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Development of a simulation model for assessing the technical condition of transformers exploited in hydroelectric stations

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Abstract. Supplying consumers with continuous electricity is one of the urgent problems of today. The main part of electricity is produced by hydroelectric stations. The perfect operation of the main electrical equipment of hydroelectric power stations is related to the reliable operation of the electrical equipment in operation. The flawless operation of power transformers in operation at hydroelectric power stations is evaluated by their technical condition. The technical condition of power transformers is determined by their electrical and non-electrical indicator values. In this article, a simulation model for determining the value of the technical condition of power transformers in operation at hydroelectric power stations using fuzzy logic has been developed.

1. Introduction

The developing world cannot be imagined without electricity. Supplying consumers with continuous electricity is one of the urgent problems of today. Production of electricity requires a lot of money and natural conditions. The use of renewable energy is getting more attention worldwide. To test control principles as they operate in electric power systems (EPS), mathematical models must be developed. Hydroelectric power plants (HPP) models, which are "traditional" renewable energy sources, also need to be modified [1, 2]. Such innovations are becoming more important for HPPs involved in the cascade. It is well known that water pressure and flow rely on the power of a hydroelectric power plant and a cascade as a whole. Hydroelectric power plants - hydroelectric power plants are the most common power plants and are a set of structures and equipment that convert the energy of water flow into electricity [3-6]. Uninterrupted supply of electricity to consumers is closely related to the reliable and continuous operation of hydroelectric power plants. The reliable and long-term operation of hydroelectric power plants is related to the reliable operation of their constituent devices: Hydro turbine, Hydro generator and Transformers. In modern conditions, increasing the operating efficiency of electrical networks is associated with the use of diagnostic control (monitoring) technology, which provides assessment and prediction of the condition of transformers, as well as determining the optimal frequency of maintenance and repair activities in terms of operational reliability. As is known, the technology of diagnostic control (monitoring) is based on measurements and interpretation of diagnostic information, identifying signs of developing defects, establishing criteria for recognizing the type of defects and assessing the condition of transformers. The lack of universal approaches that make it possible to obtain, on a unified methodological basis, a description of the reliability indicators of transformers depending on changes in operational factors and state parameters, makes it difficult to solve problems within the framework of this technology and limits the scope of its effective application. Determining the value of the condition of transformers makes it possible to prevent possible failures in them [3-7]. Modern systems based on artificial intelligence (SI) tools, such as artificial neural networks (SNT) and artificial fuzzy logic (SNM), can solve this problem due to the ability to learn input data and perform approximate calculations [7-16]. In order to evaluate the technical condition of the transformer, it is necessary to determine the parameters describing its condition.

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2. Methods

In order to assess the condition of transformers in operation at hydroelectric power stations, data on their main electrical and non-electrical indicators was collected. Based on the collected data, a program was developed that calculates the condition of transformers in operation at hydroelectric power stations with the help of Matlab software.

Insulation resistors ($R_{izol.Y_k-P_k+k}$, $R_{izol.P_k-Y_k+k}$, $R_{izol.P_k+Y_k-k}$,), absorption coefficients ($\frac{R_{60\,(Y_k-P_k+k)}}{R_{15\,(Y_k-P_k+k)}}$, $\frac{R_{60\,(P_k-Y_k+k)}}{R_{15\,(P_k-Y_k+k)}}$, $\frac{R_{60\,(Y_k+P_k-k)}}{R_{15\,(Y_k+P_k-k)}}$), winding resistors ($R_{yuq.A-B}$, $R_{yuq.A-C}$, $R_{yuq.B-C}$, $R_{past.A}$, $R_{past.B}$, $R_{past.C}$), transformer temperature (T_{Tr}),vibration level ($\forall_{trans}$) are the main indicators that provide information about the condition in the transformer.

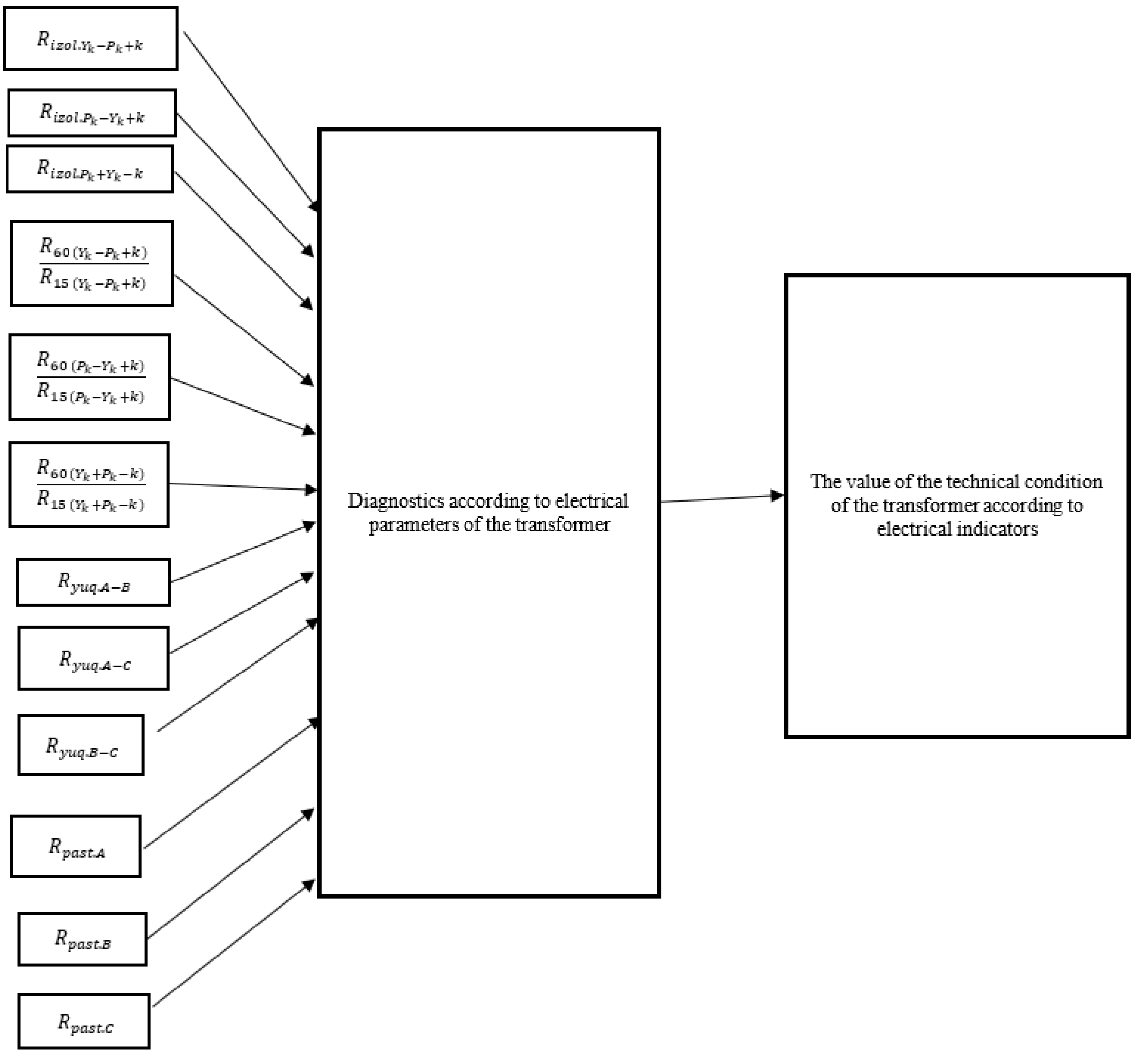

Fig. 1. Structural scheme for determining the value of the technical condition of the transformer on electrical indicators

In determining the condition of the transformer from two non-specific inputs:

- Condition of the transformer by electrical indicators;
- Consists of the condition of the transformer in terms of nonelectric indicators.

Insulation resistors($R_{izol.Y_k-P_k+k}$, $R_{izol.P_k-Y_k+k}$, $R_{izol.P_k+Y_k-k}$,),) absorption coefficients ($\frac{R_{60\ (Y_k-P_k+k)}}{R_{15\ (Y_k-P_k+k)}}$, $\frac{R_{60\ (P_k-Y_k+k)}}{R_{15\ (P_k-Y_k+k)}}$, $\frac{R_{60\ (Y_k+P_k-k)}}{R_{15\ (Y_k+P_k-k)}}$,) , lead resistors ($R_{yuq.A-B}$, $R_{yuq.A-C}$, $R_{yuq.B-C}$, $R_{past.A}$, $R_{past.B}$, $R_{past.C}$) are accepted as input variables in determining the technical condition of the transformer through electrical indicators.

It is convenient to use the "if-then" rule when assessing the technical condition of electrical devices in operation at hydroelectric power plants. If the condition of the hydro turbine is good and the condition of the hydro turbine is good and the condition of the transformer is good, then the technical condition of the hydroelectric power plant should be in good condition. Indicators defining such a situation are given in numerical value, and several rules are used to convert them into linguistic indicators. Fuzzy logic is one of these methods.

Let's take a closer look at each step of creating a neural network model. The connection between input and output variables is made by the "If-Then" (If-Then) rule. For example, let the insulation resistance $R_{izol.Y_k-P_k+k}$ be a "**bad**" indicator, then the state of the transformer can be in a "**bad**" state.

Evaluation of output as well as input variables is done using five terms: "very bad", "bad", "good", "above normal", "Excellent".

3. Results

Figure 2 presents a function of the change in the value of the state of the output variable (the value of the condition of the transformer).

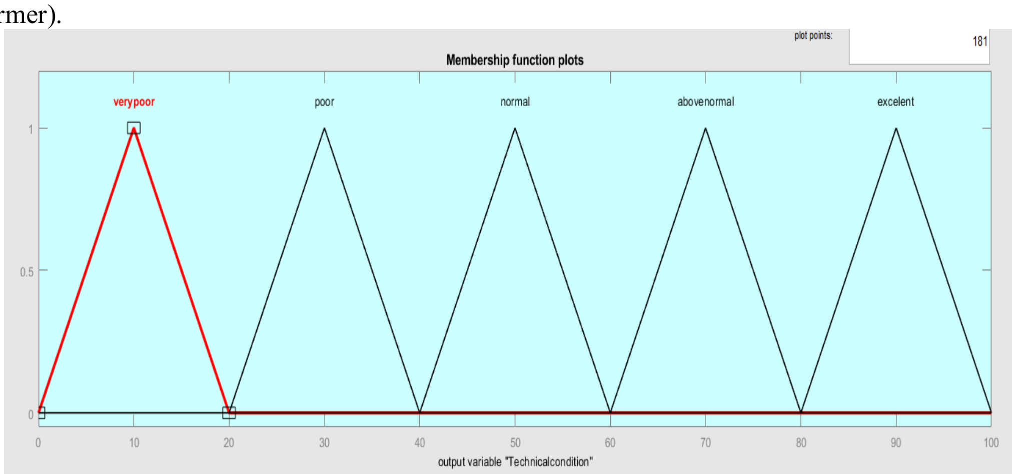

Fig. 2. The output is the regularity of the variable "Condition value of the transformer"

Output The variable "Transformer condition value" is evaluated between 0 and 100 (where 0 is the lowest value, 100 is the highest value of the transformer condition).

If the output value is between [0:20], the condition of the transformer is very poor.
If the output value is between [20:40], the condition of the transformer is poor.
If the output value is between [40:60], the condition of the transformer is normal.
If the output value is between [60:80], the condition of the transformer is above normal.
If the output value is between [80:100], the condition of the transformer is excellent.

Transformer temperature (T_{Tr}), vibration level ($\forall_{trans}$) are accepted as input variables when determining the condition of the transformer by means of non-electrical indicators.

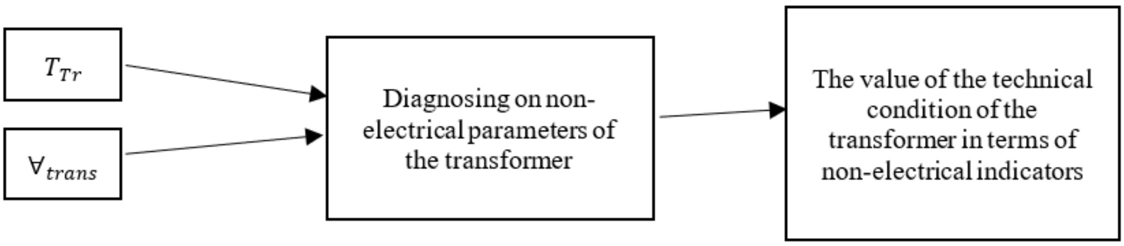

Fig. 3. The structural scheme of determining the value of the condition of the transformer according to non-electrical indicators

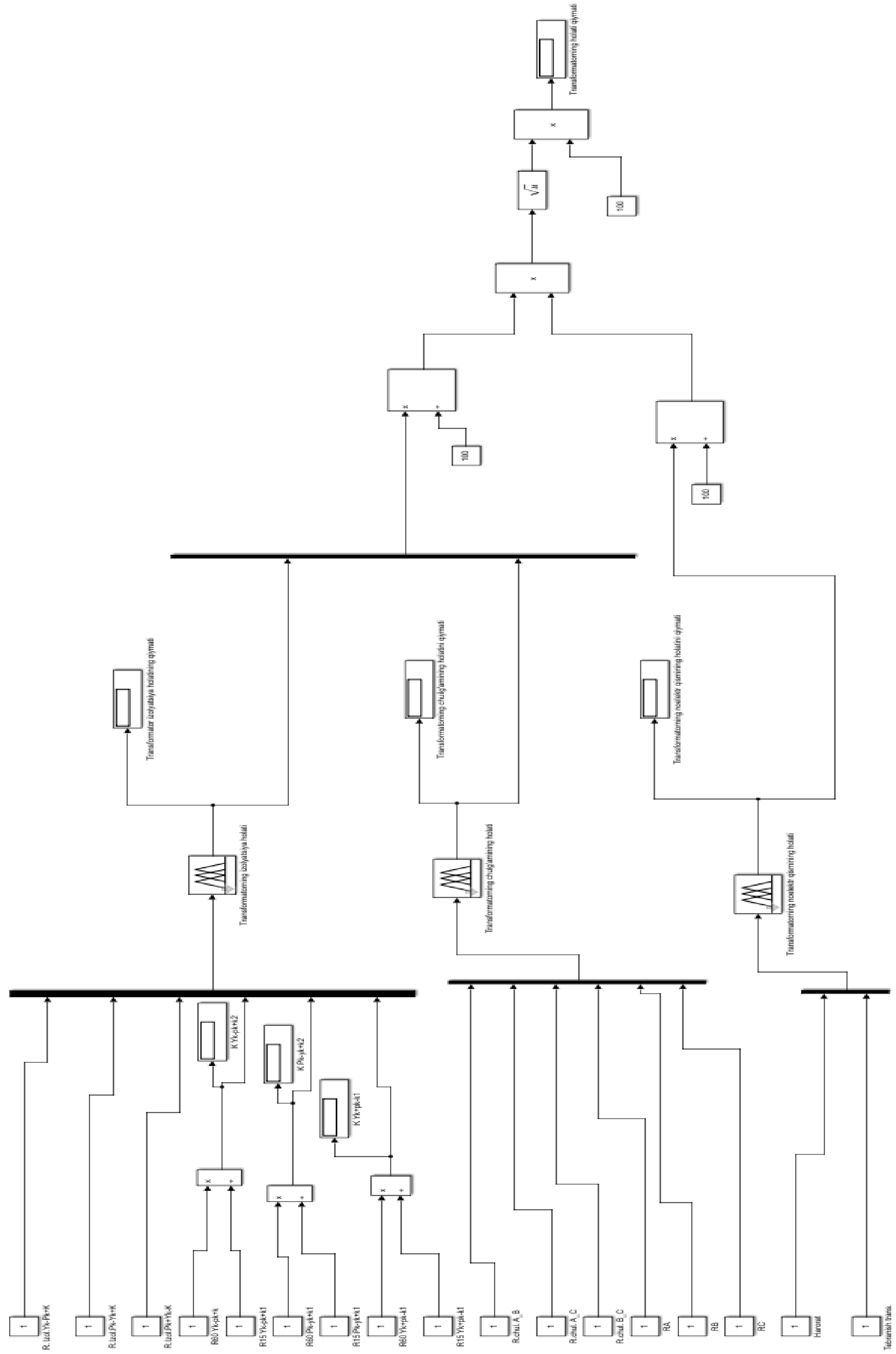

Fig. 4. Simulink model of transformer technical assessment

To determine the general technical condition of the transformer, we take as the average value of the values of the transformer according to electrical indicators and non-electrical indicators:

$$TH_{tr} = \sqrt{TH_{trans.el} \cdot TH_{trans.noel}}$$

Here

$TH_{trans.el}$ – the condition of the transformer determined by electrical indicators;

$TH_{trans.noel}$ – the condition of the transformer determined by non-electrical indicators;

The mathematical model that calculates the condition of the transformer based on electrical and non-electrical indicators is presented in Figure 4.

The mathematical model calculates the absorption coefficients and the general condition of the transformer depending on the value of the input variables.

4. Conclusion

The structural schemes for determining the value of the condition of transformers in operation at hydroelectric power plants according to their electrical and non-electrical indicators have been developed. An imitation model was developed that calculates the condition of transformers in operation at hydroelectric power plants. The developed model allows to calculate the value of the condition of the transformer according to the diagnostic parameters of the transformer. Through the calculated value, it is possible to predict in which part of the transformer a fault may occur.

References

1. D. Kodirov, O. Tursunov, K. Karimova, N. Akramova, S. Parpieva, B. Shafkarov, Application of hydro energy in small power supply systems, *IOP Conf. Ser.: Earth Environ. Sci.* **614**, 012037 (2020)
2. D. Kodirov, K. Muratov, O. Tursunov, E.I. Ugwu, A. Durmanov, The use of renewable energy sources in integrated energy supply systems for agriculture, *IOP Conf. Ser.: Earth Environ. Sci*. **614**, 012007 (2020)
3. M. Sahu, A. Barve, Reliability and Availability Evaluation of Hydro Power Station, *International Journal on Emerging Technologies* **4**, 89-93 (2013)
4. P.U. Okorie, A.M.S. Tekanyi, A.A. Sadiq, Assessment of the Reliability Performance of Shiroro HydroelectricPower Station, Minna, Niger State, *Futo Journal Series (FUTOJNLS)* **5**, 141-150 (2019)
5. D. Kodirov, O. Tursunov, K. Karimova, N. Akramova, S. Parpieva, B. Shafkarov, Application of hydro energy in small power supply systems, *IOP Conf. Ser.: Earth Environ. Sci*. **614**, 012037 (2020)
6. D.T. Yusupov, O.M. Kutbidinov, Sh.A. Samadov, E.S. Abdullaev, Investigation of winding faults of traction transformers, *IOP Conference Series: Earth and Environmental Science* **868**, 173024 (2021)
7. T. Yusupov, M. Rakhmatova, Sh. Tashmatova, Study of optimal temperature during adsorption cleaning of transformer oil under conditions of long-term operation, *E3S Web of Conferences* **383**, 04058 (2023)
8. K. Muratov, O. Ishnazarov, A. Isakov, I. Nuritov, Assessment of effect of lining material on energy efficiency of starting up ball mills, *E3S Web of Conferences* **365**, 04005 (2023)
9. Bimal Bose, Expert System, Fuzzy Logic, and Neural Network Applications in Power Electronics and Motion Control, *Proceedings of the IEEE* **82**(8), 1303 – 1323 (1994)
10. O.A. Nazarov, D.T. Yusupov, R.F. Yunusov, S.A. Shoyusupov, Q.S. Tolipov, Assessment of technical state of power transformers based on dissolved gas chromatographic analysis in oil, *Journal of Physics: Conference Series* **2176**(1), 012001 (2022)
11. O.V. Kryukov, A.V. Serebryakov, Method and decision-making system for predicting the technical condition of electric gas pumping units, *Elektrotekhnicheskie sistemy i kompleksy* **4**(29), 35–38 (2015)
12. A.M. Denmukhammadiev, D.T. Yusupov, S.A. Shoyusupov, A.U. Djalilov, O.A. Nazarov, Diagnostics of power transformers operating for many years in the power supply system through gases in the composition of transformer oil, *Journal of Physics: Conference Series* **2176**(1), 012064 (2022)
13. A.S. Steklov, D.S. Podkovyrin, Neuro-fuzzy model for diagnosing the technical condition of a synchronous generator, *Chief Power Engineer* **11–12**, 55–60 (2015)
14. A.P. Lapthorn, A 15 kVA high-temperature superconducting partial-core transformer — Part 1: Transformer modeling, *IEEE Trans. On Power Delivery* **28**, 245-252 (2013)
15. A.S. Steklov, D.S. Podkovyrin, Neuro-fuzzy model for diagnosing the technical condition of a synchronous generator, *Chief Power Engineer* **11–12**, 34–42 (2015)
16. E.S. Abdullaev, O.M. Qutbidinov, D.T. Yusupov, Sh.X. Khakimov, Development of an electronic recording system of traction transformers, *Farpi scientific and technical journal* **26**, 228-233 (2022)