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ESTABLISHMENT OF DIAGNOSING FAULTS AND MONITORING SYSTEM WITH NEURAL NETWORKS IN AIR CONDITIONING SYSTEMS

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Despite the fact that the world has different climate regions, humankind finds a living environment in a certain temperature, humidity range and clean weather conditions suitable for him. This living environment is defined as "Comfort Zone". Today, people spend most of their daily lives in closed environments. The use of air conditioners is becoming increasingly widespread in order to create a comfortable environment in the living areas, especially shopping centers. In this study; a malfunction in an air condition was detected and the malfunction information was taken and sent to a remote server database via mobile internet infrastructure. The data on the server was processed with artificial intelligence and a mobile application was developed. Again, with an Android device with network access, it was aimed to retrieve the data from the database and forward it to the technical service personnel. An electronic card is designed for the retrieval of the fault data.

Index Terms — Fault detection and diagnosis, neural networks, mobile programing

I. INTRODUCTION

THE environments in which the air conditioner is used contribute to the increase in the work force efficiency with a healthy life. For this reason, nowadays, the air conditioner has become a necessity for human life without being luxurious. Along with an increase in demand for better living standards, today, the number of air conditioning used in the world is about 140 million and the Figure spent on them is 90 billion euros[1]. The need for the establishment of climate systems is directly linked to the development of human living standards and the resulting physiological needs[2]. Therefore, it is an important issue to intervene the malfunctioning air conditioner in the shortest time when the air conditioning systems used in every life of the life, particularly in the health sector, are malfunctioning. Especially in air conditioning systems, when faults occur simultaneously, it is often hard to differentiate those issues from one another[3].

Fault detection and diagnosis is an important problem in process engineering. Early detection and diagnosis of process faults, while the plant is still operating in a controllable region, can help avoid abnormal event progression and reduce productivity loss[4]. Although fault detection and diagnosis FDD has been an active area of research in other fields for more than a decade, applications for heating, ventilating, air conditioning, and refrigeration (HVAC&R) and other building systems have lagged those in other industries. Nonetheless, over the last decade, there has been considerable research and development targeted toward developing FDD methods for HVAC&R equipment[5]. Many models and studies have been developed and done to identify fault diagnostic errors. According to V. Venkatasubramanian et al., causal origins have to be diagnosed and identified in order to detect an abnormal event in a timely manner, and that appropriate audit control decisions and actions must be taken in order to bring it to a safe and working state and have worked on a model. In this model, diagnostic methods are divided into three general categories and examined in three parts. Quantitative and model based methods, qualitative and model based methods and process history based methods. They have prepared the model in Figure 1 for this[4].

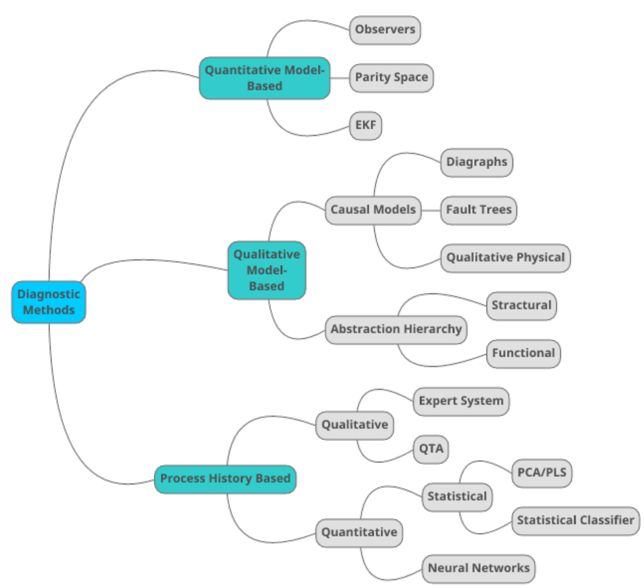

Fig. 1. Classification of diagnostic algorithms

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Y. Yu et al., provide a systematic review of existing fault detection and diagnosis (FDD) methods for an air-handling unit (AHU) and in reality, they introduced new approaches to high performance. For this goal, the background of AHU systems, general FDD framework and typical faults in AHUs, is described. Ten desirable characteristics used in a review of FDD in chemical process control are introduced to evaluate the methodologies and results. A new categorization method is proposed to better interpret the different and most recent approaches[6].

Basic building blocks of FDD systems, methods used to detect errors and then diagnose the causes. Several different methods are used to detect and diagnose faults. The major difference in these approaches is the knowledge used for formulating the diagnostics.

Model-based methods can use quantitative or qualitative models. Quantitative models are sets of quantitative mathematical relationships based on the underlying physics of the processes. Qualitative models are models consisting of qualitative relationships derived from knowledge of the underlying physics. The boundary between quantitative models and qualitative models can become blurred for some approaches, but this distinction and that between model-based and process history (data) based methods provide a useful scheme for categorizing FDD methods, which is used in this paper (Figure 2)[5].

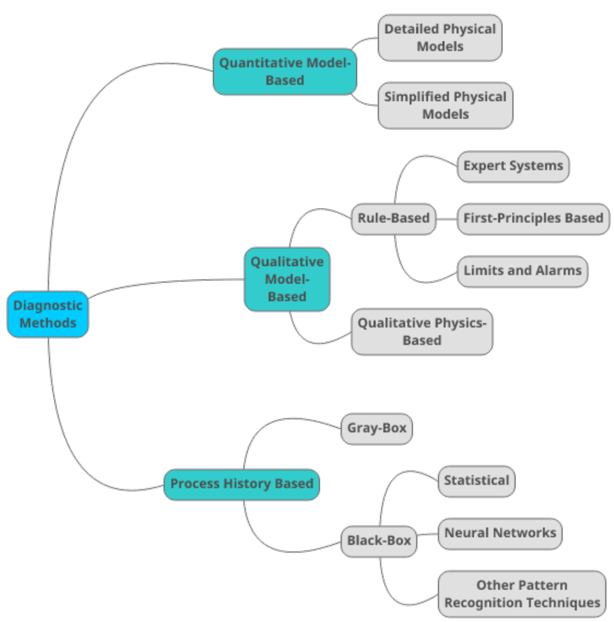

Fig. 2. Classification scheme for FDD methods

Generally, the model-based methods have been most widely developed in the HVAC systems. The good application of the model-based FDD method relies on the accurate mathematical physical models[7].

Wang et al., developed a detection model-based on a neural network in the variable air volume systems. The neural network can be used to diagnose the faults of outdoor air, supply air and return air flow rate sensors after training using operation data[8].

These studies show that neural networks are one of the most used models for fault detection and diagnosis.

In this study, It was aimed to determine the faults in an air condition and to send and process this information to a remote server via the mobile network infrastructure. For this purpose, an electronic card was designed and the air conditioner data was taken and wirelessly sent to a remote server. On the server side, a neural network model was used to classify the fault diagnosis. A mobile software has been developed for transferring online data to technical service personnel. In this way, changes and failures in the climate can be monitored in real time.

II. SYSTEM DESCRIPTION

The method used in the study consists of four stages, so the study text is given under four headings. (Figure 3). The first stage of the work is the “Air conditioning module”. It consists of a simulator system that can generate the fault. The second stage which of the work is the “Microcontroller module” which is taken the data from the “Air conditioning module”. The third stage is the “Server module” where the data is collected and processed. In the last stage, "User module" has been completed with the developed mobile program.

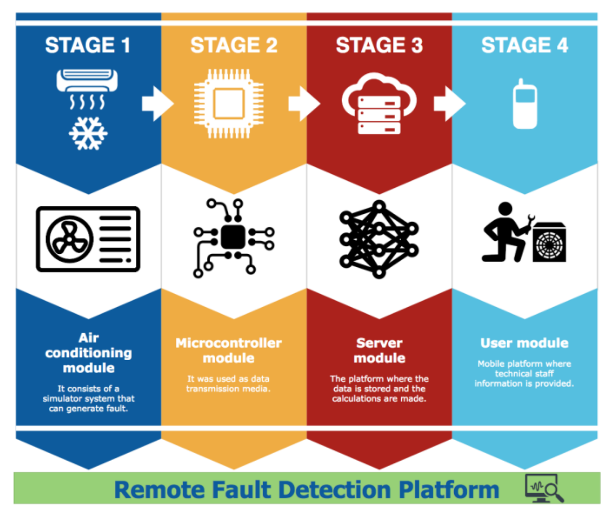

Fig. 3. Model of remote fault detection platform

A. STAGE ONE: AIR CONDITIONING MODULE

This module consists of a training simulator system in which a fault can be generated in a wall-mounted air conditioner (Figure 4). Thanks to this system, the following faults are handled manually and a control card is transmitted to the control part of the system, which is designed by means of a cable from the serial port.

With this system, the following faults can be given manually. These;

Fig. 4. Air conditioning training simulator system

In summer position:

- *Compressor valve plates leakage leaking*
- *Four-way valve leaking failure*
- *Condenser blockage failure*
- *Filter blockage failure*
- *Electronic expansion valve malfunction*
- *Capillary blockage failure*
- *Evaporator blockage failure*
- *Defective refrigerant deficiency*
- *Refrigerant surplus failure*
- *Air malfunction in the system*
- *Indoor unit pollution failure*
- *Condenser fan failure*
- *Compressor malfunction.*

In winter position:

- *Compressor valve plates leakage leaking*
- *Four-way valve leaking failure*
- *Condenser blockage failure*
- *Filter blockage failure*
- *Electronic expansion valve malfunction*
- *Capillary blockage failure*
- *Evaporator blockage failure*
- *Defective refrigerant deficiency*
- *Refrigerant surplus failure*
- *Indoor unit pollution failure*
- *Condenser fan failure*
- *Compressor malfunction*

In addition to these faults, the following information is obtained through the control card.

- *Compressor inlet temperature*
- *Compressor outlet temperature*
- *Condenser inlet temperature*
- *Condenser outlet temperature*
- *Evaporator inlet temperature*
- *Evaporator outlet temperature*
- *Storage gas quantity*
- *Compressor input pressure*
- *Compressor outlet pressure*
- *Capacitor input pressure*
- *Condenser outlet pressure*
- *Evaporator inlet pressure*
- *Evaporator outlet pressure*

B. STAGE TWO: MICROCONTROLLER MODULE

If a microcontroller is chosen for an application, this selection should be made to meet the requirements of the application being designed. The purpose of this work is to read the data received from the serial port via the air conditioning module and to communicate with the Wi-Fi module quickly and send this information to a database on the internet. For this reason, the most basic feature of PIC to be selected is that it has serial port communication support and can work at high frequency. It is also important that you have the ability to perform very fast operations.

The dsPIC33EP512MU810 (Figure 5) is used as a microcontroller in the tramped electronic circuit. The microcontroller is directly connected to the Ethernet / Wi-Fi module, RTC-E2, display and RS 232 integration. Also a GPRS integration allows SIM cards to be read and connected internally for later use on the circuit. The designed electronic circuit also uses PLL (Phase Locked Loop). Thanks to this

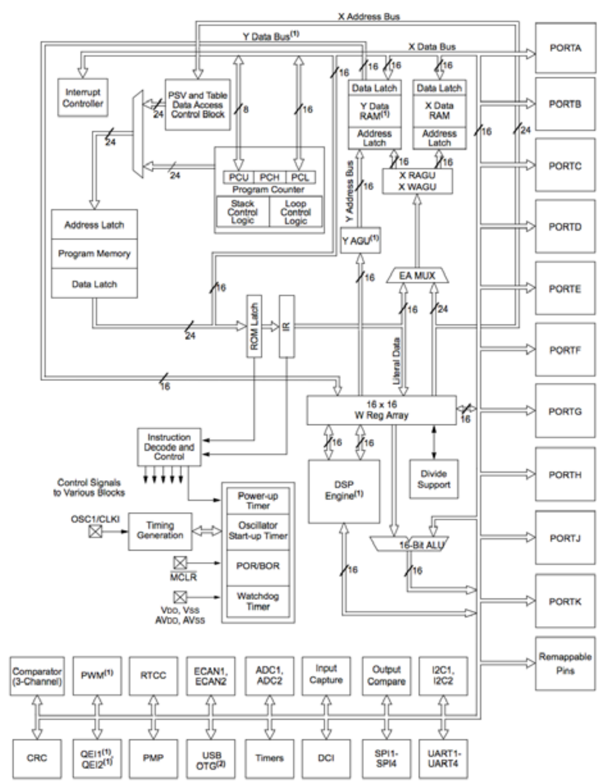

Fig. 5. dsPIC33EP512(MU)810 block diagram [9]

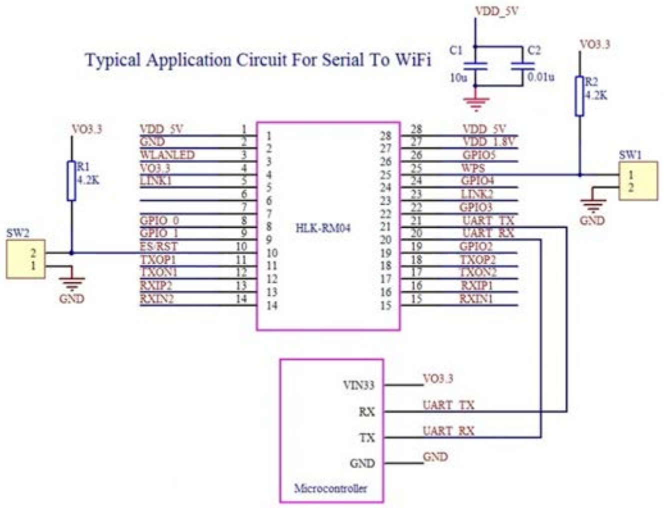

Fig. 6. Application circuit for serial to Wi-Fi.

structure, a stable frequency is produced[10, 11].

In this designed system, the wireless network module is configured[12]. For this, HLK-RM04 was used (Figure 6). This module is an embedded module based on the TCP / IP protocol, serial port, Ethernet, universal serial interface network standard that hosts wireless network. In this way, there is no need to make any configuration on conventional serial devices[13, 14]. In addition, the MPC79410 real time clock (RTC) (Figure 7) integration is used to record incoming data according to the real-time clock. The feature of this integration is that it does not lose its date and time information even if there is a power failure by generating a self-clock signal with the aid of an independent battery and an oscillator with a frequency of 32768 KHz connected to pins X1 and X2 of the integrator[15].

The first part of the designed device (Figure 8) consists of feeding and RS232 connections. In order to avoid the problem of polarity in applying the supply voltage at this stage, a circular connector structure and a bridge diode are used. For RS232 connection, an external RS232 connection is connected and DB9 connector is connected to the integrated output. This connection allows the data is taken from the air conditioning module. Another DB9 connector connected to the Rx and Tx

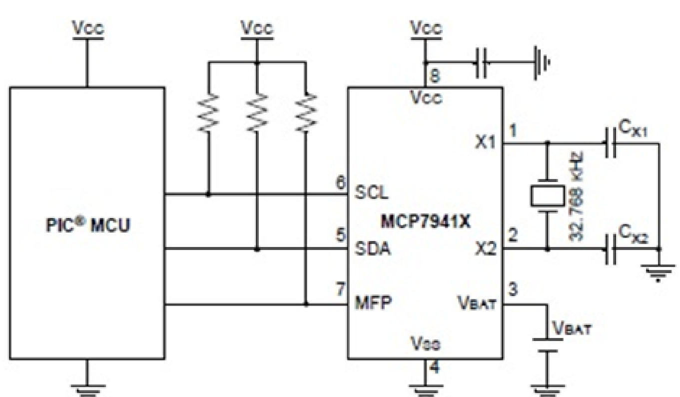

Fig. 7. Application circuit for MPC7910

Fig. 8. Designed circuit

ends of the microcontroller is connected directly so that the PIC integration can be set via the computer.

Finally, the controller, the pressure, the temperature, and the amount of gas from the air conditioner module via the serial port are sent to a database on the internet via a wireless modem via the Wi-Fi module in the system.

C. Stage Tree: Server module

In this part of the work, the data from the system are recorded in a database and the application of the neural network results obtained in chapter III is explained. The monitored data in Micro controller card is transferred to MySQL database server through internet. PHP API executes on the internet server [16]. The recorded data is useful for further analysis and may be useful for data mining. The Fast-Artificial Neural Network Library, a PHP library, was used to evaluate the failure of the experimental work described in Part III. Thus, when the fault information is applied by push messaging method, active users at that moment will beep and send a notification. The system consists of the front-end user interface part, the data filtering and processing part, the data collector part, and the module in which the data is stored. They also communicate with a PHP API (Figure 9). The Admin user (if desired front-end user) interface module supports graphical user interface through web browser with HTML and java script. The module is implemented by angular.js and node.js. The users explore and retrieve the information DB through data filtering and processing module and the information is shown in web page [17].

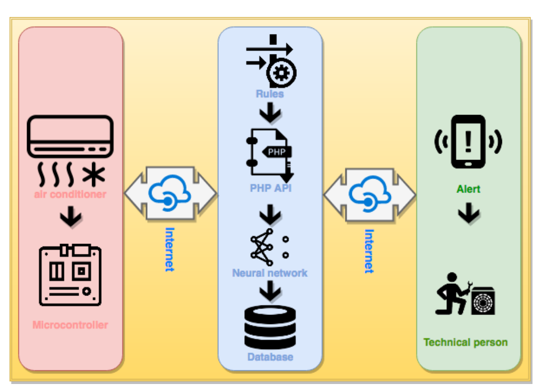

Fig. 9. Server relationship model

D. Stage Four: User Module

An Android application is developed (Figure 10) in the Android Studio using Java[18, 19]. Internet connection permissions are given in it to connect with Wi-Fi. Data from the database (located in MySQL) can be obtained on the mobile phone by clicking the developed Android application on the mobile phone. When the android program is clicked, it connects to URL of PHP API. As a result, PHP API connects with the database and returns the data to the mobile phone [20, 21].

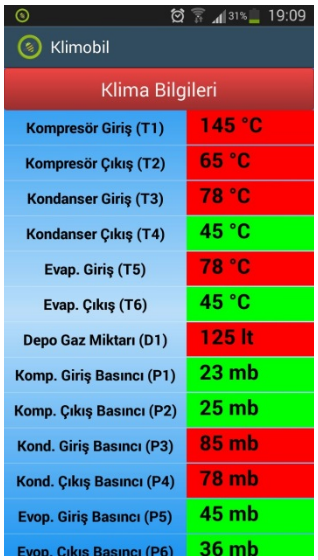

Fig. 10. Screen display showing air conditioner data

The developed mobile application also uses "push notification" for instant messaging. Mobile push notifications are an important feature of mobile computing services and they have been widely implemented in mobile applications[22]. Push notification is conceptually an event-based mechanism where remote servers push events, as and when they occur, to smartphone client apps[23]. In particular, it was used to inform the technical staff that the malfunctions that occurred instantaneously and the air conditioning system were out of working values. The Firebase Cloud Messaging (FCM) service is used for this. This is a service that developers use to send push notifications[24]. Using FCM, you can notify a client app that new email or other data is available to sync. You can send notification messages to drive user re-engagement and retention[25].

The mobile software processes the data coming from the server and displays the values other than the nominal values as red and the nominal values as green as above. The data coming from the climate is also prepared graphically according to time. The graphical screen display is shown in Figure 11. In addition, data from the air conditioner is graphically displayed on time, if desired. The graphical screen display is shown in Figure 11.

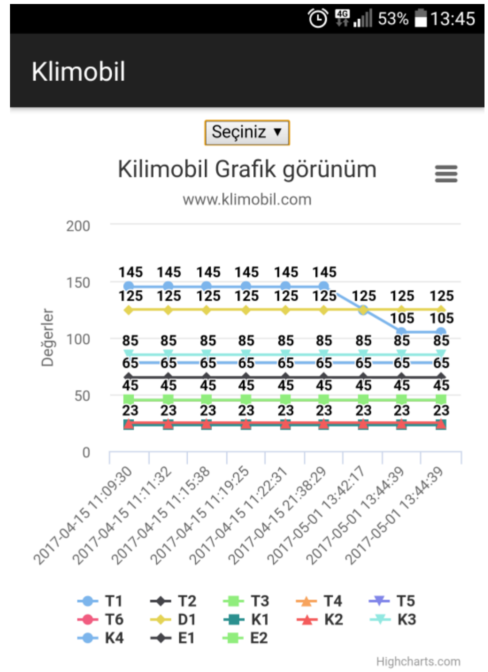

Fig. 11. Screen display of air conditioner data graphically.

III. Diagnosing Faults with Neural Networks

The work done in this section was made to create an academically ground for practice. In this study, the malfunction information of an Air-Conditioning Training Simulator device is taken and a wireless network and a server in internet environment are sent to the database and a prediction is made. For this reason, in order to evaluate the detection of such faults by means of a prediction method, sample faults were created by using hardware components from the Air Conditioning Training Simulator and the 1120 sample data were obtained.

The following fault classes have been established for this estimation, and the distributions of these data according to fault classes are given in Table I

Table I. Distribution of data according to occurrence

Evap Fan Failure	64
Evap Clogged	94
Gas Deficient	120
Gas Oversupplied	71
Element of Expansion Failure	47
Condenser Fan Failure	57
Condenser Clogged	146
Normal	521

Multilayer (MLP) neural network classification was performed using this data. Artificial Neural Networks are basic models of computation that resemble the function of a biological network of neurons and are used to solve complex functions in a variety of applications such as design, implementation, visualization, and Neural Network Simulation tools [26-28]. This is the most popular MATLAB Network Toolbox software, along with a lot of software for calculations. This software provides comprehensive support for graphical user interfaces (GUIs) that allow for the design and management of networks. The modular, open and extensible design of the toolbox simplifies the creation of customized functions and networks and transforms the neural network into software scripts called M-code[29, 30].

As can be seen in Figure 12, three different layers of input, hidden and output layers are used in this system. It consists of the sensor data ("Loadcell","KompGirişBasıncı", "KompÇıkışBasıncı","KondGirişBasıncı","KondÇıkışBasıncı,"EvopGirişBasıncı","EvopÇıkışBasıncı","T1","T2","T3","T4","T5","T6","T7","T8") as input layer. Information from the input layer is then processed in a single hidden layer; The output vector is calculated in the failure class (output) layer.

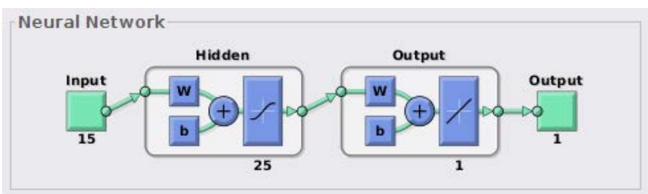

Fig. 12. Network model.

The success of the multilayer perceptron (MLP) Neural Network classification has been researched based on training, validation and test performance. The training performance of the neural network was investigated for different speeds, and the best performance for the Multi-layer network training algorithm was 99.91%.

The best training results were obtained with the Levenberg Marquardt (TrainLM) algorithm. The hyperbolic tangent sigmoid transfer function (Tansing) and Linear transfer function (Purelin) were used to optimize the input layer function. Performance ratio and training speed The best results are obtained with the linear transfer function (Purelin). The number of neurons in the hidden layer was determined by trial and error, and the results were listed for meaningful experiments. Depending on the training and performance indices, the number of layers of hidden neurons was chosen as 25. After running the multilayer perceptron (MLP) Neural Network using optimal parameters, 99.98% training performance and 96.84% test performance were achieved as described in the correlation graphs (Figure 13).

As shown in Figure 14, the multilayer perceptron (MLP) Neural Network algorithm has been successful with learning consisting of 70 iterations. Training was performed by selecting 25 hidden layers, and the other parameters were set to default values. Higher training and test rates indicate that MLP neural networks and Neural Pattern Recognition algorithms can be used safely for classifying failures.

As a result of these evaluations, the data is processed in the Artificial Neural Network layer on the server and this data is sent to the user in the instant notification via the mobile application.

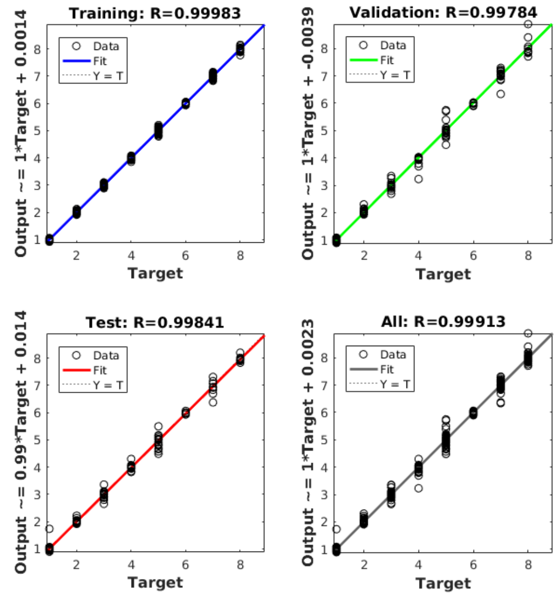

Fig. 13. Correlation Rates for Training, Verification and Test Data.

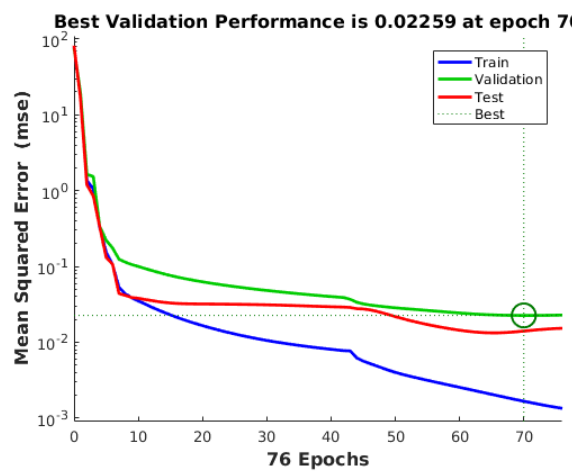

Fig. 14. The best validation performance

IV. CONCLUSION

When studies done in the literature are examined, different hardware components and cards are used for fault detection and different estimation methods are examined for fault detection. This work demonstrates that manufacturers who apply the rapidly developing IOT (Internet of Things) production technologies will be more solution oriented and make faster decisions than other manufacturers. The system itself will no longer make such malfunction decisions. When the devices are connected to each other, the generated data is rapidly transferred to each other through high speed internet support through the software that each device generates its own data and it is possible to make faster and more effective decisions by looking at the results obtained from the data. With these systems, these decisions are transferred to both the personnel at work, the manager who follows the job and all the devices and a synchronized working environment is provided. It is very important that the workforce develops and develops towards this developing technology in air conditioning maintenance and service. Because in the production phase, tasks and responsibilities in all jobs and units are influenced both by human training and by the professionalization of the person. It is unthinkable that this situation does not exist in technical service. It is clear that a system that detects failures before failures can reduce possible material and spiritual losses. However, new business profession will be born. In addition, the development of quality of service, especially in the case of malfunctions, has shown that air conditioning systems will contribute to productivity in workplaces that are heavily used during business processes. The success of the artificial neural network applications in different areas has shown that this work can be successful in predicting and transferring faults that may occur. In addition to achieving the desired outcome with this study, the evaluation of other estimation methods will contribute to both the academic studies and the sector.

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