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SMART ENERGY MANAGEMENT IN SOLAR/WIND POWER STATIONS USING ARTIFICIAL NEURAL NETWORKS

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Abstract- Smart energy management algorithm Simulink block diagram was created by using artificial neural networks in the Solar/Wind Hybrid Power Plant. It is provided to determine the system operating conditions in many possible operating situations of Wind Power Plants (WPP) and Solar Power Plants (SPP). In addition, power and current parameters of sources and loads in SPP and WPP were determined. The created system controls the power flows in the system by deciding according to the possible working situations and works by conditioning each situation. Thus, it has been ensured that SPPs and WPPs provide the load demand continuously. The energy management system is provided to store energy by looking at the difference between the produced and demand energy. Thus, the energy management system is ready for any load demand at any time. Thus, the problem of discontinuous and unstable power generation, which is the biggest problem of solar/wind power stations, has been removed.

Keywords: Energy Management, Solar/Wind Power Stations, Artificial Neural Networks.

1. INTRODUCTION

Today, unpredictable fluctuations occur in energy prices. Energy resources are dwindling. It has become necessary to increase plant life and reduce maintenance costs. The increase in the use of energy creates environmental effects such as greenhouse gas emissions. For energy producers, reasons such as to stand out in the competition, to meet and exceed customer expectations, to effectively manage brand reputation and corporate responsibilities, and to benefit from incentive premiums require an effective energy management [1, 2].

Energy management has many purposes. Energy supply security and efficiency are ensured. Diversity in energy resources and the use of renewable energy sources are increased. Losses are reduced in electricity generation, transmission, distribution and use. Energy consumption is managed within the framework of energy management programs created by organizations in line with their energy policies and objectives and targets. Improvements are made by evaluating the performance of the energy management system [3, 4]. In this study, a smart energy management computer program had been created by using artificial neural networks in solar/wind power plants.

2. ENERGY MANAGEMENT IN SOLAR/WIND HYBRID POWER STATIONS

The energy management system block diagram is shown in Figure 1.

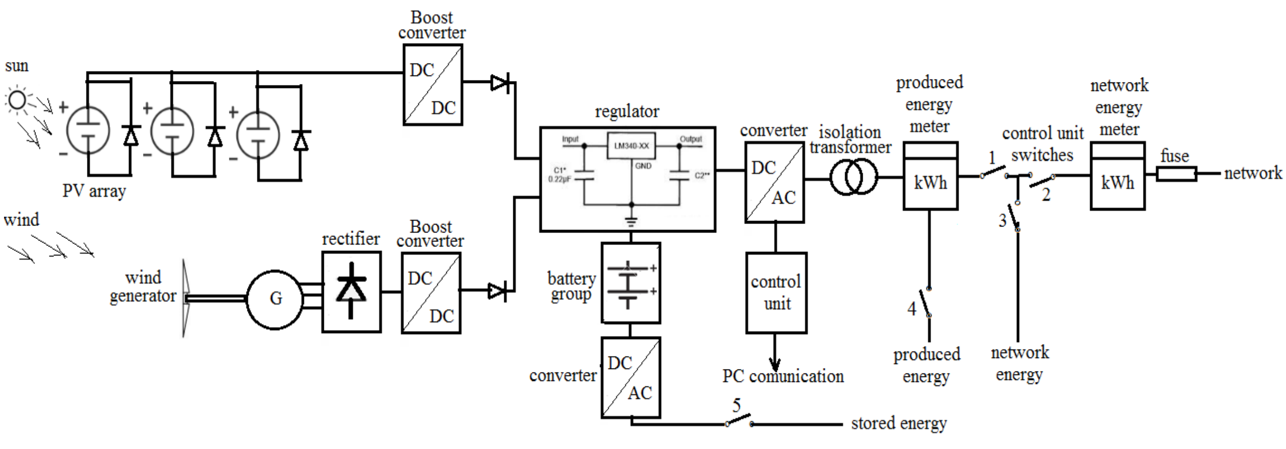

Figure 1. Energy Management System

Needs and targets are determined in smart energy management in solar/wind power plants. The solar/wind power plants, in which solar and wind energy are used jointly, have been designed and applied. Energy management processes are determined. After that, energy manager and other resources are determined. Plant measurement and monitoring plans are determined. Necessary procedures are prepared for this and applications are carried out. Internal audit, review and continuous improvement are the implementation steps of the system.

As a result of the development of smart energy management in solar/wind power plants; It is ensured that energy policy is formalized, energy consumption is managed with a systematic approach, reducing energy costs, protecting the environment, using resources effectively, reducing greenhouse gas emissions, ensuring compliance with the legislation, and being easily integrated with other management systems, especially the environmental management system. This provides real-time network information to distributors with network management and control by making decisions about distribution. Thus, by improving power quality, it increases its safety and economic operation of power plants. The relevant data and control planning at the distribution center and power plants is done over the internet.

Various operating parameters and switching states for the distribution center, switchboards and subsystems are made using telemetry and communication technology. The distribution center is controlled throughout the remote setting and control. With this study, it is aimed to use the energy management system and regionally distributed solar and wind resources optimally, to feed local loads, to reduce operating costs and to minimize emission levels.

3. ARTIFICIAL NEURAL NETWORKS

The basis of artificial neural networks (ANN) is the information processing function consisting of processes that require intelligence. This system consists of processing elements interconnected by one-way signal connections. The exit sign is one and can be duplicated upon request. There is a great similarity between the basic idea of the ANN approach and the functions of the human brain. The artificial neural network system can also be called the model of the human brain. ANN can shape their behavior according to environmental conditions [5-7]. It can adjust itself to give different answers by giving the inputs and desired outputs to the system. So, it is extremely flexible. However, it has an extremely complex internal structure. ANN have been composed elements that perform biological functions by taking the basic neurons as an example. A basic ANN Cell is shown in Figure 2.

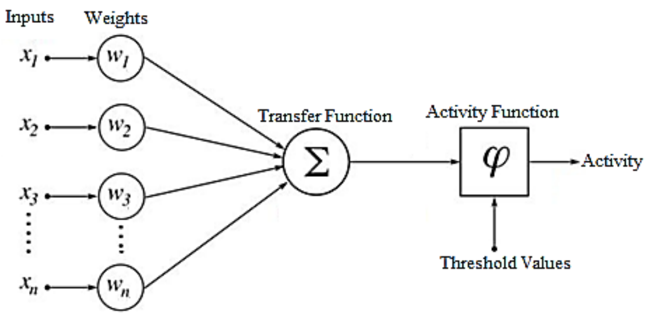

Figure 2. A basic Artificial Neural Network Cell

The threshold unit is the processing element that sums the outputs and produces an output only when the sum of the input exceeds the internal threshold. As a threshold unit, it takes the signals at the neuron synapses and sums them all up. If the collected signal strength is strong enough to exceed the threshold, a signal is sent along the axon stimulating other neurons and dendrites. Soma collects all the signals gated by synapses from the intersecting dendrites.

The total signal is then compared to the internal threshold of the neuron and if it exceeds the threshold, it emits a signal to the axon. ANN is created by connecting these simple neurons and transforming them into a network [8, 9]. The activity function (*af*) calculates the net output during the process and this process also outputs the neuron as Equation (1). The *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 [*k*].

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

The learning rule of neural networks depends on various control factors. Many points should be considered when choosing the convergence rate. In general, various factors such as the complexity of the network structure, size, parameter selection, architecture, type of learning rule and desired accuracy are the factors that determine how long the network will be trained.

4. SMART ENERGY MANAGEMENT IN SOLAR/WIND POWER STATIONS

Smart energy management algorithm Simulink block diagram was created by using artificial neural networks in the Solar/Wind Hybrid Power Plant. In Figure 3, the smart energy management block diagram using artificial neural networks in the Solar/Wind Hybrid Power Plant is given.

In Figure 4, the Solar/Wind Energy Management Program interface, which is created in the visual studio and C++ programs, is given. By entering the current temperature, air pressure, humidity, solar radiation, wind direction and wind speed data obtained from the tower sensors, the weather forecast is made for the desired day and time in the future by crossing it with the geographical locations of the sun and wind power plant. Again, by entering the current temperature, air pressure, humidity, solar radiation, wind direction and wind speed data, the energy production forecast is made for the desired day and hour in the future by crossing it with the energy production capacities of the solar and wind power plant.

Load estimation is made by crossing the previously determined public holidays, industrial production plans, system topology, environmental restrictions, contractual restrictions, demanded energy values and percent active working status of the power plants. Unit characteristics, stored energy states, referenced energy activation states, central unit characteristics, current change data and percent active operating status of the plants are crossed to determine the unit. The microcontroller and the server in the system communicate with each other via the GPRS module. Microprocessor relays are connected to the RS 232 output of the relay. With the computer interface created by the user equipment installed on the computer, all data is collected on the same screen. All values measured by relays can be seen with serial port connections in measurement units. The current and voltage values measured from the network are sent to the GPRS module via serial communication. The data received over GPRS is sent to the server. There are many possible operating states of solar power plants (SPP) and wind farms (WPP). All possible operating conditions in the system are determined. In addition, the current and power parameters of solar/wind energy sources and user loads in SPP and WPP are determined. The created system controls the current flows in the energy management system by deciding according to the possible working situations and works by conditioning each situation. The basic duty of SPPs and WPPs is to supply the load demand continuously. Then, it is to keep the battery and ultracapacitor group charged by looking at the difference between the produced and demand energy. Thus, the system becomes ready in response to the load demand at any time.

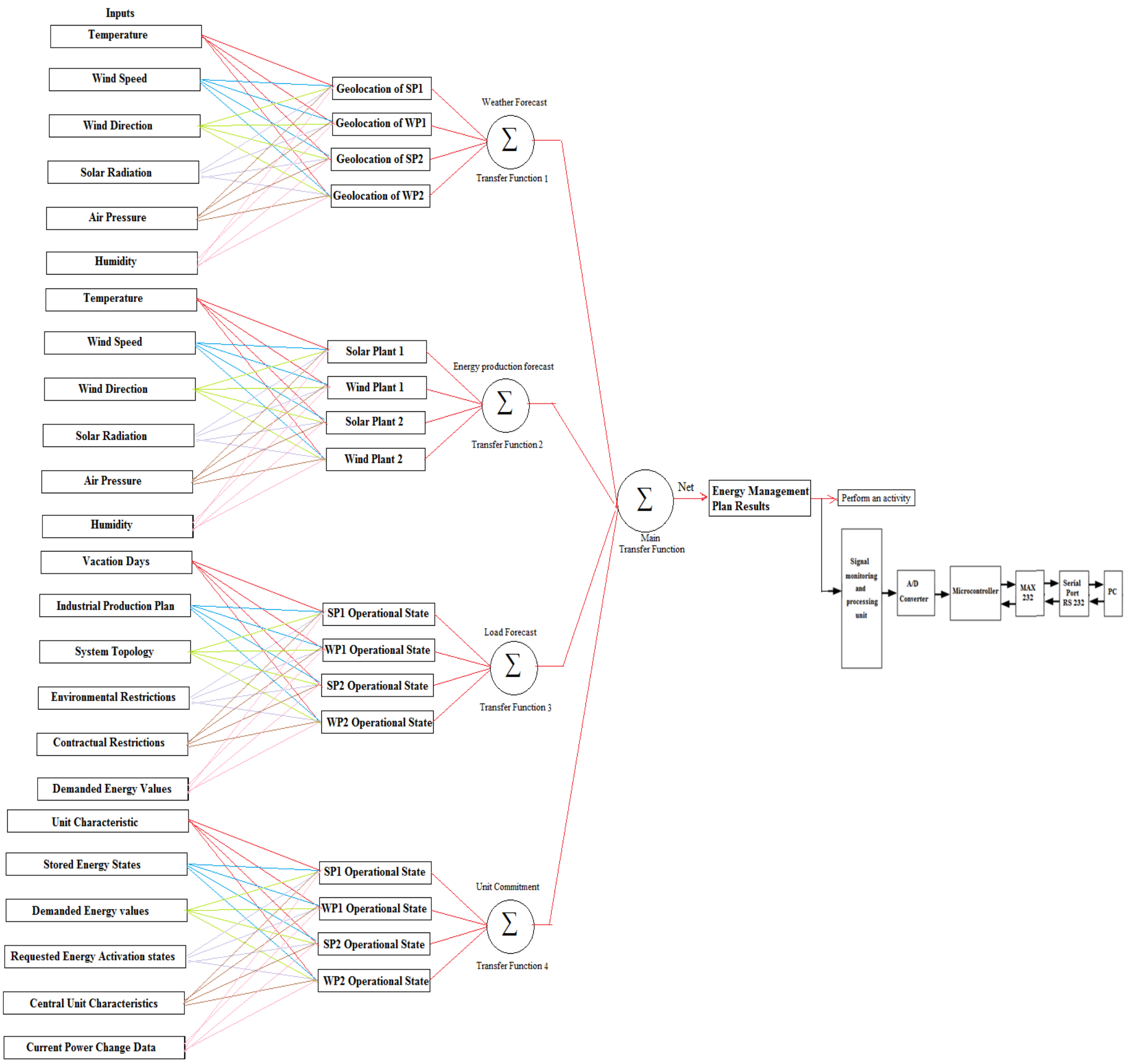

Figure 3. The block diagram of solar/wind energy management

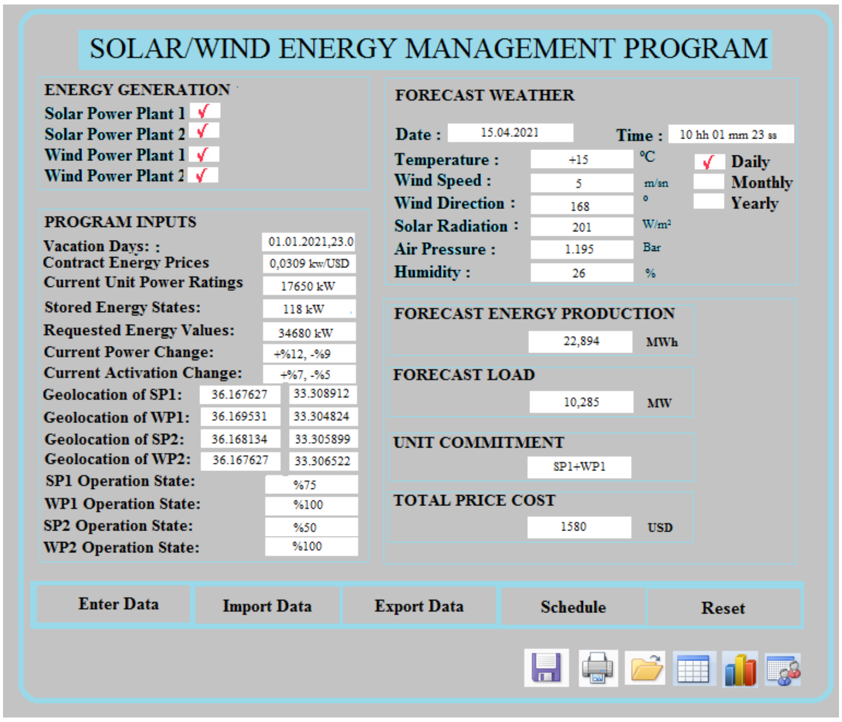

Figure 4. Solar/Wind energy management program interface

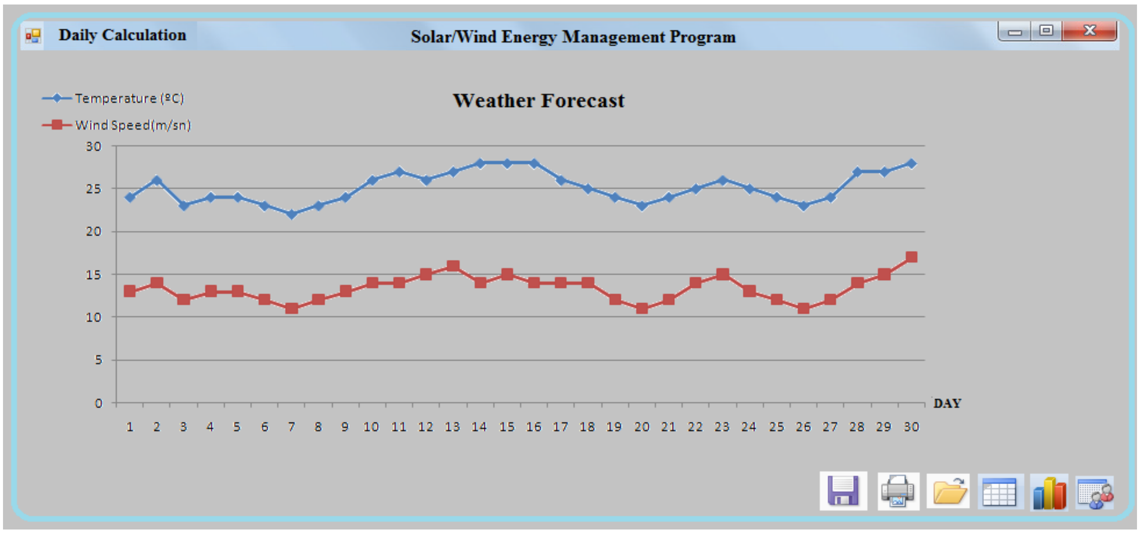

Figure 5. Weather forecast results

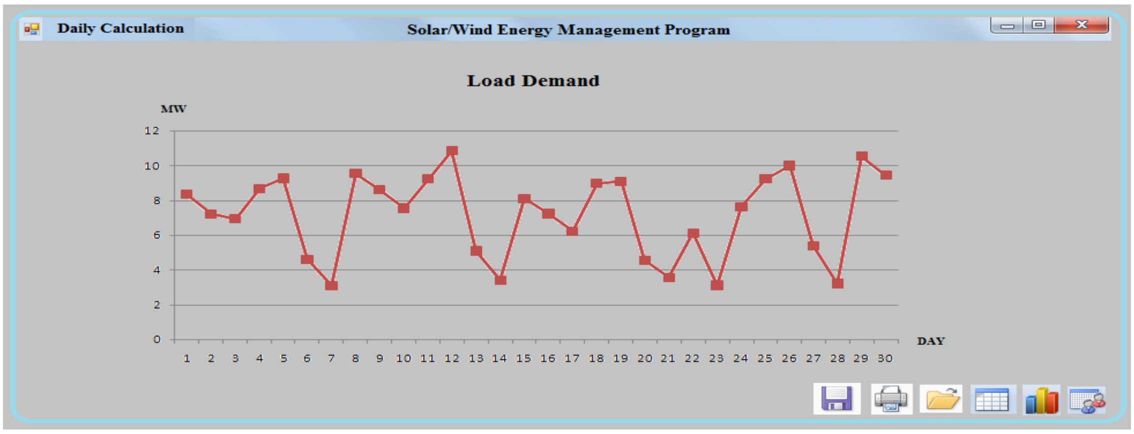

Figure 6. Load demand results

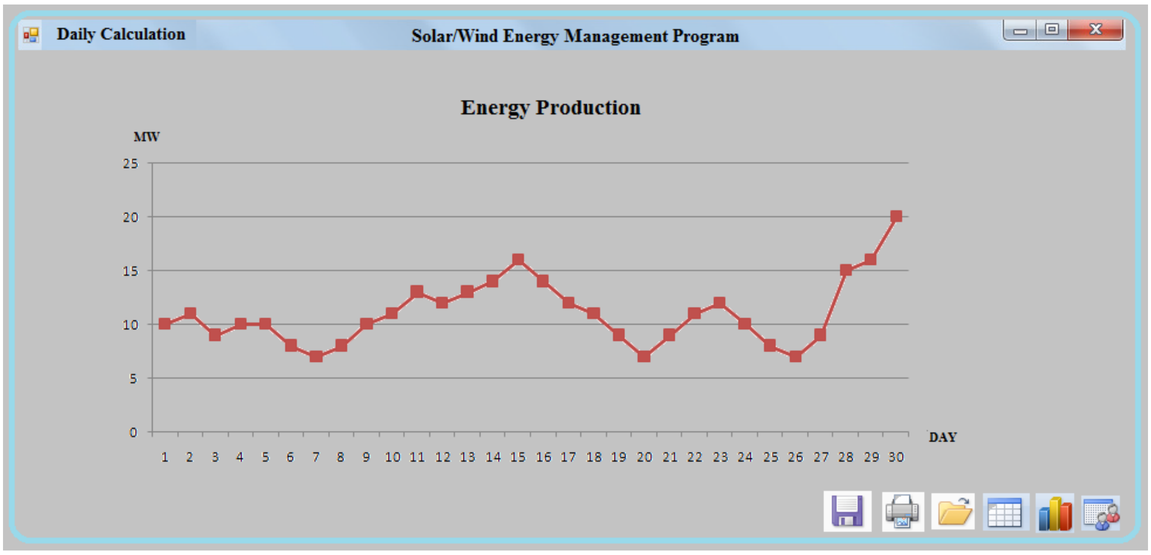

Figure 7. Energy production results

The created algorithm of solar/wind energy management not only compute the current amount of the units by looking at the power values, but also provides control of all converter components in the management system. The solar/wind energy management algorithm aims to operate the management system stably by looking at the load demand power and generated power value of SPPs and WPPs by continuously scanning the management system in 1 µs time. At the same time, by performing the energy storage process, it provides the power requirement of the load with the storage components when the SPP and WPP units do not produce energy during certain periods of the day. Thus, the problem of intermittent and unstable energy production, which is the biggest problem of solar/wind energy sources, is removed.

The management algorithm of solar/wind energy power plants not only computes the current amount of the units by looking at the power values, but also provides control of all converter components in the management system. The created management algorithm of solar/wind power plants aims to operate the management system stably by looking at the load demand power and generated power value of SPPs and WPPs by continuously scanning the system in 1 µs time. At the same time, by performing the energy storage process, it provides the power requirement of the user load with the storage units when the SPP and WPP units do not produce energy during certain periods of the day.

Thus, the problem of unstable and intermittent energy production, which is the biggest problem of solar/wind power plants, is removed. By the created program, the daily, monthly and yearly current weather forecast, the amount of power demanded and the amount of power produced by renewable energy sources can be seen on the program screen. Values taken over each time period are recorded and value graphs drawn. Weather forecast results are given in Figure 5, load demand results are given in Figure 6 and energy production results are given in Figure 7.

As seen in Figure 5, there are variations in solar radiation and wind speed on consecutive days. These differences cause the power obtained from solar panels and wind turbines to vary depending on meteorological conditions. The maximum air temperature is 28 ºC on the 14th day of the month, and the minimum air temperature is 22 ºC on the 7th day of the month. The maximum wind speed is 17 m/s on the 30th day of the month and the minimum wind speed is 10.8 m/s on the 26th day of the month. As can be seen in Figure 6, the amount of power demanded differs in successive days. These differences are due to changes in industry demands, holidays and living conditions.

The maximum demand power amount was 10.8 MW on the 12th day of the month and the minimum demand power amount was 2.8 MW on the 23rd day, which is a public holiday. Average daily demand power was 7.2 MW. As can be seen in Figure 7, the amount of power produced from renewable energy sources differs in successive days. These differences are due to changes in meteorological conditions. The maximum amount of power produced is 20 MWh on the 30th day of the month and the minimum amount of power produced is 6.8 MWh on the 20th day of the month. The daily average amount of energy produced is determined as 12 MWh.

In case the amount of energy produced is more than the amount of power demanded, the excess energy is transferred to the interconnected grid system. When the demanded energy is more than the energy produced, additional energy is provided from the interconnected network and the battery system. The energy demanded from the wind energy during the absence of the sun, and from the solar energy when there is no wind, was met. When the energy produced is more than the energy demanded, the excess energy produced is transferred to the interconnected grid system and additional batteries are charged. The simulation results of the Solar/Wind Energy Management Program created with artificial neural networks were compared with the real data obtained from the power plants.

The error rate between the energy production estimate obtained from the computer program created and the actual energy production value obtained from the power plant was ± %5 percent. The error rate between the load estimate obtained from the computer program and the actual load value was ±3% percent. The error rate between the energy costs obtained from the computer program and the actual energy costs at the power plants was ± %8 percent. For this reason, it is understood that the simulation results of the Solar/Wind Energy Management Program created with artificial neural networks are successful. There is no solar/wind power plant energy management program using artificial neural networks in the literature and industry. For this reason, there is no computer program or method that can be compared with this method and the computer program created with this method.

5. CONCLUSIONS

Solar/Wind Energy Management Program was created on the basis of artificial neural networks. With the computer program prepared using C++ and Visual Studio package program, it is possible to make weather forecast, load demand forecast, power forecast from renewable energy plants power generation units and unit determination. By using this computer program, it is aimed to make optimal use of regionally distributed resources, to feed local loads, to reduce operating costs and to minimize emission levels. It is possible to analyze the obtained data daily, monthly and annually with graphics.

The simulation results of the Solar/Wind Energy Management Program created with artificial neural networks were compared with the real data obtained from the power plants. The error rate between the energy production estimate obtained from the computer program created and the actual energy production value obtained from the power plant was ±5% percent. The error rate between the load estimate obtained from the computer program and the actual load value was ±3% percent. The error rate between the energy costs obtained from the computer program and the actual energy costs at the power plants was ±8% percent. For this reason, it is understood that the simulation results of the Solar/Wind Energy Management Program created with artificial neural networks are successful.

The energy management system is provided to store energy by looking at the difference between the produced and demand energy. Thus, the energy management system is ready for any load demand at any time. Thus, the problem of discontinuous and unstable power generation, which is the biggest problem of solar/wind power stations, has been removed. Further studies will be created by adding different production units according to the situation of different renewable resources in the region to be established. With the implementation of such a system, the use of renewable energy resources will be encouraged, environment and country's economy will be contributed, and dependence on fossil fuel energy production in electricity energy production will be reduced.

REFERENCES

[1] M. Marzband, N. Parhizi, J.M. Adabi, "Optimal Energy Management for Stand-Alone Microgrids Based on Multi Period Imperialist Competition Algorithm Considering Uncertainties: Experimental Validation", International Transactions Electric Energy Systems, Vol. 26, pp. 1358-1372, 2016.

[2] T. Liu, X. Tan, B. Sun, "Energy Management of Cooperative Microgrids: A Distributed Optimization Approach", International Journal of Electrical Power & Energy Systems, Vol. 96, pp. 335-346, 2018.

[3] J. Sarshar, S.S. Moosapour, M. Joorabian, "Multi-Objective Energy Management of a Micro-Grid Considering Uncertainty in Wind Power Forecasting", Energy, Vol. 139, pp. 680-693, 2017.

[4] V.S. Tabar, M.A. Jirdehi, R. Hemmati, "Energy Management in Microgrid Based on The Multi Objective Stochastic Programming Incorporating Portable Renewable Energy Resource as Demand Response Option", Energy, Vol. 118, pp. 827-839, 2017.

[5] S. Haykin, "Neural Networks and Learning Machines", 3rd Edition, Pearson Prentice Hall, 2008.

[6] S. Srivastava, K.C. Tripathi, "Artificial Neural Network and Non-Linear Regression: A Comparative Study", International Journal of Scientific and Research Publications, Vol. 2, No. 12, 2012.

[7] A. Landi, P. Piaggi, M. Laurino, D. Menicucci, "Artificial Neural Networks for Nonlinear Regression and Classification", 10th International Conference on Intelligent Systems Design and Applications, 210, Cairo, Egypt, 29 November-1 December 2010.

[8] M. Zile, "Improved Control of Transformer Centers Using Artificial Neural Networks", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 40, Vol. 11, No. 3, pp. 28-33, September 2019.

[9] M. Zile, "Design of Power Transformers Using Heuristic Algorithms", International Journal on Technical and Physical Problems of Engineering, (IJTPE), Issue 38, Vol. 11, No. 1, pp. 42-47, March2019.

BIOGRAPHY

Mehmet Zile was born in Ankara, Turkey, 1970. He received the B.Sc. degree from University of Yildiz (Istanbul, Turkey), the M.Sc. degree from University of Gazi (Ankara, Turkey) and the Ph.D. degree from University of Yildiz, 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 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 IEEE.