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Research Paper

SYNTHESIS OF AN AUTOMATED CONTROL SYSTEM FOR THE FLOW OF ACTIVE POWER ALONG A POWER LINE IN OVERLOAD CONDITION

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Abstract

Currently, there are practically no automated systems for controlling power flow within the specified limits when the power line is overloaded by active power. Regulation is assigned to the dispatchers of the power system or is carried out by means of emergency automation, which disconnects consumers. Therefore, an urgent task is to expand the arsenal of tools for automatic control of active power flow in overload mode. **Relevance.** A significant increase in electricity consumers leads to a complication of the electric power system. The workload for dispatching personnel is increasing. Maintaining the smooth operation of the elements of the power system is a very important and responsible task. In modern electric power industry, timely warning and elimination of overloads of network elements are relevant. **The study aims** are development and research of an intelligent automatic control system for the flow of active power along a power line based on the mathematical apparatus of fuzzy logic. The system is based on the use of the regulating effect of the load. **Research methodology.** Methods of calculating static load model during their actualization were used. The method of fuzzy sets was used in the construction of an intelligence control system for active power flows in overload condition. The effectiveness was estimated by expert methods. **Results.** The use of artificial intelligence methods for automatic regulation of transformer voltage under load allows up to 5–7 % reducing the flow of active power in overload mode.

Keywords: overload, automation, power systems, voltage regulation under load.

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1. Introduction

The overload condition is characterized by deviations of the operating parameters and the achievement of the highest value of the permissible flow of active power through power lines. This condition requires rapid elimination and entry of overflow parameters within allowable limits. It is most effective to solve this problem by means of automatic condition control. At the same time, it is desirable to avoid the operation of emergency automation, which turns off some consumers. In the works [1, 2] it is proved that, using the data of static load model (SLM), it is possible to reduce the power flow by 5–7 % by influencing the voltage. The voltage is changed by raising the excitation on the generation, changing the transformation ratio and using reactive power compensating devices [3]. In this article, the possibility of using an automatic voltage regulator of a transformer on-load tap-changer (AROLTC) is investigated. The automatic regulator uses data from a special monitoring program with SLM.

Problem statement – synthesis of the OLTC system software package using SLM data to control the flow of active power. The power line does not have reactive power compensation devices.

2. Automatic voltage regulation under load

SLM reflects the properties of the load, manifested by slow changes in the parameters of the condi-

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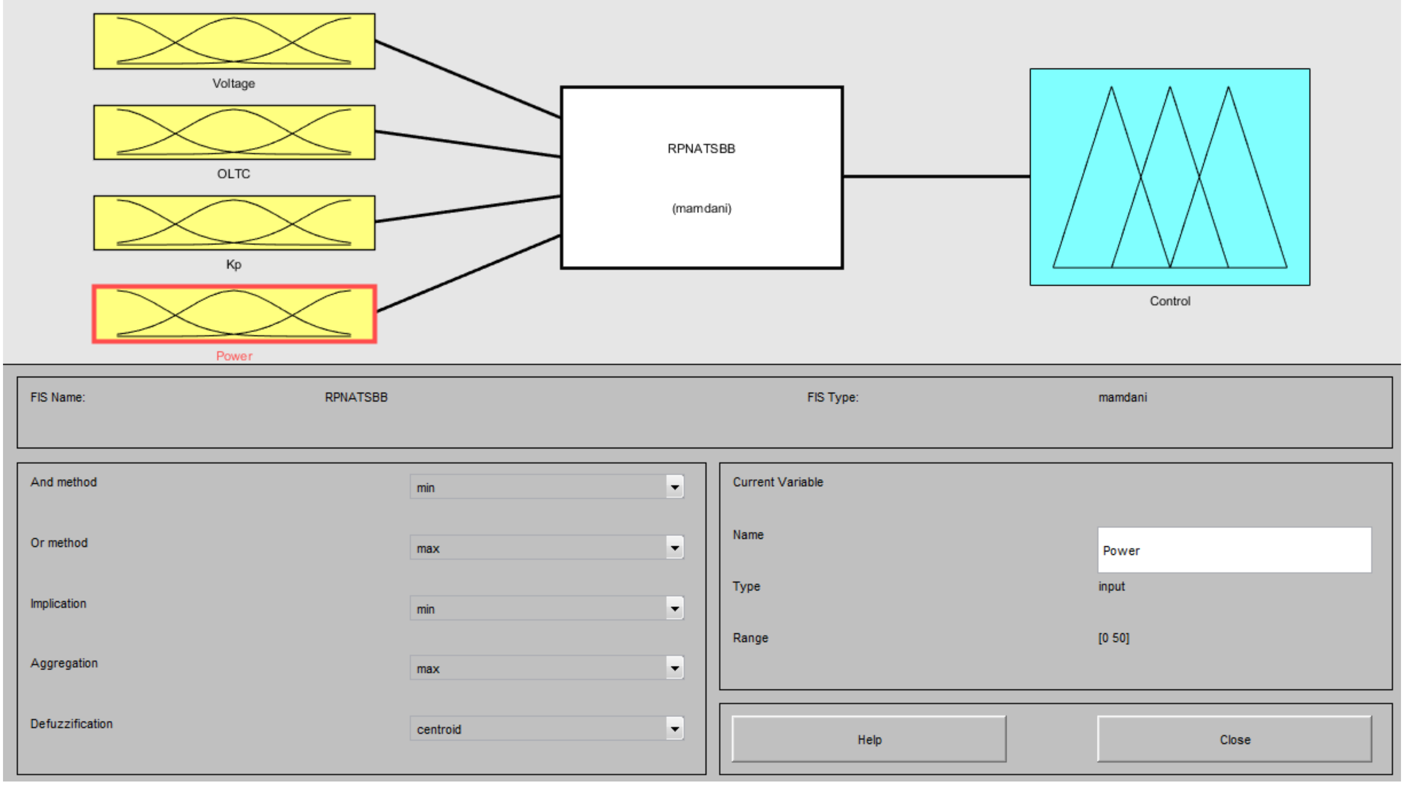
tion. The SLM has a load regulating effect (LRE). With the help of LRE, it is possible to influence power flows. This can be used under operational management of the network overload condition [4].

Currently, technical means and algorithms have been developed that are capable of monitoring changes in the SLM [5]. At the output of the SLM control unit, the characteristic value is formed in the form of a polynomial function and a regulating load ratio (the first derivative of the function). The algorithm for developing the control action is created in the presence of the value of the regulating load ratio (RLR). This happens when the overload condition is reached. With a positive RLR a reduction in power consumption is achieved by reducing the voltage. With a negative RLR a decrease in power consumption is achieved by increasing the voltage. When the RLR is close to 0, a change in voltage will not lead to a change in power [6]. To synthesize the active power flow control system in overload condition the Matlab mathematical modeling software package with the integrated Fuzzy Logic Tollbox package was selected. Mamdani's algorithm was chosen as a fuzzy algorithm.

The input variables are four parameters: voltage, power, regulating load ratio, OLTC position (Fig. 1).



FIS Name: RPNATSBB
FIS Type: mamdani

And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid

Current Variable
Name: Power
Type: input
Range: [0 50]

Fig. 1. Fuzzy controller

Each of the parameters has three membership functions (terms): voltage – «High – Negative», «Normal – Medium», «Low – Positive»; power – «Underload – Negative», «Normal – Medium», «Overload condition – Positive»; regulating load ratio – «Negative», «Zero – Medium», «Positive»; OLTC position – «Extreme small – Negative», «Working position – Medium», «Extreme large – Positive».

The values of three input parameters come from technical measuring instruments. The value of the regulating load ratio is formed by a special monitoring program of the SLM, implemented in a separate block.

For the input parameter «Voltage», the terms are triangular membership functions (trimf). These terms are shown in Fig. 2.

Terms for all input parameters were created in the same way. A characteristic feature of creating terms for OLTC position was the use of trapezoidal membership function (trapmf) for positions from 2 to the penultimate. The output parameter is a control signal about switching to the OLTC stage. Membership functions have also been created for it, as shown in Fig. 3.

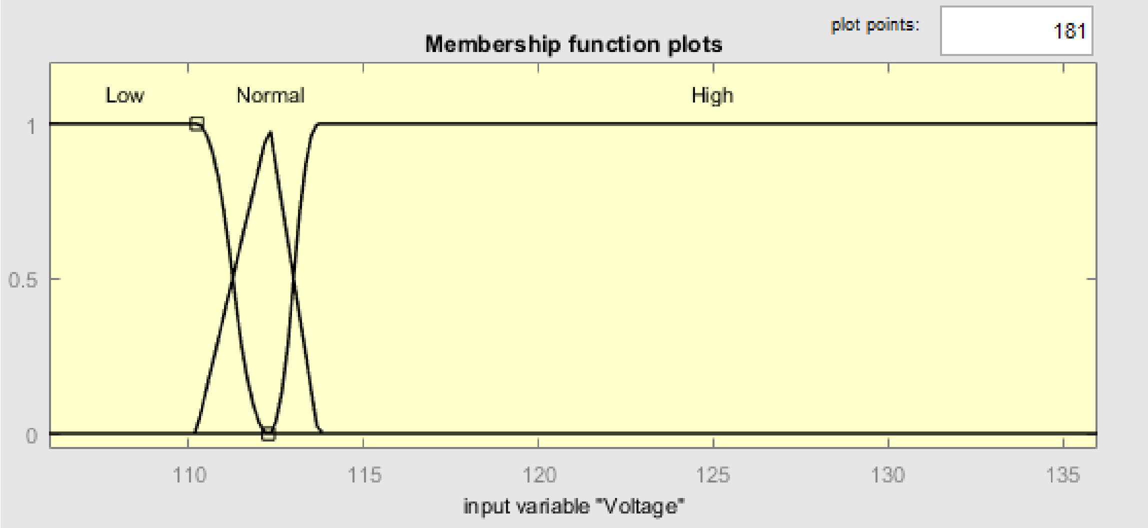


Fig. 2. Terms of the output parameter «Voltage»

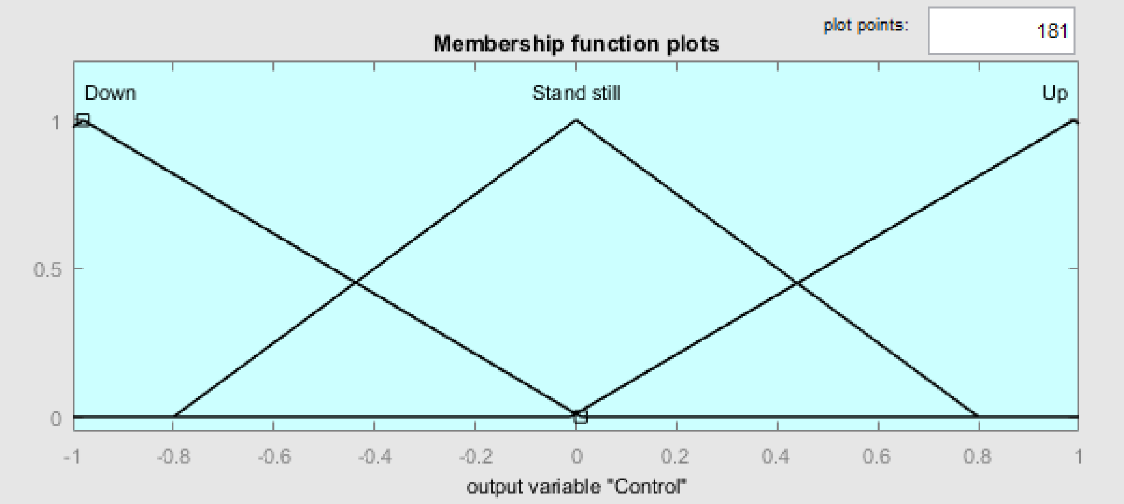


Fig. 3. Output terms

The relationship between the input parameters and the control action is formed on the basis of the rule base. The creation of the rule base is based on the following logical conditions:

1. The control action in the under load condition is generated based on the voltage setpoint, that is, the AROLTC maintains the set voltage value.
2. In the overload condition the control action is generated based on the level of active power flow, taking into account the regulating effect of the load. After OLTC switching, there should be a decrease in power flow [7, 8]. The created rules are summarized in Table 1.

3. Results

The control system for the flow of active power in overload condition, when checking it on mathematical models, worked logically correctly. In the overload condition, the reduction of the active power flow reached 5 %.

Passport data of the real power transformer ATDTSTGN-63000/220/110/10 were used in the models. Fig. 4, 5 show options for developing a control action in two different operating modes. In Fig. 4 OLTC position occupies position 6, at which the voltage has increased to an unacceptable value (130 kV), the power is not in overload mode (25 MW), the regulating load ratio is not taken into account. At the output, as a result, we received a signal to switch the OLTC to a higher stage. This led to a decrease in voltage by 1,46 kV, the power also changed, but only slightly.

Fig. 5 shows the case when the power is in overload condition (45 MW), the voltage is reduced (109 kV), the OLTC takes position 19, and the regulating load ratio is positive (0,8). At the output we get a signal to reduce the voltage. That is, the OLTC position switches to a higher position. The power decreased by 0,8 MW. When switching to 7 stages, the power flow becomes nominal.

Table 1. Rule base

№	U	P	Kp	OLTC position	Control OLTC
1	M	M	–	N	0 (stand still)
2	P	M	–	N	U↓(up)
3	N	M	–	N	U↑ (down)
4	M	N	–	N	0 (stand still)
5	P	N	–	N	U↓(up)
6	N	N	–	N	0 (stand still)
7	M	M	–	M	0 (stand still)
8	P	M	–	M	U↓(up)
9	N	M	–	M	U↑ (down)
10	M	N	–	M	0 (stand still)
11	P	N	–	M	U↓(up)
12	N	N	–	M	U↑ (down)
13	M	M	–	P	0 (stand still)
14	P	M	–	P	0 (stand still)
15	N	M	–	P	U↑ (down)
16	M	N	–	P	0 (stand)
17	P	N	–	P	0 (stand still)
18	N	N	–	P	U↑ (down)
19	–	P	N	N	0 (stand still)
20	–	P	N	M	U↑ (down)
21	–	P	N	P	U↑ (down)
22	–	P	M	N	0 (stand still)
23	–	P	M	M	0 (stand still)
24	–	P	M	P	0 (stand still)
25	–	P	P	N	U↓(up)
26	–	P	P	M	U↓(up)
27	–	P	P	P	0 (stand still)

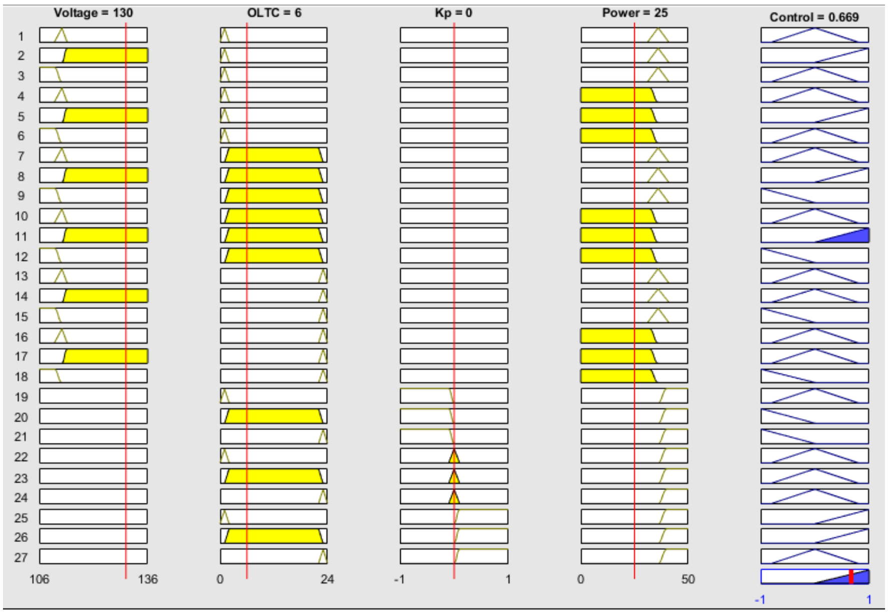


Fig. 4. Model example

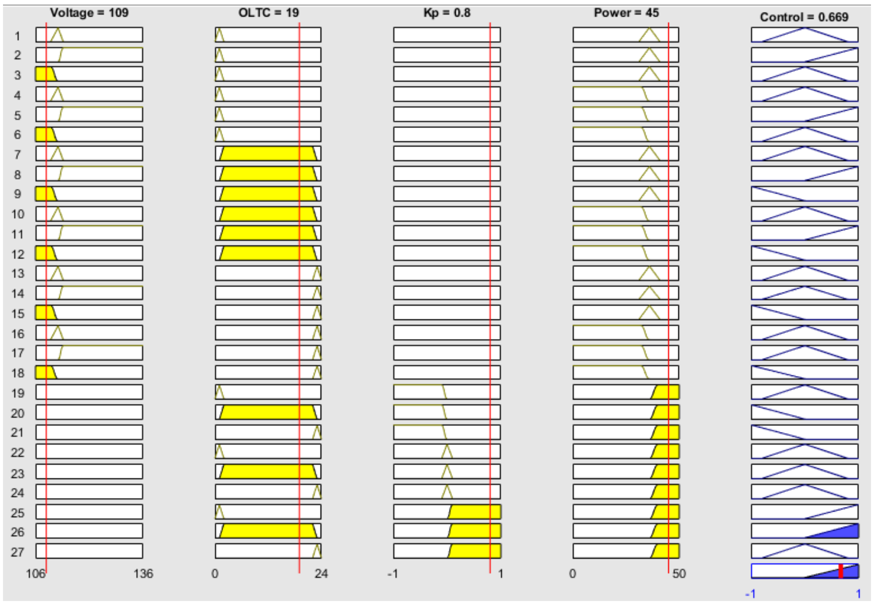


Fig. 5. Model example

4. Conclusions

An automated power flow control system for overloading the active power of the power line has been developed. The system is based on the method of artificial intelligence. This system allows up to 5–7 % reducing the flow of active power in overload condition. This makes it possible to more efficiently provide the necessary throughput of the line and shows the feasibility of using it.

References

[1] Petrov V.V. *Razrabotka metodik upravleniya transportom elektroenergii v predelakh zadannoy propusknoy sposobnosti setevykh elementov* [Development of methods for managing the transport of electricity within a given capacity of network elements]. Krasnoyarsk, 2019. 157 p.

[2] Buslov V.V., Chemborisova N.Sh. The static characteristics of modern load types and their influence on the electric network operating modes. *Bulletin of MPEI*, 2021, vol. 2, pp. 20–28. In Rus. DOI: 10.24160/1993-6982-2021-2-20-28.

[3] Bainiyazov B.A., Gauanov G.Z. Snizhenie poter elektroenergii za schet regulirovaniya napryazheniya i kompensatsii reaktivnoy moshchnosti [Reduction of electricity losses due to voltage regulation and reactive power compensation]. *Molodoy ucheny*, 2021, no. 23 (365), pp. 9–12. Available at: https://moluch.ru/archive/365/82075/ (accessed 27 September 2021).

[4] Babaei A., Ziomek W., Gole A.M. Transient characteristics of on-load tap changers during change-over operation. *Electric Power Systems Research*, 2021, vol. 197, 107296. DOI: 10.1016/j.epsr.2021.10729.

[5] Polishchuk V.I., Pankratov A.V., Batseva N.L., Shuvalova A.A. *Svidetelstvo o gosudarstvennoy registratsii programmy dlya EVM «Sravnenie i analiz modeli staticheskoy nagruzki № 2021616764 ot 28.04.2021»* [Certificate of state registration of a computer program «Comparison and analysis of static load model № 2021616764 dated April 28, 2021»].

[6] Petrov V.V., Baratova K.V., Polishchuk V.I. Sposob obespecheniya dopustimogo balansa-peretoka moshchnosti v reguliruemom sechenii [A method for ensuring an acceptable balance-flow of power in a controlled section]. *Aktualnye voprosy energetiki. Materialy Vserossiyskoy nauchno-prakticheskoy konferentsii s mezhdunarodnym uchastiyem* [Topical issues of energy. Materials of the All-Russian scientific and practical conference with international participation]. Omsk, 2020. pp. 70–74.

[7] Nigamatullin R.M., Gazizova O.V., Malafeev A.V. Study of the influence of regulating load effect on the voltage of the supply substation taking into account the power of the short-circuit of the energy system. *Electrotechnical Systems and Complexes*, 2020, no. 2 (47), pp. 19–25. In Rus. Available at: https://doi.org/10.18503/2311-8318-2019-2(47)-19-25 (accessed 26 September 2021).

[8] Alyabyev V.N., Bulkina E.D. Razrabotka algoritma snizheniya urovnya otkloneniya napryazheniya v raspredelitelnoy seti [Development of an algorithm to reduce the level of voltage deviation in the distribution network]. *Energeticheskaya bezopasnost. Sbornik nauchnykh statey III Mezhdunarodnogo kongressa* [Energy security. Collection of scientific articles of the III International Congress]. Kursk, 2020. pp. 116–120. Available at: https://elibrary.ru/item.asp?id=44469331 (accessed 20 September 2021).

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