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IMPROVED CONTROL OF TRANSFORMER CENTERS USING ARTIFICIAL NEURAL NETWORKS

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Abstract- By regulating the voltage level of electrical energy by means of transformers, the energy is transferred to electricity distribution and transmission networks consumers. In order to provide consumers with uninterrupted or minimal interruption of energy, systems that are widely distributed should be monitored continuously. Thus, the most important factors are the detection and removal of the faults in the transformer centers in the fastest way. By this study, the faults in the transformer centers is understood more quickly by the algorithm created on the basis of the artificial system networks and visualized with an interface created in the computer. Digital relays, which are produced with microprocessor technology, are used in substations, transmission and distribution systems for protection and control purposes. In the study, using the relays, monitoring of the systems and interfering with the system has been made possible by a remote local computer network.

Keywords: Transformer Centers Control, Artificial Neural Networks, Energy Transmission

I. INTRODUCTION

One of the most important features of electrical energy is that it can be transported to very remote areas from where it is produced. In order for this transportation to be carried out efficiently and to reduce losses, the voltage must be sufficiently high [1, 2]. The voltage levels should be selected according to a certain optimization so that the incoming conductor cost does not increase too much. The voltage of alternating current electrical energy can be increased or decreased to the desired levels with the help of transformers [3, 4]. The voltage that is set to a certain level in the transformer centers is carried by the electricity distribution networks. The increasing need for electrical energy leads the organizations responsible for providing quality energy to the consumers with more detailed and careful planning and investment studies on the distribution networks [4, 5]. Energy should be continuous in electricity networks. If abnormal changes in current and voltage values for different reasons reach the dimensions that would damage the system, the power is interrupted.

In such cases, the protection relays operate, disabling the defective equipment [6, 7]. These unwanted interruptions in the electrical installation will affect the plant and the plant-related consumers. Therefore, the automation of electrical installations is very important. In automation, electrical power systems, it is ensured that an error is detected by continuously monitoring the system and opening of the breakers [8, 9].

Nowadays, it provides electricity transmission to provinces, districts, towns and smaller settlements via Transformer Centers. with increasing energy consumption and demand, the number of transformers is increasing rapidly and parallel to this, the problem of business is growing. For this purpose, energy transmitting institutions have entered a search for central control of substations. In this study, control of the transformer centers has been performed with artificial neural networks.

II. TRANSFORMER CENTERS

Energy transmission lines and transformer centers are given in Figure 1.

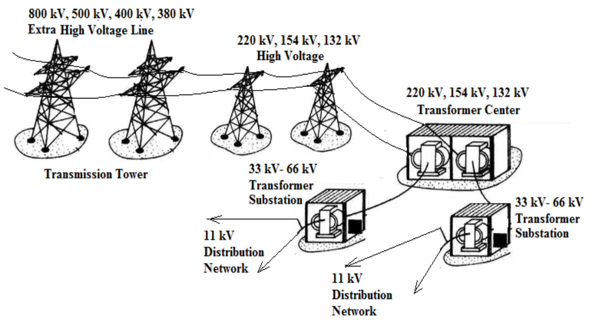

Figure 1. Energy transmission lines and transformer centers

The power plants are built away from consumption centers. The electrical energy produced in the power plants is delivered to the consumption centers with the help of the transformer centers. These centers include separators, breakers, bus bars, amplifying transformers, relays, fuses, output feeders and other auxiliary elements. Transformer centers receive power from one or more transmission networks and deliver it to the low voltage transmission networks.

The energy taken from the transformer centers is transformed into utilization voltages in the transformer branches. For voltages greater than 60 kV, these centers are installed in the open air because the volume of sections and switchgear materials will grow. For smaller voltages, they are installed inside the building. The electrical energy produced in power plants is around 13.7 kV. It is not economical to carry electrical energy at this voltage level. Transformer centers are needed to increase or decrease the voltage level. Outdoor voltage transformers do not have a voltage limitation.

Each transformer integrates with a central switchyard. Systems similar to the bus bar systems used in the power plants are applied here. The transformers are separated from the mains by a separate circuit breaker apart from the other installation. In the primary and secondary circuits of the transformers, each line to the grounding bus bar shall be provided with a control mechanism which can be controlled under voltage. There must be oil accumulation pits under the transformers. Necessary precautions must be taken when buildings for ventilation of the transformers. Switchgear facilities have high voltage, transformer and low voltage sections. The high-voltage section includes separators, breakers.

The transformer section includes transformers and ventilation and cooling systems. In the low voltage section there are cutters, separators and measuring instruments. All surge arresters and metal parts must be earthed in switchgear installations. Transformer branches serve as a bridge between high voltage and low voltage. The energy carried by high voltage is reduced to medium voltage by the help of transformer centers. The energy transmitted to the transformer branches as medium voltage is transformed into low voltage and distributed here. There is a medium voltage surge arriving at the energy input to the transformer branches.

In the medium voltage side of the transformer branches, transformer, bus bar, separator, breaker, power switches, current and voltage transformers, ground separators and surge arresters are located. On the low back side, there are output lines, automatic switches, fuses, some measuring instruments, voltmeter commutators, counters and street lamps with astronomer and photocell switches and time clocks.

Medium and low voltage sides are protected by separate surge arresters. Direct-type transformer branches are made up to 300 KVA power, and in larger powers pavilion type or tower type substations are constructed. For this type of transformer branches, there is a low voltage board near the place where they were installed. Fuse separators are used as high voltage tripping and protection device. The high voltage tripping device is connected to the surge arrester and transformer pole, provided that the bare voltage points are within the height specified in the regulations. Tower type transformer branches are installed in closed, tower-shaped buildings. The energy is taken from the air line with bushings, and after passing through the circuit breaker and fuse, it reaches the transformer. The surge arresters are grounded under the entrance gate isolator outside the tower.

Measuring elements and protection relays are connected to the circuit via current and voltage transformers [10, 11].

III. ARTIFICIAL NEURAL NETWORKS

A basic neural network cell is information processing systems that aim to learn, generalize, recall. Artificial nerve cell is the smallest and basic information processing unit that forms the basis for the operation of artificial neural networks (ANN). All neurons in the network receive one or more inputs and produce a single output. This output may be the output of the artificial neural network or used as input to other neurons. The components of the artificial cell model are inputs, weights, coupling function, activation function, and output [12]. A basic Artificial Neural Network Cell is shown in Figure 2.

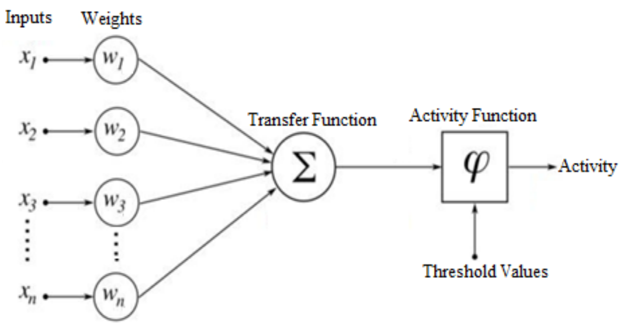

Figure 2. A basic Artificial Neural Network Cell

Data from the external environment is connected to the neuron via the weights and these weights determine the effect of the respective input. The total function calculates the net input, the net input is the result of multiplying the inputs and the weights associated with these inputs. The activity function (*af*) calculates the net output during the process and this process also outputs the neuron as Equation 1.

$$af = f(\sum_{i=1}^{n} W_i.X_i + C) \quad (1)$$

where, C is a constant and is the threshold value of the activation function, X is the inputs and W weights matrix as well as n is the number of entries. With various learning algorithms, the error is reduced and the actual output is approached.

The weights of the renewed artificial neural network during this study. Weights are tried to be achieved by renewing each cycle. The measure of reaching or approaching the purpose is also an external value. If the artificial neural network input-output pairs have reached the goal weight values are stored. Generally, 80% of the samples in the hand are given to the network and the network is trained. Then the remaining twenty percent is given and the behavior of the network is tested. Learning is achieved by observing the answers of the entries [13]. The following steps are followed in all learning algorithms. First, the inlet is propagated in the forward direction and then backward. Finally weights and balance are updated [14].

IV. THE IMPROVED CONTROL OF TRANSFORMER CENTERS USING ANN

Electrical components in the substation are low voltage winding, high voltage winding, magnetic core, low voltage input, high voltage input, tap changers, buchhozz relay, disconnectors, breakers, protection elements, fuses, surge arresters, protection conductor, grounding, protection relays, measuring instruments, measurement transformers, distribution boards and cables. Mechanical components are wave boiler, oil boiler, core, core components, sleepers, insulators, low voltage busing, high voltage busing, cylinder parts, connectors, busbar assembly, grounding inputs.

Causes of electrical failure in substation are static overvoltages, transient overvoltages, voltage fluctuations, lightning, atmospheric discharges, overload and heating effects, and changes in system frequency [15, 16]. Causes of mechanical failure are shock, shaking, crushing, bending, rupture, circuit connection errors, wrong relay work, incorrect relay coordination, foreign bodies, oscillations and vibrations [17, 18]. Causes of environmental failure at the substation; rain, fog, storm, snow, ice, climatic conditions, earthquakes, humidity, temperature, dust, oil, exhaust, such as pollution and chemical factors. The negativities of the environmental conditions in the substation damage the dielectric materials, insulators, cooling system and mechanical components [19-21]. The improved control system of Transformer Centers using Artificial Neural Networks is shown in Figure 3.

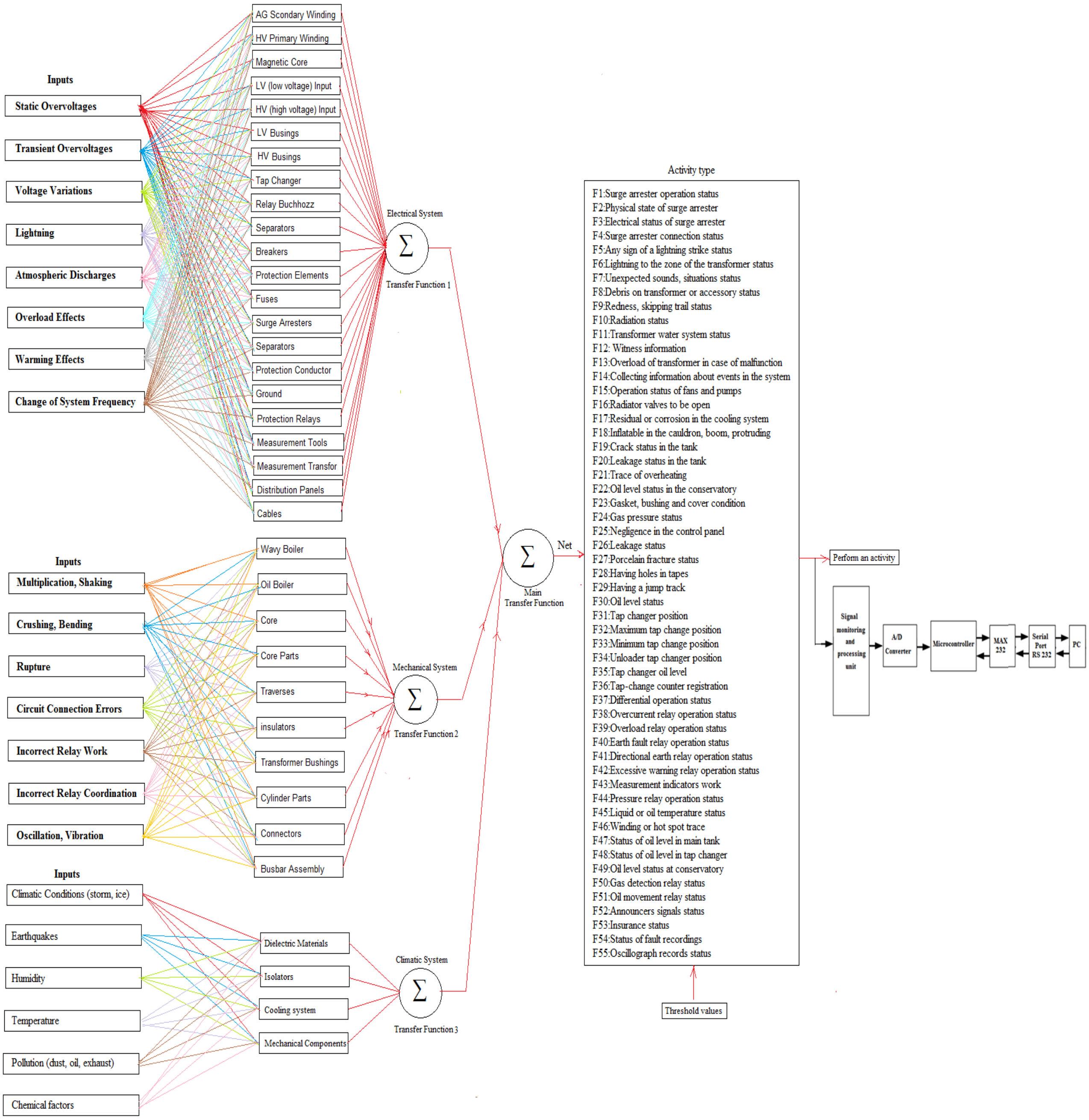

Figure 3. The improved control system of Transformer Centers using Artificial Neural Networks

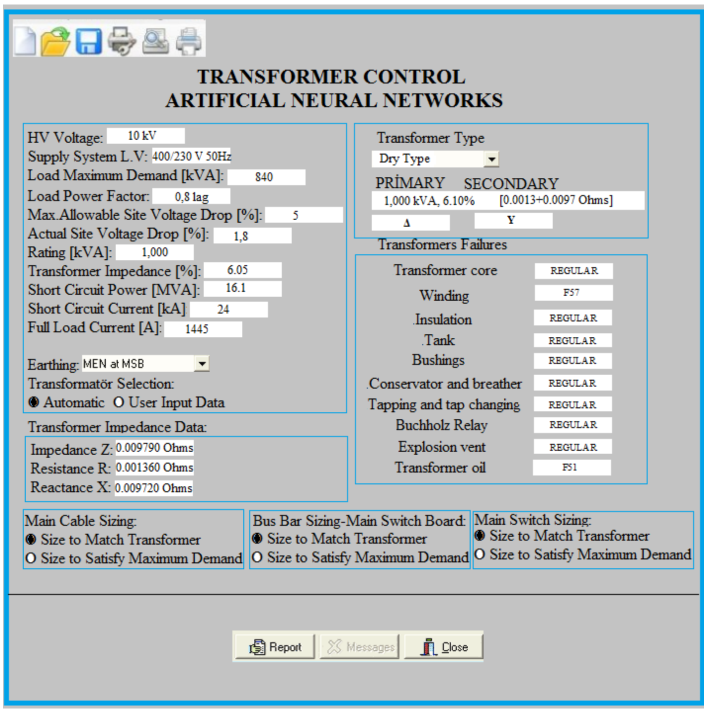

Figure 4. The improved computer interface of the transformer control system using Artificial Neural Networks

The improved computer interface of the transformer control system using ANN is given in Figure 4. In the laboratory environment, based on three-phase current and voltage measurements, the overcurrent and voltage limit values were compared with the measured current values. As a result, if the measured values are greater than the limit value, the relay coil that energizes the circuit breaker is energized. Over current and voltage failures occurred over the network. The microcontroller reads at short intervals. When fault information is received from any phase, the fault signal or breaker setup command has come through the local network.

Thus, the breaker is installed. The reading process has started again. The breaker trip relay coil remains energized and the circuit breaker is prevented from setting until the fault clearance or breaker setup command is received. The microcontroller and server in the circuit communicated with each other via the GPRS module. The microprocessor relays are connected to the RS 232 output of the relay and all the data are collected on the same screen with the computer interface that is created by the user equipment installed on the computer.

In digital protection and measuring units, all the values measured by the relays via serial port connections are seen. The measured current and voltage values from the network are sent to the GPRS module via serial communication and the fault information is sent to the server which is the server via GPRS. In addition, the measured current and voltage values are compared with the value set by the microprocessor. If the difference is more than the set value, the computer which is the server is sent the fault information in the same way. Measured current and voltage values are monitored. If a malfunction occurs, kind of malfunction occurs. Cutters can be intervened and opened at any time.

The breakers are activated by correcting the fault. The results obtained from transformers of different powers with secondary power of 400 kV with the developed control of Transformer Centers using ANN are given in Table 1.

Table 1. The results obtained from transformers of different powers with secondary power of 400 kV

Transformer Power (MVA)	Full Load Current (Amps)	Fault Current (kA)	Max. Current (kA)
500	715.06	3.16	6.89
250	350.48	6.59	13.94

The results obtained from transformers of different powers with secondary power of 220 kV with the developed control of Transformer Centers using ANN are given in Table 2.

Table 2. The results obtained from transformers of different powers with secondary power of 220 kV

Transformer Power (MVA)	Full Load Current (Amps)	Fault Current (kA)	Max. Current (kA)
250	645.23	5.93	13.94
100	258.79	2.34	4.86

The results obtained from transformers of different powers with secondary power of 110 kV with the developed control of Transformer Centers using ANN are given in Table 3.

Table 3. The results obtained from transformers of different powers with secondary power of 110 kV

Transformer Power (MVA)	Full Load Current (Amps)	Fault Current (kA)	Max. Current (kA)
100	218.61	4.67	9.92
50	257.38	2.17	4.92

The percentage errors of fault detect in the system are given in Figure 5. It is understood that the error in the data obtained from the developed system is between ±1% and ±5%.

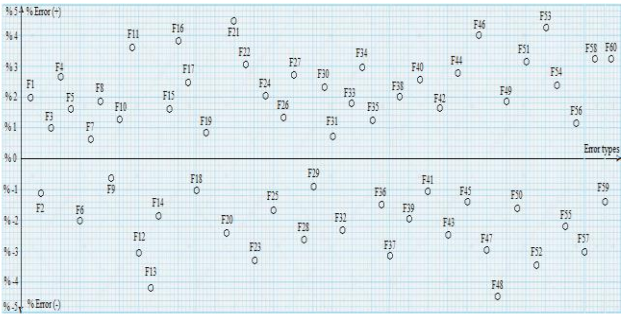

Figure 5. The percentage errors of fault detect in the system.

V. CONCLUSIONS

Substations are used to transmit electrical energy to the provinces, districts, towns and small settlements from where electricity is generated. In this study, new approaches have been introduced by using artificial neural networks. By the improved system formed on the basis of artificial neural network, it has become possible to monitor and control digital protection and measurement units used in substations and electricity distribution networks from remote local network.

Based on the three-phase current and voltage measurements performed in the laboratory, over current and voltage limit values were compared with the measured current values. In digital protection and measurement units, all values measured by the relays with the interface program created in the computer with serial port connections have been seen.

In modular cells with digital protection and metering cells, it has become possible to monitor the updated measurement values, three phase current average, currents of each phase, actual power, power factor, circuit breaker status, instantaneous value readings, and previous value record using local network connection.

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BIOGRAPHIES

Mehmet Zile was born in Ankara, Turkey, 1970. He received the B.Sc. degree from Yildiz Technical University, Istanbul, Turkey, the M.Sc. degree from Gazi University, Ankara, Turkey and the Ph.D. degree from Yildiz Technical University, all in Electrical and Electronic Engineering, in 1992, 1999, and 2004, respectively. Currently, he is an Assistant Professor of UTIYO at University of Mersin, Mersin, Turkey. He is also an academic member of UTIYO Information Systems and Information Technology Department at University of Mersin and teaches information systems and control systems. His research interests are in the area of control systems and electrical machines. He is a member of the International Electrical and Electronic Engineers (IEEE).