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Development of a Diagnostic System for Klystron Modulators Using a Neural Network

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Abstract

The diagnostic system for klystron modulators using a neural network has been developed. Large changes in the voltage and current of the main circuit in a klystron modulator were observed just several ten milli-seconds before the modulator experienced trouble. These changes formed a peculiar pattern that depended on the parts with problems. Diagnosis was possible by means of pattern recognition. The recognition test of patterns using a neural network has shown good results. This system, which is built in a linac control system, is presently being operated so as to collect new trouble patterns and to carry out tests for practical use.

I. INTRODUCTION

In the electron linac, high-power klystrons are used as an amplifier that provides rf power to accelerate electron beams. Five modulators driving five klystrons are installed at Tohoku University's 300 MeV electron linac.

Since a klystron modulator, which generates pulsed power output of high voltage and a large current, is operated under severe conditions, it has problems most frequently among the devices in a linac. The Tohoku linac is at fist adjusted by the accelerator group and is then operated under regular conditions by experimentalists who use the linac for their experiments. However, they are not always specialists in the accelerator field. When the various devices comprising a linac have problems, it is necessary to install support systems for linac operation in order to suitably dispose of these problems and to continue linac operation. Therefore an expert system for the diagnosis of beam operation [1] and the diagnostic system for a klystron modulator have been developed.

In designing this system, it was noticed that large changes in the voltage and current of the main circuit in a klystron modulator existed just several ten milli-seconds before the modulator had a problem. These changes formed a peculiar pattern that depended on the parts with problems. Some interesting patterns were observed in preliminary tests [2]. Diagnosis was possible by means of pattern recognition. A neural network having an excellent ability for pattern recognition was used for comparisons between learned and actual patterns. It was useful to apply the neural network to this system in order to improve the accuracy of the diagnosis, to simplify diagnostic programs and to reduce the development period. In order to increase the accuracy of this system, more trouble patterns should be learned; as of now, very few patterns

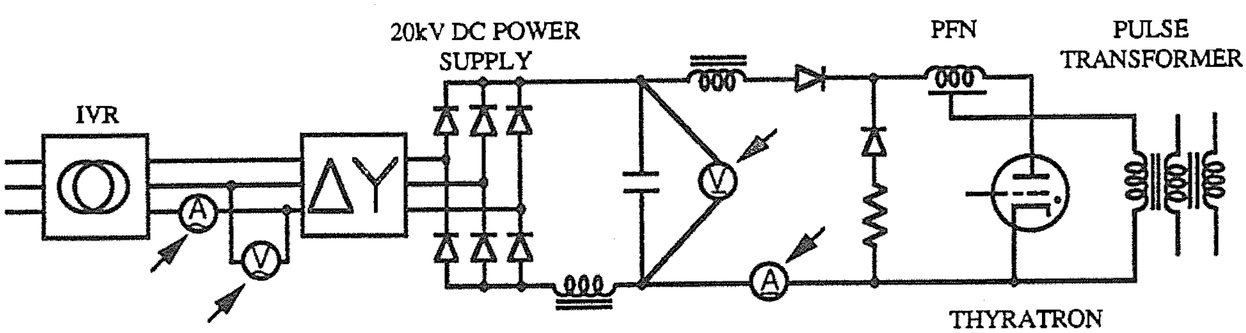

Fig.1. The klystron modulator circuit.

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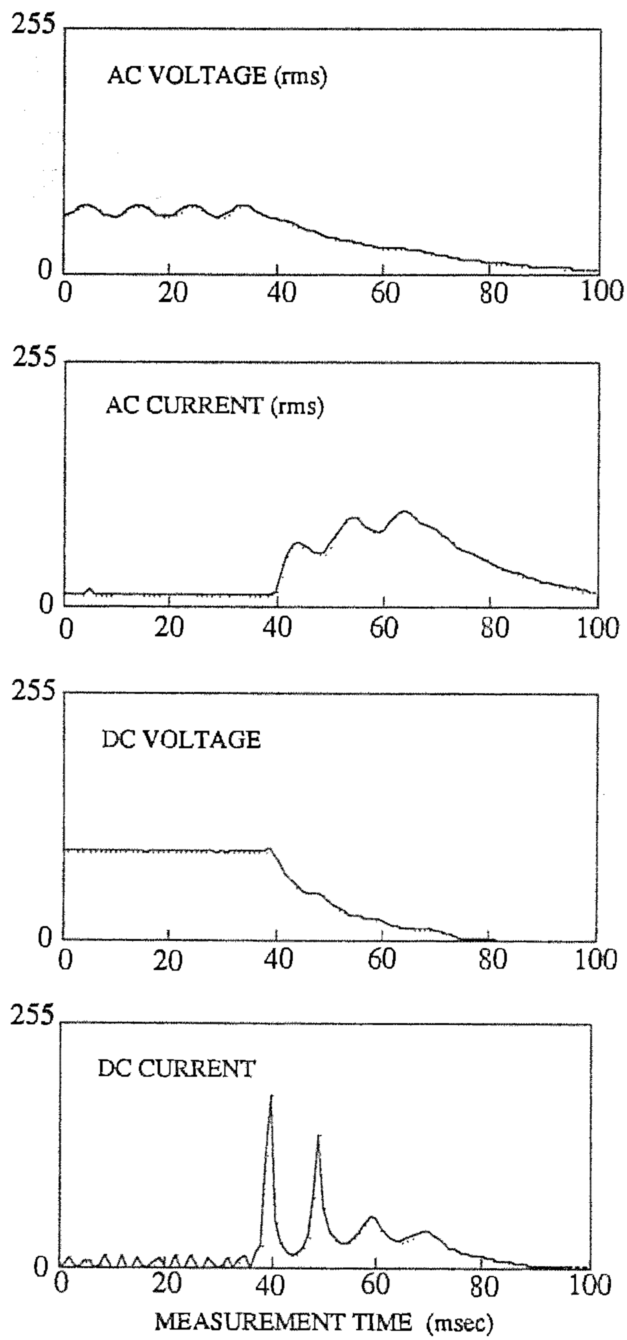

Fig.2. The typical pattern observed just before shutdown. Large current was flowed by a continuous conductive state in the thyratron and large voltage drop was simultaneously caused. Y-axis is an output value of ADC. Each curve is constructed by 100 sampling data.

have been collected. This system has been constructed and operated so as to collect new trouble patterns and the system diagnoses two klystron modulators for practical use.

This system comprises data-taking equipment built into each klystron modulator, as well as a personal computer with a simulation function of the neural network. The personal computer is also associated with the linac control system. Any diagnostic result is communicated to a linac control computer, and is shown on a display of the operater's console in the control room.

II. CONSTRUCTION

A. Klystron modulator

Fig.1 shows the main circuit in a klystron modulator. A pulsed high voltage and a large current are generated by composing of a pulse-forming network (PFN) and a thyratron, stepped up by a pulse transformer and supplied to a klystron. These signals, which are used for diagnosis of the modulator, are measured at four positions, which are shown arrow mark (fig.1); these are the AC voltage and its current, as well as DC voltage and its current. Fig.2 shows a typical pattern observed just before shutdown; this pattern shows the situation of an over current caused by a continuous conductive state in the thyratron. These signals are continuously measured by a data-taking equipment, as shown in fig.3. The data-taking equipment comprise isolation amplifiers, special elements to convert AC rms to DC (rms/DC), a multiplexer (MPX), a sample and hold (S/H), an 8-bit analog to digital converter (ADC), a memory to store the measured pattern data, an asynchronous serial communication interface adapter (ACIA) and a microprocessor (Intel 8085) used to control all of this equipment. These signals are sampled regularly at intervals of 1 msec and the data of 100 samples are stored in memory. When this equipment receives a shutdown signal from the klystron modulator, it immediately stops sampling these signals and sends the pattern data (4 positions x 100 samples) to a personal computer installed in the control room with ACIA (9.6 kbit/s) through an optical fiber cable.

B. Neural network

The personal computer FMR-70HX3 (Intel 80386, 25MHz, MS-DOS or OS/2) manufactured by Fujitsu is used. It has the function of a neural network simulator. This simulator works by combining simulation software (NEUROSIM/L) and an exclusive board (neuro-board) with a digital signal processor (MB86332) for high speed floating-point operations and 4 M bytes of memory for interconnections between neurons. The simulator is capable of making up to 1000 neurons at most, and the process speed is 4 M connections/s at most. The NEUROSIM/L functions as a simulator that can be accessed by user's programs with C language, and a tool for both learning and recognizing through MS-WINDOWS. The neural network in this system has a 3-layered structure; the number of the neurons in each layer is 60 in an input-layer, 10 in a midle-layer

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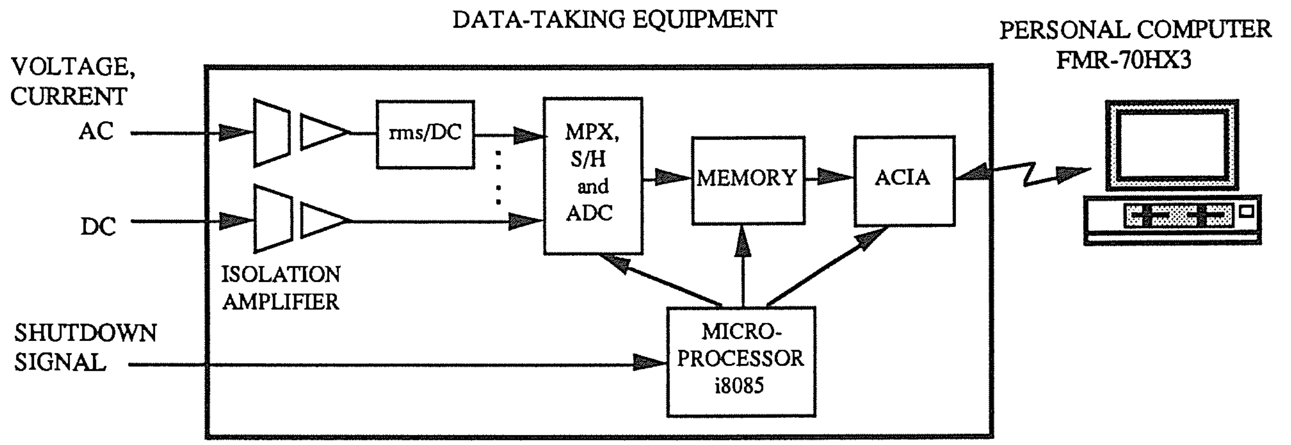

Fig.3. Block diagram of the data-taking equipment.

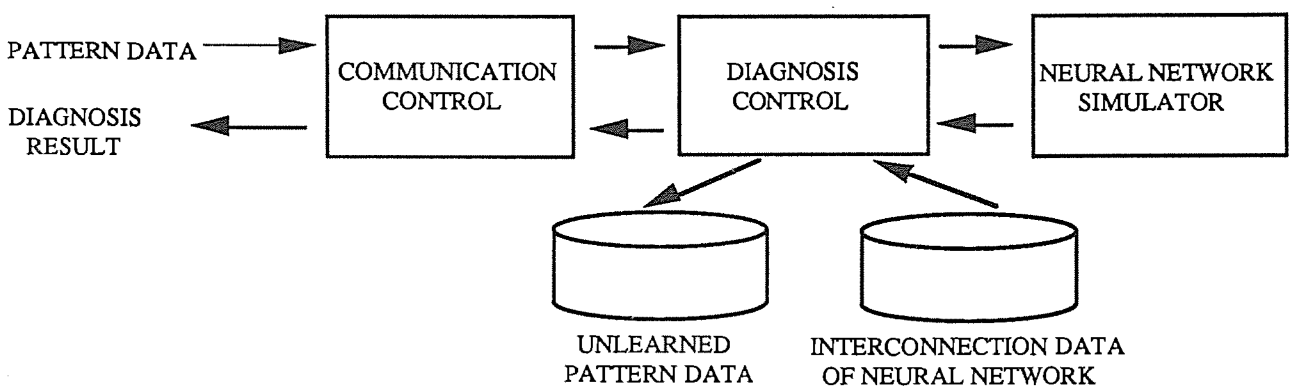

Fig.4. Software architecture in the personal computer.

and 5 in an output-layer, respectively. The abnormal part of the pattern accepted from the data-taking equipment is added to the input-layer. Each output in the neural network simply corresponds to each cause of trouble. A back propagation method was used for learning. The learning time depends on the learning parameters; the optimum value of the parameters are obtained by repeating the learning process trials. It then takes a few hours for this process. Afterwards, the constructed neural network is stored in the disk of the personal computer and is then loaded into the memory in the neuro-board when this system starts. Although the learning process has been used as only an exclusive tool, the new version of NEUROSIM/L has been so improved as to be able to set various learning parameters and to be operated the learning by the user program without any manual operation. The system is therefor able to provide an automatic learning function.

The program used for diagnosis in the personal computer comprises a simulation unit of the neural network, a diagnosis control unit and a communication control unit (fig.4). Before the diagnosis, the interconnection data of the neural network which has already been learned are loaded from the disk into the memory of the neuro-board. The pattern data for the diagnosis sent from the data-taking equipment is processed so as to supply the input-layer in the neural network at the diagnosis control unit; it is then sent to the simulation unit. The diagnostic results obtained at the simulation unit are returned to the diagnosis control unit. If the diagnosed pattern is applicable to the pattern already learned, the diagnostic results are sent to linac control computer so as to inform the linac operator; if not, the pattern data from the data-taking equipment are stored in the disk for the next learning process.

C. Diagnostic system in the linac control

Fig.5 shows the diagnostic system in the linac control system. In the linac control system [3], an original control loop of a Micro VAX-II is connected with magnet power supples, the klystron modulators and graphic displays on the console

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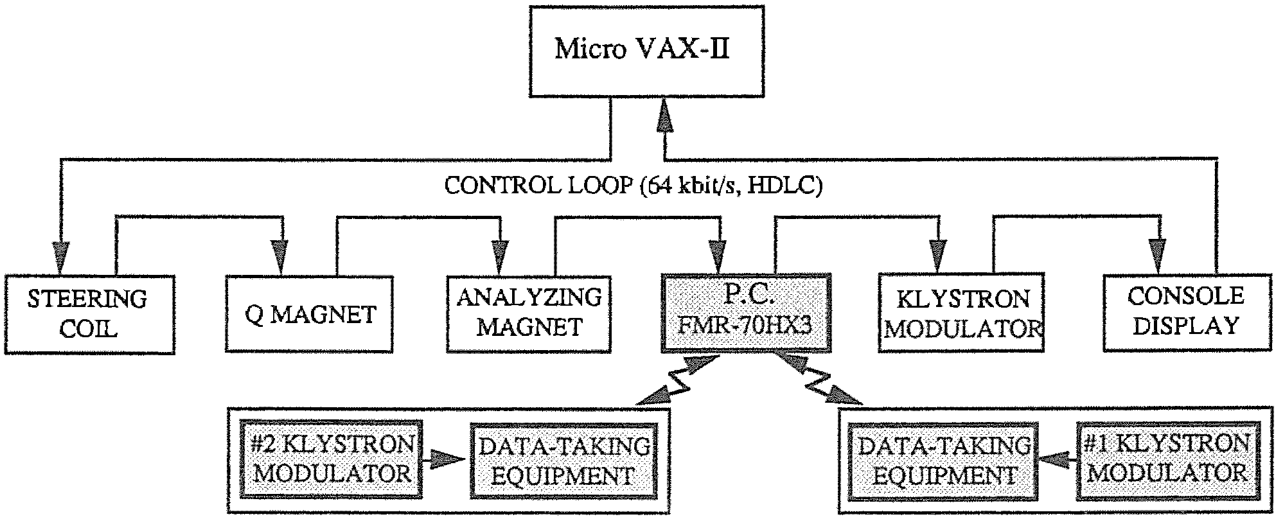

Fig.5. Block diagram of the linac control system, including the diagnostic system for the klystron modulator.

desk. The control loop is a 64 kbit/s synchronous transmission mode based on the High-level Data Link Control procedure (HDLC). Intelligent controllers based on a VME bus, which control the devices comprising the linac, are connected to each node of the control loop. The diagnostic results from the personal computer are sent to the Micro VAX-II through the control loop; they are also informed to the linac operator by graphic display and recorded on the linac operation log, together with other useful information from the linac.

III. CONCLUSION

As of now, various tests have been conducted. In the future, increasing the amount of pattern data will become a serious problem, such as increasing the learning time and establishing how to learn efficiently. In order to increase the learning time, the extraction of special features from a pattern and reducing the total number of neurons in the neural network must be improved. As for the learning method, this system should provide an automatic learning function, so that it can work when it obtains a new pattern, relearns without any manual operation and changes an old neural network to a new one. The addition of an automatic relearning function to this system is in progress.

As our next step, this diagnostic system will be associated with an expert system for the diagnosis of a klystron modulator [4] in order to realize higher accuracy.

IV. REFERENCES

[1] Y.Shibasaki, M.Mutoh and I.Abe, "Expert system for the diagnosis of beam operation trouble," Proceedings of the 16th Linear Accelerator Meeting in Japan, Tokyo, September 1991,pp.333-335.

[2] M.Mutoh et al., "The diagnostic system of klystorn modulator using neural network," Proceedings of the 15th Linear Accelerator Meeting in Japan, Sapporo, September 1990, pp.251-253.

[3] M.Mutoh et al., "Improvement of the control system for linac and pulse beam stretcher at Tohoku university," Proceedings of the 7th Symposium on Accelerator Science and Technology, Osaka, December 1989, pp.240-242.

[4] I.Abe et al., "Expert system for diagnosis of klystron modulator," LINAC conference 1990 in Los Alamos USA, September 1990.