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DjalalEddine KHODJA
Boukhemis Chetate

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DJ.Khodja*, B.Chetate**
(*) *Faculty of Sciences and Engineering Sciences, University Muhamed Boudiaf of M'sila*
B.P N° 116 Ichebilia (28000), Algeria, Tel/Fax: +213 35 55 18 36,
E-mail: djalal_ed@yahoo.fr
(**) *Research laboratory on the Electrification of industrial enterprises,University of Boumerdès, Avenue de l'indépendence, Boumerdès (35000), Algeria, Tel/fax : 213 24 81 70 50,*
Email : bchetate@umbb.dz

Abstract**--** In the article is told about the device of automatic diagnostic of asynchronous motor. This diagnostic system is based on Artificial Neural Network (ANN), in order to find the different defects by classification. The machine health identification process is mainly based on recognition and comparison of real-time captured standard signature as stator current, rotation speed of machine. The features extraction of the instantaneous signals will then input to an Artificial Neural Networks (ANN) for recognition and identification. The output of the neural network was trained to generate a healthy index that indicates the machine health condition. In this work, the entries used in the neural network were the various types of signals: the instantaneous values and the effective values (root mean square) of the machine parameters.

Key words: Automatic Diagnostic, failures, artificial neural Network (ANN), values effective (root mean square).

I. INTRODUCTION

The necessity of the asynchronous drive working exact model is obvious to be considered. Moreover, this mathematical model (further – working model) should take into account changes occurring in a drive as a result of aging and influence of an environment, which change its parameters as against nowadays existing models where this factor is not paid attention.

Up to our days one parameter for definition of a failure (stator current) has been used only in diagnostic systems therefore there were mistakes because of the incomplete information, and it is more probable in the frequency way case of failure detection [1]. It was marked in works [1,2,3] (Boek, Filippetti and Nandi) of asynchronous drive diagnostics, which was carried out under the fuzzy- logic and expert system help that the further development of the given direction is inconvenient.

It is necessary to note that artificial neuron networks (ANN) are most applicable in the diagnosing due to the unique advantages: Signals classification ability; Ability to find out failure quickly; Presence of the high-speed program; Insensitivity to perturbation influence and parameters changing; ANN has ability to generalize results of the previous cases, which has been acquired during network training. We came to the conclusion that it is necessary to develop new diagnostic failure automatic system architecture of an asynchronous machine on the ANN base and to proceed using three basic information signals for failure definition with high degree of reliability

DJ.Khodja is with Faculty of Sciences and Engineering Sciences, University Muhamed Boudiaf of M'sila. B.P N° 116 Ichebilia (28000), Algeria, Tel/Fax: +213 35 55 18 36,E-mail: djalal_ed@yahoo.fr
B.Chetate is with Research laboratory on the Electrification of industrial enterprises,University of Boumerdès, Avenue de l'indépendence, Boumerdès (35000), Algeria, Tel/fax : 213 24 81 70 50,
Email : bchetate@umbb.dz

II. CRITICAL ANALYSIS OF THE EXISTING METHODS OF DIAGNOSIS

The performances of the diagnostics methods based on modelling very strongly depend on the use of the model, which obtaining requires a strong effort. For the estimate of the dynamic model of a process, it must be linearized around a point of operation [2]. However the external diagnostics methods, they do not require the knowledge of the mathematical model of the process for detection of a failure, but they require the representative data to learn them. These data are obtained starting from the human expertise based on the experience feedback. These methods are simple to apply or realize but the task of calculation depends many on the facts of the case to study. Moreover, it is noticed that the development of a diagnostic system based on the technique of the expert systems, requires a strong effort (for its design and its realization). On another side, fuzzy logic can be applied to replace the expert systems by linguistic rules, when the problem to be solved is too complex. On the basis of the consideration that the principal character of the diagnostic system is to constitute a catalogue defect-symptoms, the neural networks appear very interesting for the installation of the diagnostic procedure [3,4,5]. In addition, the neural networks have characteristics allowing the resolution of complex problems, namely:

- Capacity of classification of the signatures and the forms, which corresponds well to the case studied in this work;
- ANN can learn from rules and from examples (defects) i.e. that one can work out with a ANN a nonparametric model which can describe all the states of the machine (normal and abnormal operations) and, this model can

generalize this identification with other examples which were not learned.

• The capacity storage of the examples, by distributing them on the weights of connection of the structure, such as the loss of a neuron or a connection, does not influence the memorizing of the examples.

In the light of the critical analysis of the methods of diagnosis, it is clear that the internal methods (which base on physical or functional modelling process) cannot profit from exact models for the nonlinear systems (such as the asynchronous machine). Indeed, this type of methods can be applied successfully only to the linear systems or the systems whose models are perfectly known. With regard to the external methods, the method adopted in this work is the technique of the networks of neurons.

III. DEVELOPMENT OF ANN MODULE FOR FAULT IDENTIFICATION

Considered neuron networks were multilayer, trained by back-propagation algorithm. Actually, several parametric studies were carried out for these two neural networks for optics to choose the most suitable network and most powerful for the implementation of the diagnostic system of the failures; there were in total four principal studies [4,5,6]:

- Choice of the variables of entries;
- Construction of training base;
- Construction of the block of ANN;

A. Choice of the variables of entry of ANN (Parameters Representative of Defects)

The variables used are the current stator, the rotation speed and as well as the supply voltage, because they are the parameters most representative of the defects (their paces vary considerably in the event of application of a defect) and, in addition, their measurement is accessible [5]. In fact, in what follows, we will study the electric and mechanical behavior engine when this last is subjected to stator imbalances, this is carried out in the case of defects of supply voltage during one operation life of the asynchronous motor, this one being supposed initially under stationary operation (established mode).

Using software of simulation MATLAB, we obtained the curves representing the various abnormal operations (defects) from the phase asynchronous motor.

The simulation results are presented on the figures.1 and 2; the latter represent the curves of evolution of the various parameters (speed value and the effective value of the stator current).

During the abnormal modes, the electric quantities are characterized comparing to the normal mode by an abrupt variation at the time of appearance of the defect, in our case the defect east creates at moment 1 second (the engine is in established mode).

In addition, the defects (cut, imbalance) of the supply voltage also influence the mechanical behaviors of the engine; this influence is characterized by a fall of the value speed according to the type of defect.

By analyzing the modes of the defects for the various parameters, we notice that the evolution of the stator current in the various cases of defects is characterized by a remarkable variation compared to the state normal; in other words, these two sizes represent the state of the asynchronous machine better.

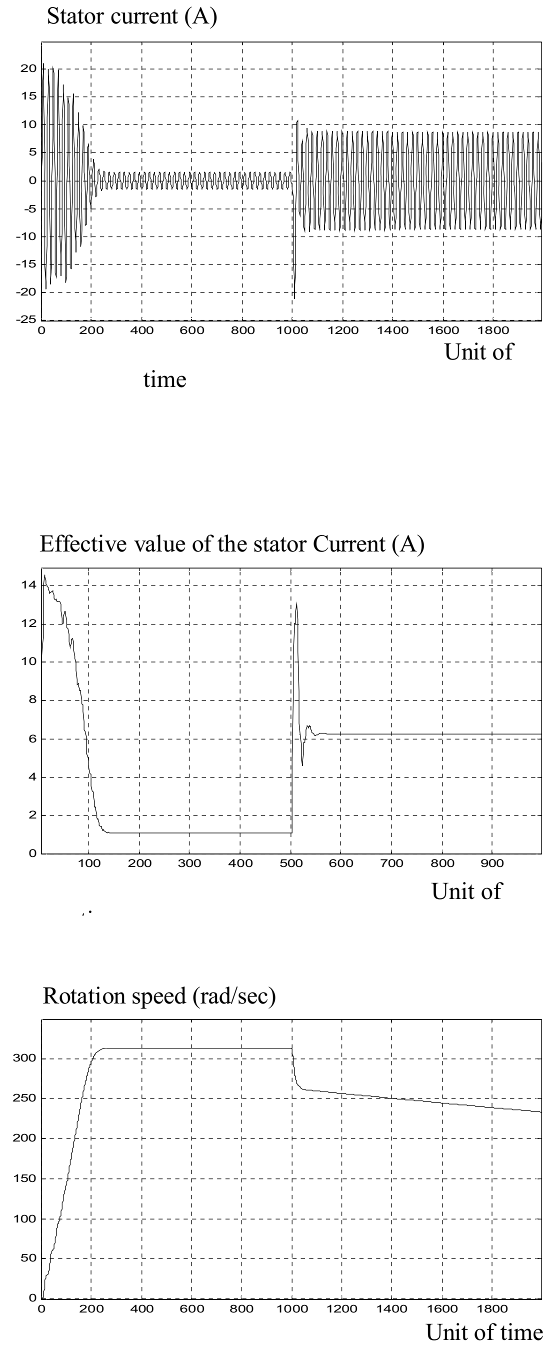

Figure 1 Defect of single-phase cut of tension

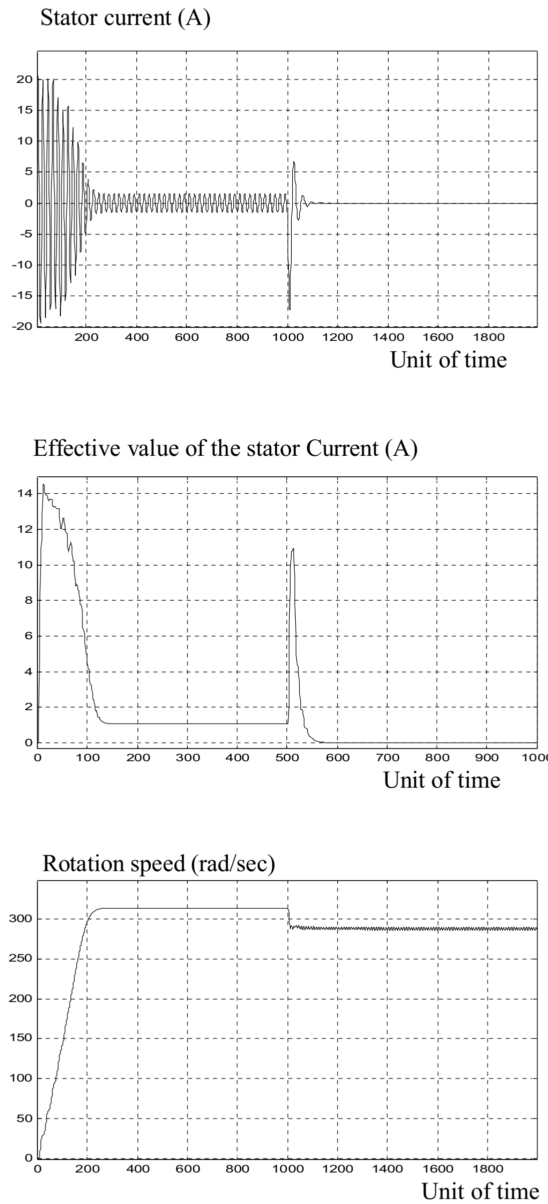

Figure 2 Defect cut three-phase of the tension

B. Construction of training base

To build a nonparametric model (ANN) describing the behavior of the electromechanical system (normal and abnormal operations) we must build a very rich data base, which represents a quantity of sufficient information on the defects in various operations and various forms (information on a defect must be extract in a redundant way). To carry out the latter we have proceed as follows:

-Each defect was simulated in normal circumstances.

- In mode in load, with various disturbances (25%, 50%, 75% and 100% of the nominal load) it was considered for all defects.

- The pretreatment carried out on the acquired signal, makes it possible to take the action pursuant of the values provided by the sampling of this signal.

- The extraction of the data (sampled values) can be considered by applying an operator of delay for each variable. The taking into account of this last is obtained simply by shifting the extraction of one or several moments (as from the first moment of sampling); i.e. each pattern of a defect must be extract (in a redundant way) at moments shifted one period from the signal [6,7].

From these sampled and disturbed signals, the files including values of the three variables (stator currents, phase voltages and speed value) were established; those enable us to establish the bases of trainings of the two networks to be studied.

To pass at the stage of classification is used here 7 types of operation including normal operation. In addition, a total of 890 input patters corresponding to different faults, as describing in table.I, are used. The healthy state 140 patterns, in which 15 patterns represent a motor start and others 125 patterns, represent various load conditions ranging from no load to full load at selected increments of load. Each defect 125 patterns were selected with different loads. The defects are:

TABLE I
NUMBER OF TRAINING PATTERN PER FAULT

Types of defect	Number of patterns
Healthy State	140
Single-phase cut	125
Two-phase cut	125
Three-phase cut	125
Unbalance single-phase current	125
Two-phase imbalance	125
Unbalance three-phase	125
Total	890

C. Construction of the ANN block

The neural networks which we all simulated are of the multi-layer networks which use the algorithm of retro propagation for their trainings.

For the implementation of ANN block in the automatic system of diagnosis, we propose to study two neural networks. So that then, after the phase of test and the comparison between the two networks, one can choose among them that which are most suitable and most powerful to achieve the spot of the diagnosis. The stages of construction and validation of the neural networks are divided into three phases:

1) Choice of the entries of the networks: The three parameters (the stator current, the supply voltage and the rotation speed) were selected, because they contain characteristic variations on their paces and they are appreciably affected, by the change of the operation of the electromechanical system.

However, these parameters inputs were utilized for the neural network. Sensing of these parameters could be achieved as rms values or as instantaneous values. Based on a combination of these possibilities, two different architectures are studied on the inputs used:

- Method1: instantaneous values of current and rotation speed;

- Method 2: rms values of phase currents, phase voltages and speed rotation value.

Method1: (Instantaneous values)
The variables selected will make it possible to identify the entries of each network; the first network studied has 20 entries on the input layer which are the instantaneous values of the stator current and the rotation speed (see figure.3).

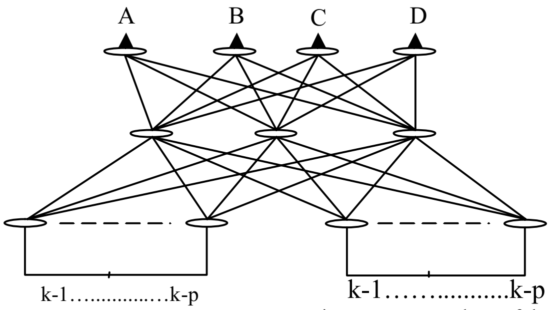

Figure 3 Structure of the network using the instantaneous values

Method2: **(rms values)**
With regard to the second network has 7 entries, they are the rotation speed and the effective values (root mean square) of the three measured stator currents, those of the supply voltages (see figure.4).

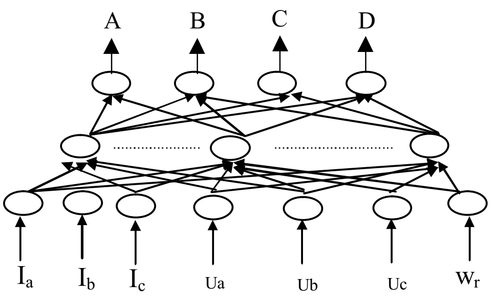

Figure.4 Structure of the network using the effective values (root mean square values)

2) Choice of the output of the network: We have to decide to associate each class a code; and during detection of a defect, the network must indicate an unspecified binary number (for example 0001) to its output, which corresponds to this defect (defect of single-phase cut) i.e. each output of the network must have only one value 1 or 0.
The defects are represented on table 1; with their associated symbols and their codes. The number of output for each network is equal to 4 [5] (see table.II)..

TABLE II
CLASSIFICATION OF THE TYPES OF DEFECTS

Category	Types of defect	Code A B C D
1	Healthy State	0 0 0 0
2	Single-phase cut	0 0 0 1
3	Two-phase cut	0 0 1 0
4	Three-phase cut	0 0 1 1
5	Unbalance single-phase current	0 1 0 0
6	Two-phase imbalance	0 1 0 1
7	Unbalance three-phase	0 1 1 0

3) Test results of the selected networks: We can describe this stage for the two networks in the following way, we carried out a machine learning using MATLAB until where we obtain the quadratic error smallest. For the first network we have obtained the smallest error after 41 iterations; and for the second after 56 iterations; when this stage is carried out, we fixed the two networks (see table III and IV).

TABLE III
VARIOUS TEST OF TRAINING OF ANN

Neuron number	Average quadratic error	Number of epochs
RNA N1	8.35552 e-18	41
RNA N2	3.57362 e-17	56

4) *Choice of the general architecture of the two studied networks:* For the choice of the general architecture of the neural network studied; we considered a step of sampling (0.002) at the time of the phase of the acquisition of the data.

According to the results obtained, we notice that the average quadratic values of studied network (according to step of sampling) are very close to zero; what wants to say that architecture reaches its best performance in the phase of training [5].

TABLE IV
VARIOUS TEST OF TRAINING OF ANN

Neuron number	Input layer	hidden layers	output layer
RNA N1	20	10 – 4	4
RNA N2	7	12 – 7	4

IV. TESTS OF THE ANN ON THE NEW EXAMPLES

Once that the two networks of neurons are built and that their training reached satisfactory performances, we pass at the stage of comparison between examples at the entry of the network. In fact, these examples belong to two data bases, the first being 0.

With regard to the test, the two networks on the examples which were not learned in the phase from training (new examples) their results are presented in the tables below.

TABLE V

Results of simulation (test) of the first ANN (single-phase cut for various disturbances)

Exits Of the RNA	NOMINAL LOAD IN %				
	90 %	80 %	60 %	40 %	20 %
1	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.34 e-11	2.322 e-13	1.299 e-13	3.185 e-13	8.134 e-13
3	6.383 e-23	1.975 e-16	1.379 e-14	6.279 e-16	2.011 e-17
4	6.974 e-10	4.104 e-10	3.085 e-10	3.374 e-10	3.781 e-10

TABLE VI

Results of simulation (test) of the second ANN (single-phase cut for various disturbances)

Exits Of the RNA	NOMINAL LOAD IN %				
	90 %	80 %	60 %	40 %	20 %
1	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.443 e-13	1.337 e-13	9.642 e-14	1.183 e-13	1.351 e-13
3	3.913 e-10	2.674 e-10	1.744 e-10	2.33 e-10	2.185 e-10
4	5.896 e-12	5.869 e-12	6.944 e-12	6.017 e-12	5.884 e-12

The examples tested represent one of the defects selected before, but this time, this last is simulated for other operation (i.e. other levels of disturbance which is different from those which were considered in the base of training).
In these tables the exits of the two networks with various operations are presented. Indeed, according to the results we note that the two networks are powerful; then the choice of the type of signature depend of the nature of the defects studied; but in the second method we can use the minimum of entries and the maximum of parameters (i.e each time we increase the number of parameters, we obtain a efficacy diagnosis)[4].

V. LOCALISATION OF THE FAILURES

When the system of detection (ANN) detects a defect, the stage comes from the localization of this defect, by giving its type, its cause, its place of appearance and if possible the remedies to eliminate it (see figure.5).

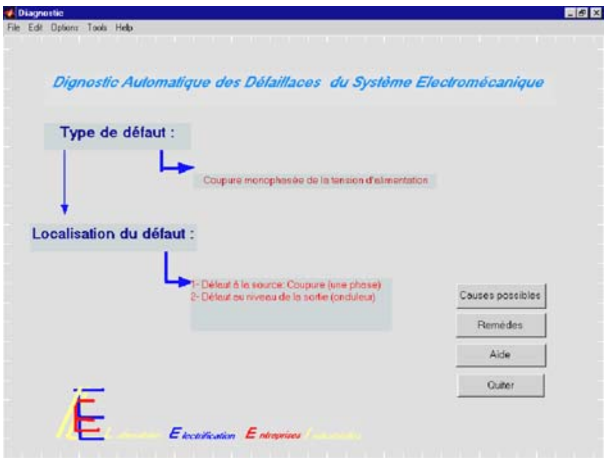

Figure 5 Maintenance protocol delivered by module of interpretation of information

All these stages are carried out by the computerized decision-making system, which interprets codes (ABCD) given by the exit of the network of neurons. Before these codes are interpreted, we must very accesses round the output of the ANN to the zero values and we facilitate the task of interpretation to the computerized decision-making system. Consequently the methodology retained (see figure.6) in this phase is as follows: when the system of diagnostic receives at its entry an example, the neural network classifies this example, by giving its corresponding output, then the latter is interpreted like a data representing a normal operation, if all the exits of the network are smaller than 0.5 (i.e. nearer to zero).

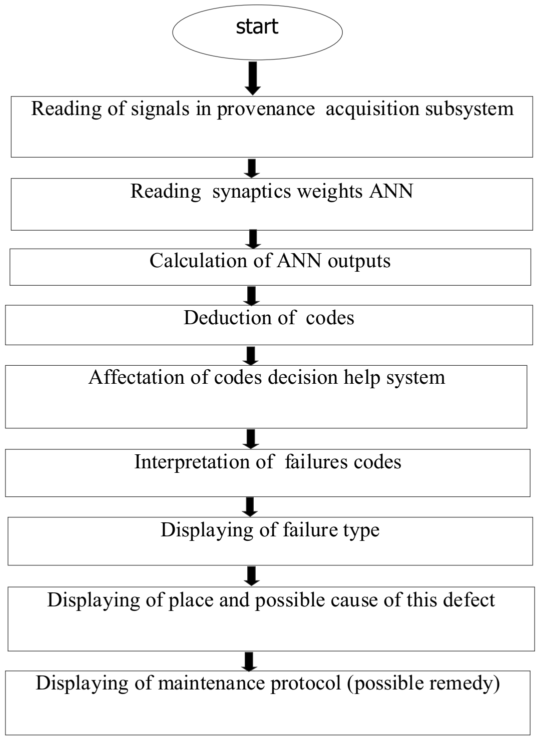

Fig.6: Identification diagram of type and nature defect

VI. CONCLUSION

The implementation of the neural network, must be passed by several parametric studies (choice of the type of network, choice of the entries, choice of the output…) these studies were preceded by the operation by data acquisition. The purpose of which is to establish the base of training of each network in order to define during the training phase the number of hidden layer and number of neurons by hidden layer (dimensioning of the final network architecture).
Finally, the results obtained in the test phase of the two networks enabled us to select the second network to implement it in the automatic system of the diagnosis. The choice of this last is justified by its simplicity, because the

entries of the neural network come directly from the sensors of the currents, tensions and rotation speed, i.e. the effective values (root mean square) of the stator currents and the tensions and the measured value of rotation speed. In addition, in the second method we can use the minimum of entries and the maximum of parameters (i.e. each time we increase the number of parameters, we obtain a efficacy diagnosis).

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