learn to recognize simple patterns and it's function is to determine whether an input belongs to one of the two categories [2]. The reason why this kinds of perceptron is not widely used is because it only produces correct results when training is apparently separable. So to solve this problem, the engineers have developed multi-layer perceptron. The learning rule applicable for multi-layer perceptron is called the 'generalised delta rule'. Its basic theory is to minimize the error of the desired output with the actual output by reversing the error from the output layer to the hidden layer. Because of this advantage, multi-layer perceptron is the most widely used ANN, which is used for identification, control, classification and other operations [2]. In general, engineering applications are generally divided into five steps:

-Step 1: input selection-feature extraction;
-Step 2: training data;
-Step 3: selecting ANN based on input size, hidden neurons, hidden layers, etc.;
-Step 4: training ANN;
-Step 5: final testing [2].

Training is a noteworthy part of the above steps, as all training is done to ensure that ANN is learning and not memorizing. Therefore, the criterion for judging whether ANN has been trained effectively is whether ANN can make the same error response to the training mode and the test mode [2] .

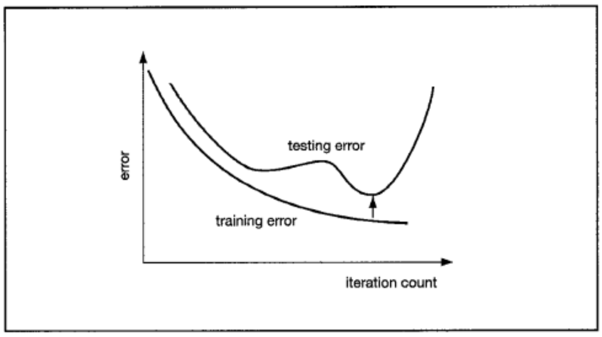

Figure 2.variation of error with number of iterations [2]

As the picture shows, the training error decreases according to the number of iterations, and the test error decreases and then increases with the number of iterations and then decreases again and then increases. Based on the picture results, it can be seen that the best learning result is around the minimum value indicated by the arrow. Hopfield neural network is a recursive network belonging to a feedback system that can have the ability to cope with all possible situations like a nonlinear system, one of the special cases facing a stable system. In this system, when a fixed point is input into the dynamic system, an identical point is output, and by keeping this state, the same point is output continuously, which means that the Hopfield network remembers these points. In contrast to the "test error" learning method mentioned earlier, the learning method here is called "route" learning[2]. Hopfield neural network is limited to learning the internal representation of the training pattern because of the lack of implicit neurons, so to improve the performance of ANN, it is also necessary to connect Hopfield network with neurons.

3. Applications in power system

3.1. Application in wind power system

The application of ANN in power systems mainly implements some prediction, detection, classification, and control tasks. For example, in wind power systems, ANN can predict wind speed and wind power. In general, wind prediction is done by physical means: numerical weather forecasting. However, ANN is more accurate in predicting short-term wind speed than physical means in long-term wind speed prediction [4]. The prediction of wind speed is relevant to the decisions made by energy suppliers, wind plant owners and maintenance teams when planning. Ekonomou et al. designed an ANN model to calculate the optimal number of wind turbines for a wind farm by inputting factors such as topography, wind speed, wind direction, and wind turbine cost[6]. Similarly, ANN can be used to detect faults not only in predictive computing, but also by pattern recognition of complex nonlinear relationships to determine whether certain signals are faulty or not. ANN models are designed to evaluate specific parts of complex mechanical instruments, for example

In wind turbines, different detection models are set up to detect gearboxes, generators, electronics, electrical controls, etc. This can effectively reduce the probability of detection false alarms and improve the efficiency of maintenance [4]. Due to its excellent stability, ANN is also used in control tasks. While ensuring the normal and safe operation of wind turbines in changing and unstable wind speeds, the speed and torque of the motors are controlled to achieve maximum power at output and increase productivity [4].

3.2. Application in solar energy system

In addition to wind power, ANN can also help improve systems in photovoltaic solar energy. Like wind power systems, solar power is also affected by the weather, even more so than wind power. Because the intensity of solar radiation determines the amount of electricity produced by a solar system, it is especially important for power plants to be able to accurately predict the weather [5]. The radial basis functions (RBF) model is currently designed by ChangSong Chen et al., and the RBF model is divided into input, hidden, and output layers [7]. Solar power generation is estimated by entering daily solar irradiance, minimum temperature, maximum temperature and maximum temperature. With this 24-hour solar power generation forecast, the optimal performance of the system can be simulated [7]. The limitation of solar power generation is the low distribution density of solar irradiance, which requires a large area to build solar power stations. The ANN model is used to simulate and select a reasonable location to build a power station. At the same time, solar energy takes a short time to obtain electricity, and the ANN model to predict the intensity of solar radiation can make the power generation system to complete the power generation task most efficiently.

3.3. Application in tidal energy system

To date, ANN has helped to improve the efficiency of wind and solar power systems. Tidal energy from the ocean is also a huge, clean energy source, and ANN is being developed for tidal energy applications. The magnitude of tidal energy depends on the variability of waves, and to improve the utilization of tidal energy depends more on ANN assessment and prediction than wind and solar energy [8]. A. Castroa et al. used ANN models to predict wave energy in offshore areas and compared them with SWAN (simulating waves nearshore) to verify the reliability of ANN models [8]. The ANN model is trained by taking the water depth, wave height, wave peak period and average wave direction as input values and the wave power value at the prediction point as output variables. The SWAN model is used to calculate the wave power near the coast by bringing the data measured by the buoy (a floating marker) into the equation.

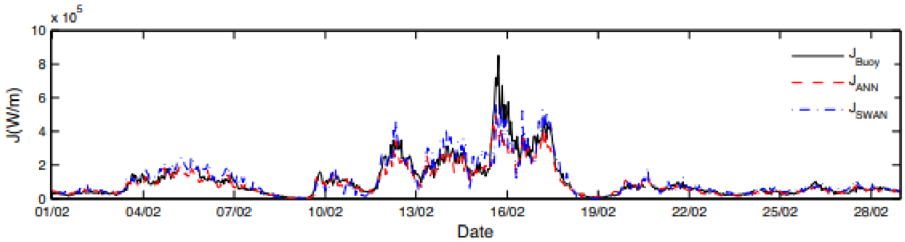

Figure 3.Nearshore wave power obtained from ANN model and SWAN model [8].

Figure 3 compares the results of the two models and it can be seen that the results obtained by the ANN model are superior to those of the SWAN model except at the highest peak, while both models are inaccurate under the interference of factors such as storms. The two models exemplify consistency, which indicates that the training results of the ANN model are correct [8] . This project demonstrates that ANN models can be used instead of physical methods to predict the wave power near the coast and reduce the prediction cost. This will help to select a reasonable geographical location to build power plants and improve the power generation efficiency of tidal power plants.

The use of wind , solar, and tidal power does not produce pollution and the electricity produced is clean energy, but these systems are severely limited by the weather conditions, and weather and climate determine the efficiency of power generation. ANN is very beneficial to these systems because it predicts climate change in the short term through calculations and produces more accurate results than those obtained by traditional methods. This is beneficial for clean energy systems to improve the efficiency of electricity production.

4. Limitation of ANN

ANNs can indeed perform some prediction tasks quickly and with a certain degree of accuracy. However, based on the existing documents, ANN can only be applied in short-term prediction, and in long-time prediction tasks, there are non-negligible errors due to the amount of computation [4]. In long-term forecasting tasks, ANN is even less accurate than physical means [4]. The cost of computation should also be factored into the assessment of ANN performance. Although short-term prediction ANNs can be computed very accurately, the huge amount of computation will also bring about energy consumption. If a lot of electrical energy is consumed to complete the computational task, the efficiency will be greatly reduced. Complex instruments have different ANN models corresponding to different detection tasks, and after the reduced number of instrument false positives, there will still be false positives occurring between different ANNs.This does not have a completely positive effect on the maintenance of complex machinery and can even prolong the overhaul time.

5. Conclusion and Future Work

Artificial neural networks have been used in a large number of control areas, and power systems as a field that requires detection, prediction, and control can fully exploit the value of ANN. In this paper, I introduce the types of artificial neural networks and the applications of artificial neural networks in power systems. As well as with the strengthening of environmental awareness, clean energy systems are getting more and more attention, and the application of ANN greatly improves the efficiency of clean power systems in producing electricity. Nowadays, power systems have changed from traditional programming to ANN for testing and design, which not only improves efficiency but also saves cost. In addition, traditional power systems need to manually update environmental data when subjected to changes in environmental factors to adjust parameters and ensure that the power output is at its maximum. However, there is a non-negligible delay in this approach. Manual adjustments inevitably miss the optimal time for power generation, such as missing the maximum wind value when using wind power generation and the moment of the strongest solar radiation when solar power is generated. Using ANN it is possible to predict these times and avoid missing the best moments of electricity production. As a result, traditional power systems have been greatly optimized, but ANNs still have some shortcomings. In the case of clean energy such as wind,solar energy, and tidal energy still receive environmental and weather effects, resulting in inaccurate test results. In the near future, by improving the accuracy of the detection, ANN can be maturely used in clean energy.

References

[1] Aggarwal, Reference, & Song, Y. (1997). Artificial neural networks in power systems. Part 1: General introduction to neural computing. Power Engineering Journal, 11(3), 129–134. doi:10.1049/pe:19970306

[2] Aggarwal, Reference, & Yonghua Song. (1998). Artificial neural networks in power systems. Part 2: Types of artificial neural networks. Power Engineering Journal, 12(1), 41–47. doi:10.1049/pe:19980110

[3] Aggarwal, Reference, & Yonghua Song. (1998). Artificial neural networks in power systems. Part 3: Examples of applications in power systems. Power Engineering Journal, 12(6), 279–287. doi:10.1049/pe:19980609

[4] Marugán, A. P., Márquez, F. P. G., Perez, J. M. P., & Ruiz-Hernández, D. (2018). A survey of artificial neural network in wind energy systems. Applied Energy, 228, 1822–1836. doi:10.1016/j.apenergy.2018.07.084

[5] Karabacak, K., & Cetin, N. (2014). Artificial neural networks for controlling wind–PV power systems: A review. Renewable and Sustainable Energy Reviews, 29, 804–827. doi:10.1016/j.rser.2013.08.070

[6] Ekonomou, L., Lazarou, S., Chatzarakis, G. E., & Vita, V. (2012). Estimation of wind turbines optimal number and produced power in a wind farm using an artificial neural network model. Simulation Modelling Practice and Theory, 21(1), 21–25. doi:10.1016/j.simpat.2011.09.009

[7] Changsong Chen,Shanxu Duan,Tao Cai,Bangyin Liu(2011). Online 24-h solar power forecasting based on weather type classification using artificial neural network .Solar Energy Volume 85, Issue 11, November 2011. doi.org/10.1016/j.solener.2011.08.027

[8] Castro, A., Carballo, R., Iglesias, G., & Rabuñal, J. R. (2014). Performance of artificial neural networks in nearshore wave power prediction. Applied Soft Computing, 23, 194–201. doi:10.1016/j.asoc.2014.06.031