Real Time Detection Of Alternator Failures Using Intelligent Control Systems

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Abstract

On todays vehicles, dynamos are being left gradually and alternators take the turn instead for charging systems. Alternator is an electromechanical device which converts mechanical energy into electrical energy. Superior feature of alternators is that they can be charged on idling epoch and they have more output current. On the other hand by using diodes alternative current can be converted into direct current. Alternators are the main component of the charging system on modern vehicles. In this study, alternator failures are detected using fuzzy logic and artificial neural network. These are double diode failure, excessive current, excessive stretch belt, loose belt, loose brush, regulator failure, short circuits on coils, one broken connection on rotor coil, two broken connection on rotor coil, broken connection on tridiode and tridiode short circuit. For detecting the failures, current, accumulator voltage, alternator voltage and the epoch number of the alternator is measured and alternator failure detection classification is implemented by designing an intelligent system inference according to these measured values.

1.Introduction

Alternator(charging dynamo) is a device that converts the mechanical energy into electrical energy while an engine works and produces current according to the epoch of the engine. As alternators don't have a convertor to produce direct current, they are simpler, lighter and harder than direct current generators. After 60's vehicle manufacturers started using alternators instead of direct current generators because of the dicreasing costs of semiconductor diodes [1].

Many studies are being done on performance of the alternator and failures of the alternator's parts. A.Moyes and his friends had detected the failures by professional system techniques. They pointed out that by using information taken from a professional's report, failure detection can be implemented with a professional system [2].

Doctor R. Shuttleworth and his friends had detected the failures on an alternator's rotor by using artificial intelligence techniques. On the tests, they had predicted the field current which is measured on the stator's terminal. With using microcontroller on failure detection, they had classified current, voltage and epoch number by measuring them [3].

The main purpose of this study is to control the failures that occurs on an alternator using intelligent control systems techniques and monitor the alternator's condition.

2. Artificial Neural Network

Artificial neural network is a data processing system that aims to give abilities of learning, generalizing, remembering to the systems by imitating the behavior of brain. An artificial neural network learns by considering the changes on an input set and produces an output for it. Learning process comes true with a learning algorithm which produces the same output for similar input sets [4].

2.1. Education and Test of ANN

Education substantially takes its place instead of programming on development of artifical neural network which is a branch of the artificial intellegence technologies. Detecting the connection weight values of the process components is called "educating network"[5].

On learning period, the weights are changed according to the chosen learning approaches. A change on weights means learning. For ANN, if no change on weights, it means learning had stoppped. At the beginning, random weights are assigned. ANN changes the weights while some samples are pointed out to them. For a network, reaching true weights means it can do some generalizations on the event represented by samples, on other sayings "network learns". After artificial neural network learns, by implementing some inputs that is not implemented before, approaches on neural network and real output are analysed. If it also get close to the newly samples, it means that neural network learns the job [5].

2.2. Feed Forward Neural Network And Backpropagation Algorithm

A feedforward neural network is an artificial neural network where connections between the units do *not* form a directed cycle. This is different from recurrent neural networks. The feedforward neural network was the first and arguably simplest type of artificial neural network devised. In this network, the information moves in only one direction, forward, from the input nodes, through the hidden nodes and to the output nodes.

Backpropagation algorithm is a commonly used supervised algorithm to train feed-forward networks. It was first introduced by Paul Werbos. The basic idea is to determine how the neural network behaves for a sample input, compare how different it is from the desired behavior and then adjusting the weights of synapses to minimize thedifference. This process is repeated for all training samples in the set multiple times to ensure proper training [4].

3. Fuzzy Logic

Fuzzy logic, is a computer logic revolution that helps the computers by some logic applications which are like human behaviours. Some basic advantages that fuzzy logic provide are listed below [6]:

1. It is close to the human thinking system and style.
2. System can be published easily as the software is simple.
3. It is more flexible than other control systems as for using membership values.
4. It allows modelling of non linear functions.
5. With just only experience of experts, a modelling against fuzzy logic can be easily designed.

3.1 Fuzzification

In fuzzy systems, typical values of linguistic variables are represented in subsets and every subset is expressed by a membership function. For example, belongingness of a universal subset called X whose components are x to a fuzzy subset called A is interpreted as membership functions and equation can be interpreted as showed in equation 1 where μA(x) is the membership function [7].

$$\mu A(x):X \rightarrow [0,1] \quad (1)$$

3.2 Fuzzy Logic Rule Base

On rule base, by arranging system output values in rule lines that suits logically according to the input values that system gets, rule base is created. Rules that create control base have some properties listed below[6]:

1. Every rule has free data section.
2. New rules can added into the rule base free from other rules.
3. Old rules can be changed free from other rules.
4. It includes the control system decisions and solutions.

3.3 Defuzzification

On most practical applications control command is issued as an exact value. Therefore, the fuzzy inference result need to be clarified. Defuzzification is a period of obtaining a non fuzzy controlled activity on a fuzzy controlled activity that shows the dispersal of probability. In literature, there are eight types of defuzzification methods mostly used. These are: Max-membership principle, Min-membership principle, Centroid method, Weight average method, Mean max membership, Center of sums, Center of largest area and first or last of maxima [8].

4. Charging System and Alternators

While engines of vehicles engine does not work, all receivers in usage are fed from a battery. When engine starts working, this process is done by charge system. While vehicle's engine works on a low epoch, the current generated by charge system may not be enough to feed receivers. In such cases dynamo and battery together feed receivers. While engine works on high epoch electrical receivers may not be used. At that time battery may be full charged. In such cases, regulator which is an element of the charge system bounds the charge current and makes it work idle by taking its turn. Nowadays, dynamos are not used. Instead, alternators took their turn. Alternator(charging dynamo) is a device that converts the mechanical energy into electrical energy while an engine works and produces current according to the epoch of the engine [9].

Figure 1. General view of an alternator

4.1 Parts of an Alternator

Rotor: It is the part that can turn around an axis of an axle and where movement is delivered.

Stator: Stator is the fixed part in which rotor turns and electrical connections are implemented.

Diodes: There are three items negative and three items pozitive diodes in identical loaded diode bases. The current generated by alternator is delivered from pozitive loaded diode base which is isolated from edge flaps [9].

4.2 Working of an Alternator

Alternator works in the same way with direct current generators. When the magnetic field around a conductor changes, current flows through on the conductor. On a modern typical alternator, magnets called rotor turns around or inside the iron surrounded with fixed conductor coils which is called stator. Just after the rotor is turned by the mechanical energy, magnetic field around the conductors changes and electrical current is generated [10].

4.3 Claw Type Alternators

Modern charging systems used on vehicles charged small over the last 40 years. Changes on alternator, regulator and also included cabling system are so small. Alternator converts mechanical energy into electrical energy. This energy is used to make the internal combustion engine run and meet the need of electricity on the car. On vehicles, the mechanic energy is delivered to the alternator by a belt.

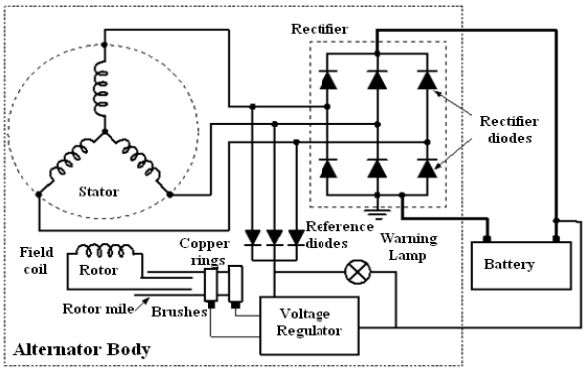

Figure 2. Most basic alternator and charging system on vehicles

In figure 2, the open schema of a current alternator and charging system is given. The output of the alternator is converted to direct voltage by diodes. The generated voltage is so high without a regulator. This high voltage makes the accumulator overcharge and breakdown the electrical equipment on the system.

Regulator implements some needed voltage calibration to avoid the overcharge or low charge of the accumulator. Changing of the current on rotor coil takes approximately 100 ms or more. This time cause high stator loss. So it affects the alternator's efficiency and output power.

4.4 Testing Mechanism

The test mechanism established for detecting the failures that may ocur on alternators is like shown in Figure 3.

Figure 3. Testing Mechanism

The LA-55P current sensor placed in the mechanism has direct connected or line isolated working principle. It is a fast modular sensor with linear RMS output and 4-22 mA standart current output [11].

The LV-25P voltage sensor works on Hall-Effect principle and has line isolated working principle. Also it has very high accuracy ratio with 99.2 %, very high linearity, high band width and low response time [11].

PCI 1710HG is a data acquisition card that has a high resolution with 16 bits and is a multi functional input/ouput card. It has many special functions that can meet the needs of the users.

5. Failure Detection With Intelligent Controlling Systems

5.1 Fuzz Logic Failure Detection System

Fuzzy logic failure detection system that has developed for detecting the alternator failure consist of four section. On the first section, input variables is taken and those chosen input variables is transfered to the program by each a sensor. The second section is the fuzzification part which is executed according to the type of the membership function and the membership number. The third one is the fuzzy inference section. In this section, values of the output membership functions and membership functions are found towards the rules defined by experts and using fuzzy logic functions. Defuzzification is implemented on the fourth section and with this process fuzzy logic detection system gives the result.

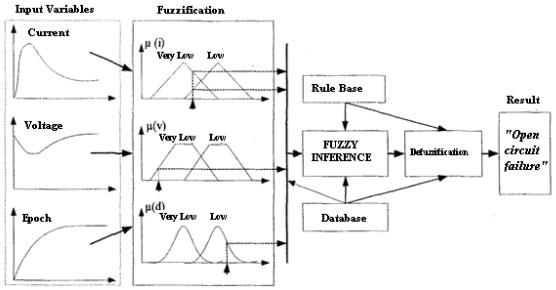

Figure 4. Block diagram of the fuzzy logic failure detection system

5.2 Software of the Fuzzy Logic Failure Detection System

The main window of the developed failure detection system software is given in Figure 5. The system can get the input variables by three ways. Random values can be generated by computer. If the user wants he can enter values from outside and he gets the results for the values he entered. It can get values online by PCI 1710HG Advantech card.

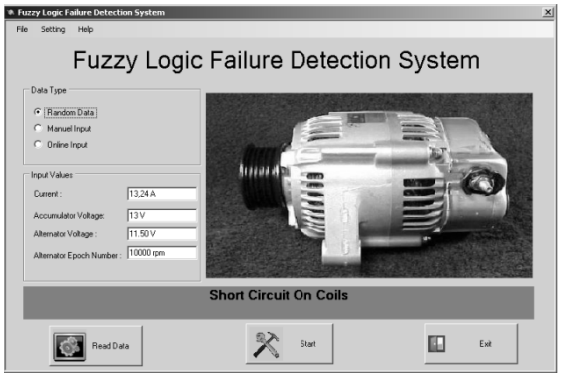

Figure 5. The main window of the fuzzy logic failure detection system software

Failure detection program has two running modes. On automatic mode, the program reads the data at intervals and concludes the detection. On manual mode, the user can first make program have the data read and then click the start buton and see the reults. The detection result is pointed out with the failure names and in some cases system may return more than one failure results. On the other hand, when a data, that is out of range of alternator's running data, is passed to the system, the software warn us that this situtation can not exist.

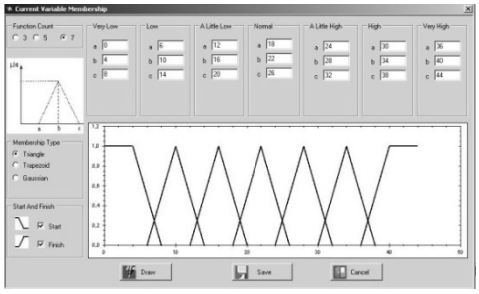

Figure 6. The window prepared from the input values for the current

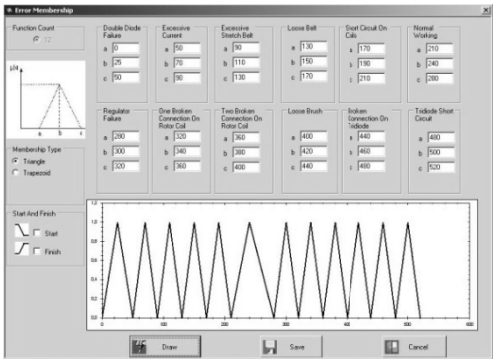

Figure 7. The window prepared for failure(output value)

The membership function number and type of both input and output variables of the software developed for the fuzzy logic failure detection system can be selected (Figure 6, Figure 7). User may enter the values for each membership function from this menu. Also user may draw the membership function again for the values entered and use that values on the failure detection.

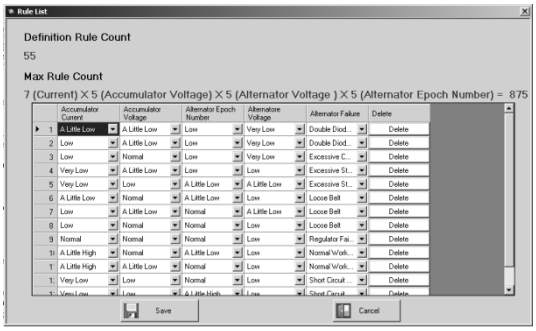

Figure 8. The rule base window

In the failure detection software it is possible to see the current defined rules that belong to the system (Figure 8). If user wants he/she may add, delete and edit rules on the rule base. The access of the user to the rule base and availability of changing data on rule base provides great flexibility for the failure detection program.

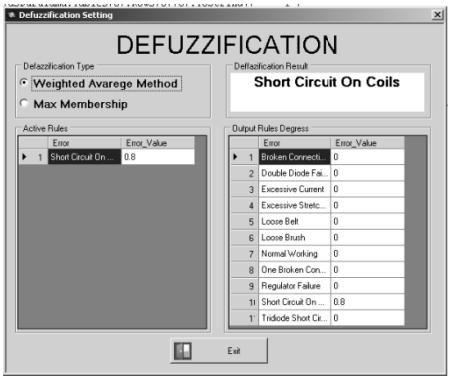

Figure 9. The defuzzification window and properties.

User may see the active rules and membership degree of each rule on the fuzzy logic failure detection system defuzzification window. User may see which output membership functions are affected on the conclusion of defuzzification process of current active or user defined rule (Figure 9).

5.3 Failure Detection On Alternators Using Feed Forward Neural Network

On a feed forward network neural cells divided into layers. Signals are transfered from input layer towards output layer by single direction connections. A failure signal is gathered by comparing the output values with required output values and network weights are educated upon updating. Backpropagation algorithm is used on education of feed forward neural network.

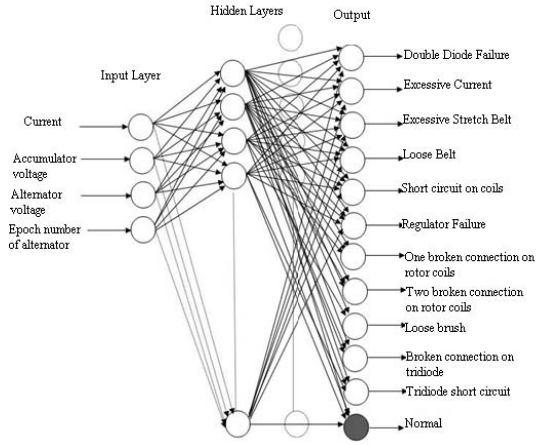

Figure 10. The structure of feed forward neural network using for failure detection on alternators

The input neuron number of the feed forward network structure used in this study is 4. It has two secret layers and there are 50 neurons in the first layer, and 20 neurons in the second layer. In the output layer there are 12 neurons. The average of measured current, accumulator voltage, alternator voltage and the epoch number of the broken alternator is implemented to the input of the network. Number of secret layer and neuron numbers in the secret layers may be changed by user. The twelve type of failures exists on alternators is adjusted as output in the output layer of the network. The twelfth output of the network gets active when the alternator is normal (Figure 10) .

5.4 Feed Forward Neural Network Failure Detection Software

Failure detection on alternators using feed forward neural network software is developed using Visual Studio 2005 (c#.net). In this software, data which will be used for education is stored in Access file with extension mdb. If wanted the detection is performed by getting data directly from PCI 1710HG. The properties of the network and educated parameters are stored in a file named ysa.ndn.

The values that will be used in education of feed forward neural network, number of secret layers, number of neurons in the secret layer and number of neurons in the output layer may be changed before education optionally by user. The activation function of each layer in the network may be selected. This property provides user to determine the fittest activation function for the diefined network (Figure 11).

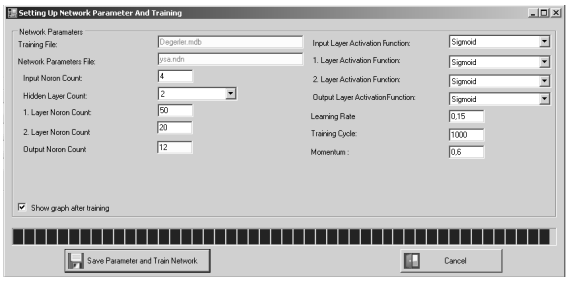

Figure 11. Feed forward neural network education window

In order to test the educated network, the signal that will be implemented to the input of the network should be chosen. For an input signal, selected values or the values gathered from PCI 1710 may be implemented to the input of the network directly. To which failure is close the signal impemented to the network, corresponding output gets active. Output value may be 1 or may be as close as tolerance value to 1. In case of failure detection, the round near the failure is selected and background color turns to red. In case of normal operation the background color turns to green and alternator is labeled as good conditioned (Figure 12).

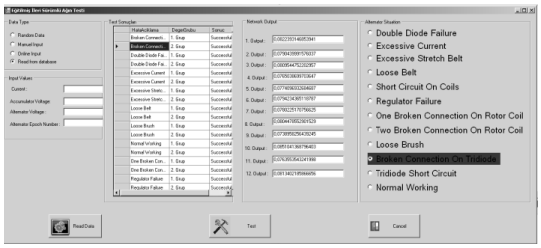

Figure 12. Feed forward neural network test window

5.5 Comparison of Artficial Intelligence Techniques

The features of the artificial intelligence techniques used for detecting the failures of alternator is shown in Table 1.

Table 1. Comparision of Artificial Intelligence Techniques Used For Failure Detection System

Feature	Artificial Intelligence Techniques	
	Fuzzy Logic	**Feed Forward Neural Network**
Learning	Expert knowledge	Yes
Flexibility	Too many	Yes
True Classification	Good	Very good
Data Updating	Very easy	Easy
Time for Failure Detection	3s	4s
Detection of Failure in Advance	No	Yes
Failure Estimation	Yes	Yes
Input Number Implemented to System	4	4
Input Values Implemented to System	Current accumulator voltage, Alternator voltage and epoch	Current accumulator voltage, Alternator voltage and epoch
Detected Failure Type Number	12	12
Average Detection Number	80-90%	85-95%

6. Conclusions

In this study, double diode failure, excessive current, excessive stretch belt, loose belt, loose brush, regulator failure, short circuit on coils, one broken connection on rotor coil, two broken connection on rotor coil, broken connection on tridiode and tridiode short circuit are detected by failure detection softwares that use artificial control systems.

By using fuzzy logic this twelve types of failures can be detected successfully. With membership functions that defined according to the input values of fuzzy logic failure detection system, numerical values turns into linguistic. Fuzzy logic generates an inference by comparing this linguistic definitions with current rules. It is possible that more than one rule may be active at the same time. Defuzzification process will generate results with different degrees for ouput membership functions of active rule or rules.

Failures monitored on alternators frequently also had been detected using feed forward neural networks. These failures had been classified by artificial neural network. The developed artificial neural network software allows the parameters of feed forward network and backpropagation algorithm to be changed by user. This feature brings the software in flexibility and provides to get beter results on failure detection.

7. References

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