THE USING OF ARTIFICIAL INTELLIGENCE IN THE RELIABILITY INDICES OPTIMISATION OF ELECTRICAL EQUIPMENT

C. PANCU, C. NEMEŞ, A. BARABOI, M. ADAM

"Gh. Asachi", Technical University of Iaşi, Faculty of Electrical Engineering

Abstract: In this paper a system based on artificial intelligence is proposed in order to optimisation the reliability indices of the electrical equipment. Using this method it obtains the distribution function type of the various failure of electrical equipment. This approach is much more efficient than the classic method if it knows a historical behaviour of analysed equipment..

Keywords: artificial intelligence, reliablity, electrical equipment.

1. INTRODUCTION

The maintenance has a great influence to the elements availability, but it must to exist equilibrium between the reliability and maintenance costs. It must to exist an economical optimum between the expenses of preventive and corrective maintenance, this thing being established after the optimisation of reliability indices.

Electric power systems are examples of systems where a very high degree of reliability is expected. Reliability indices are therefore an important aspect of system design and operation. It is widely recognized now that the proper measures of system reliability can only be described in the context of probability. Many simple power system problems can be analyzed with the help of elementary probability theory.

2. RELIABILITY ANALYSIS USING THE DISTRIBUTION FUNCTIONS

From a reliability point of view, a system is characterized by multiple modes of failure, and the analyses of various failure modes is a principal technique currently applied in power system studies. Each of the potential failure modes can be analysed in terms of component behaviour [1], which, in reliability terms, can be connected in series or parallel or combination.

If the experimental data are available, a histogram representing variability of the experimental information can be constructed. From the histogram, we will select the probability distribution function and will obtain certain characteristic measures of the experimental data (modelled as a random variable), in particular, its mean value (or average) and a measure of dispersion.

Any function possessing the proprieties that their integration is one, can be used as a probability distribution function. In case of a continuous random variable, the probability distribution function is usually assumed to be a certain form like normal distribution, exponential distribution, lognormal distribution, Gamma distribution, Weibull distribution, Table 1, [2].

Table 1 Distribution functions type

Distribution type	Definition interval	Distribution function $f(t)$	Reliability $R(t)$	Average	Dispersion
Rectangle	$a \le t \le b$	$\frac{1}{b-a}$	$\frac{b-t}{b-a}$	$\frac{a-b}{2}$	$\frac{(b-a)^2}{12}$
Normal	$0 \le t < \infty$ $0 < \mu < \infty$ $\sigma > 0$	$\frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(t-\mu)^2}{2\sigma^2}\right)$	$\frac{1}{\sigma\sqrt{2\pi}} \int_t^\infty \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) dx$	μ	σ^2
Lognorm	$0 \le t < \infty$ $-\infty < \mu < \infty$ $\sigma > 0$	$\frac{1}{\sigma t\sqrt{2\pi}} \exp\left(-\frac{(\log t-\mu)^2}{2\sigma^2}\right)$	$\frac{1}{\sigma\sqrt{2\pi}} \int_{\log t}^\infty \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) dx$	$\exp\left(\mu - \frac{1}{2}\sigma^2\right)$	$\exp(2\mu-\sigma^2)\cdot$ $[\exp(\sigma^2)-1]$
Exponential	$t \ge 0$ $\lambda \ge 0$	$\lambda e^{-\lambda t}$	$\exp(-\lambda t)$	$1/\lambda$	$1/\lambda^2$
Rayleigh	$t \ge 0$	$kt \exp\left(-\frac{kt^2}{2}\right)$	$\exp\left(-\frac{kt^2}{2}\right)$	$\sqrt{\frac{\pi}{2k}}$	$\frac{2}{k}\left(1-\frac{\pi}{4}\right)$
Erlangian	$t \ge 0$ $\lambda > 0$	$\lambda^2 t \exp(-\lambda t)$	$(1+\lambda t)\exp(-\lambda t)$	$2/\lambda$	$2/\lambda^2$
Weibull	$t \ge 0$	$\frac{\beta}{\eta^\beta} t^{\beta-1} \exp\left[-\left(\frac{t}{\eta}\right)^\beta\right]$	$\exp\left[-\left(\frac{t}{\eta}\right)^\beta\right]$	$\eta\Gamma\left(\frac{1}{\beta}+1\right)$	$\eta^2\left[\Gamma\left(\frac{2}{\beta}+1\right)\right.$ $\left.-\Gamma^2\left(\frac{1}{\beta}+1\right)\right]$
Gamma	$t \ge 0$	$\frac{t^{\beta-1}}{\eta\Gamma(\beta)} \exp(-t/\eta^\beta)$	$\frac{1}{\eta^{2\beta}\Gamma(\beta)} \int_t^\infty x^{\beta-1} e^{-x/\eta^\beta} dx$ *sau* $\exp\left(-\frac{t}{\eta^\beta}\right) \sum_{j=0}^{\beta-1} \left(\frac{t}{\eta^\beta}\right)^j \frac{1}{\Gamma(j+1)}$	$\beta\eta^\beta$	$\beta\eta^{2\beta}$
Extreme values – Minimum	$t > \tau$ $\beta > 0$	$\frac{1}{\beta} \exp\left[\frac{t-\tau}{\beta}\left(-\exp\frac{t-\tau}{\beta}\right)\right]$	$\exp\left[-\exp\left(\frac{t-\tau}{\beta}\right)\right]$	- for minimum	$1.6461\beta^2$
Extreme values – Maximum		$\frac{1}{\beta} \exp\left[-\frac{t-\tau}{\beta}\left(-\exp\left(-\frac{t-\tau}{\beta}\right)\right)\right]$	$\exp\left[-\exp\left(-\frac{t-\tau}{\beta}\right)\right]$	+ for maximum	

Knowledge more exactly of the distribution function type leads to determination more precisely of their parameters, in specially the mean time between failure (MTBF), value that represents one of the most important reliability indices

Naturally, we would like to choose the distribution and determine the values of its parameters based on our experience, taking into account the available statistical data. These data will be in the form of a sample of observed values of variable, these may be obtained from records of equipment operation. An alternative to out experience is the artificial intelligence which is a powerful tool for the solving of approximation problems.

3. ARTIFICIAL NEURAL NETOWRK

Many of the applications solved with the help of artificial intelligence in the approximation problems, how it is and the reliability indicators optimisation of the electrical equipment uses the artificial neural networks (ANN) of

Multilayer Perceptron type. This type of ANN is characterised through a relative simple architecture (an input layer, an output layer and one or more hidden layers, between those existing complete or partial connections) and through performance learning algorithms (back propagation with moment and adaptive learning rate), [3].

The proposed ANN architecture (Fig. 1) has the three layers complete connected; the input layer receives distribution curve, represented through 12 points, while output layer provides the estimation of distribution function type, that have been indexed from 1 to 6.

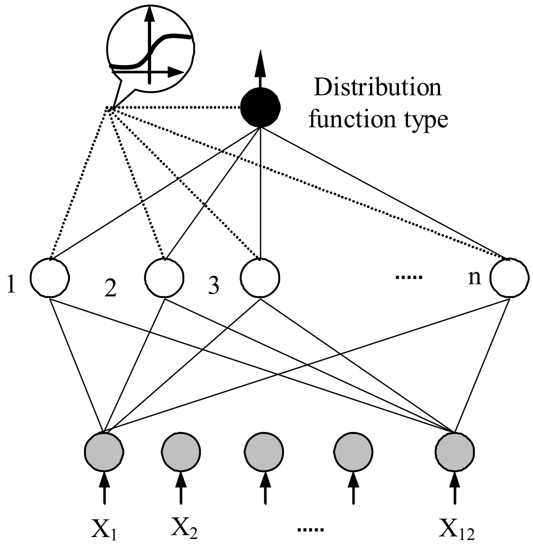

Fig. 1 The architecture of artificial neural network

Each neurone has the following behaviour: for the neurones from the input layer, their outputs are the received signals without any processing. For the neurone *i* from the hidden or output layer, its output can be written in the following shape:

$$v_i = g(\sum_j w_{ij} v_j) \quad (1)$$

$$g(x) = \frac{1}{1+e^{-x}} \quad (2)$$

where v_j, w_{ij} şi g(x) are the output of the neurone *j*, the weight between neurone *i* and *j* and signoid function respectively. The using of the function needs to scale the training dates in the range 0.15÷0.85, to avoid the saturation zones of the logistic signoid function, [4], [5].

The used learning algorithm is the backpropagation with batch method. The convergence criterion is defined by mean square error between desired output and actual outputs. The training data, which satisfy the other convergence criterion, are not used in the weight update; some training data, which can be easily learned, are excluded from the weight update sequence. This criterion is defined by the absolute maximum error between desired and actual output.

4. NUMERICAL RESULTS

For the ANN configuration, 382 input-output patterns has been used, 370 from these being used in the learning step, while the rest of 12, that haven't been used anterior, have realised the test set.

It was analysed different topologies of the ANN (with different number of nodes on the hidden layer), the optimum topology being with 36 neurones on the hidden layer. For this topology Fig. 2 and Fig.3 shows the errors on test set and real and estimated distribution function type, respectively.

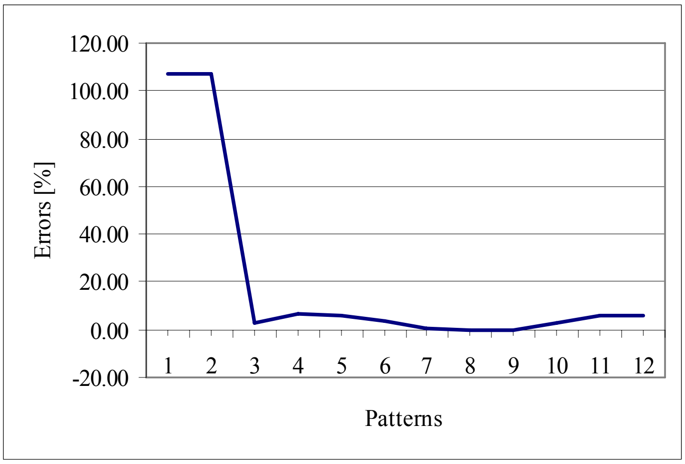

Fig. 2 Errors on test data

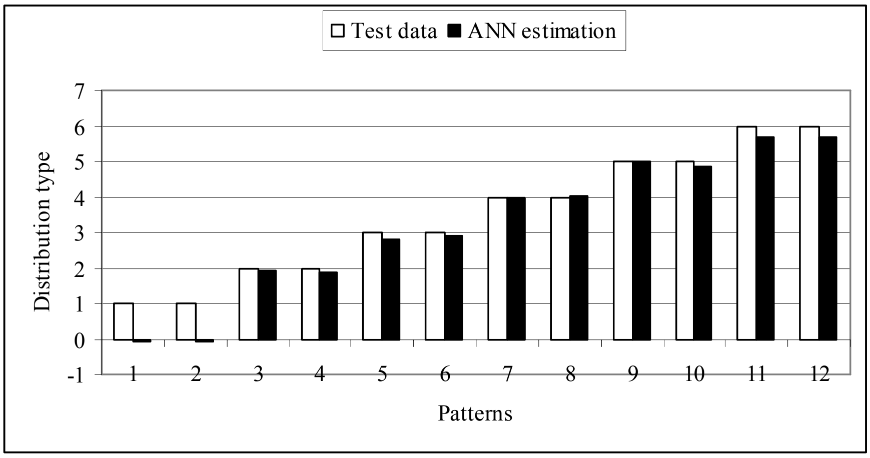

Fig. 3 Real and estimated distribution function type

It can observes that the evaluation given by the ANN is very closing of real values., the relative error being of 3,46%, excepting the estimation fort the distribution function type number 1 for which the error is 107%.

To solve this problem the database has been reorganised. In this case the patterns are random arranged and the ANN topology is changed. Thus, the new ANN architecture contains 48 neurons on hidden layer and 100000 iterations was necessary in the learning step.

Fig .4 and Fig. 5 shows the new errors and the ANN estimation of distribution function type of electrical equipment, respectively.

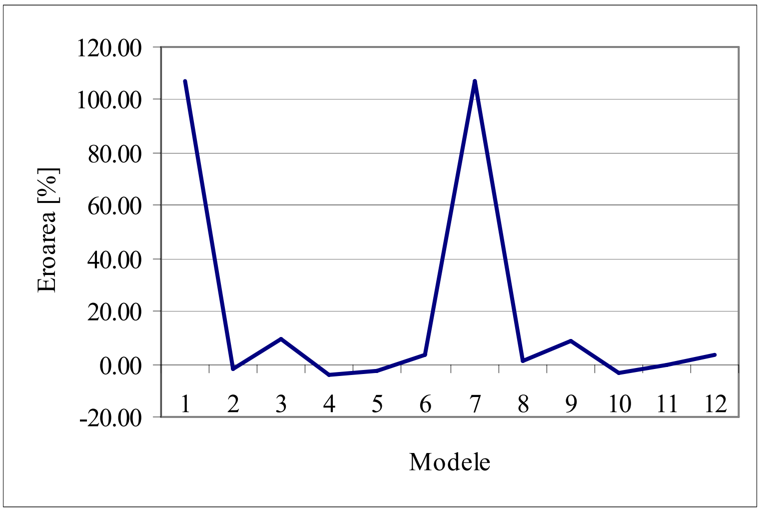

Fig. 4 Errors on the new test data

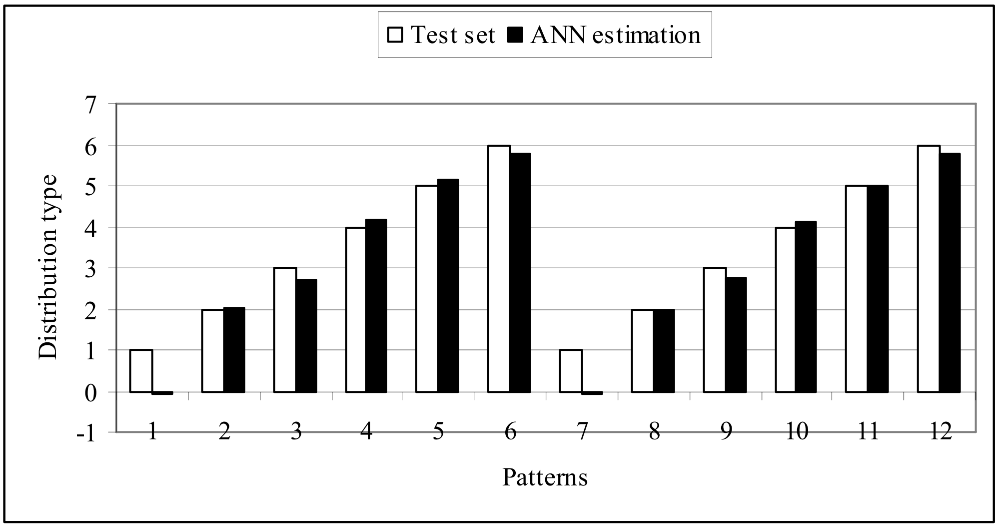

Fig. 5 Real and estimated distribution function type in new case

It consists that the ANN has the same good results, but the problem with the estimation of distribution function type number 1 persists. In this case it could try to use a new data set specific to this type of distribution Another possibility is to realise an ANN specific for this type of distribution function.

5. CONCLUSIONS

Electric power systems are examples of systems where a very high degree of reliability is expected. Reliability indices are therefore an important aspect of system design and operation. Knowledge more exactly of the distribution function type leads to determination more precisely of their parameters, in specially the mean time between failures (MTBF), value that represents one of the most important reliability indices

Many of the applications solved with the help of artificial intelligence in the approximation problems, how it is and the reliability indicators optimisation of the electrical equipment uses the artificial neural networks (ANN) of Multilayer Perceptron type.

It was analysed different topologies of the ANN (with different number of nodes on the hidden layer). It consists a good performance in the estimation of distribution function type, relative error being 3.46%, exception doing the evaluation of distribution function type number 1. In order to solves this problem it could try to use a new data set specific to this type of distribution Another possibility is to realise an ANN specific for this type of distribution function.

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