Power autotransformer choice for ensuring power supply of oil and gas fields

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Abstract. In this article the algorithm of the power autotransformer choice is offered. According to this algorithm the program for the power autotransformer choice is developed. The program can be used as an educational tool for studying of the theoretical section. Also the program can be used for the analysis of the power autotransformer operation modes for power station and substation after carrying out calculation of the operational modes on the specified objects. Composition checks of the entered data and a correctness of the autotransformer choice are provided in the program, and in all cases of a deviation from the correct decisions the relevant information is given.

1. Introduction

Now the oil and gas industry is one of the major branches in world economy. This branch includes exploration of oil and oil and gas fields, drilling of slits, production, transportation, oil refining and associated gas. At all these stages electrical energy is required.

The power stations generated energy is transferred on power lines to high-voltage switchgear (HV switchgear) of substations. Then energy will be transformed to the required voltage level of low-voltage switchgear (LV switchgear). The medium-voltage switchgear (MV switchgear) is possible on powerful substations.

For electric power transformation from one voltage level to other voltage levels power transformers are used. In case of HV switchgear and LV switchgear on substation double-wound transformers are used; in case of HV switchgear, MV switchgear and LV switchgear - triple-wound. At a voltage of HV switchgear of 220 kV and above and voltage of MV switchgear of 110 kV and above the Russian industry produces power autotransformers – variety of triple-wound transformers (figure 1).

Also power autotransformers are used on power stations for connection between of HV switchgear and MV switchgear (figure 2) and as generator autotransformers in case of connection of the generator in the winding of the low-voltage of the autotransformer (figure 3).

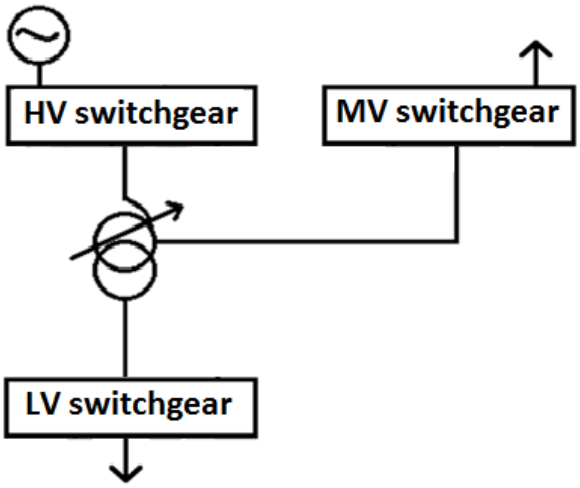

Figure 1. Substation simplified block diagram.

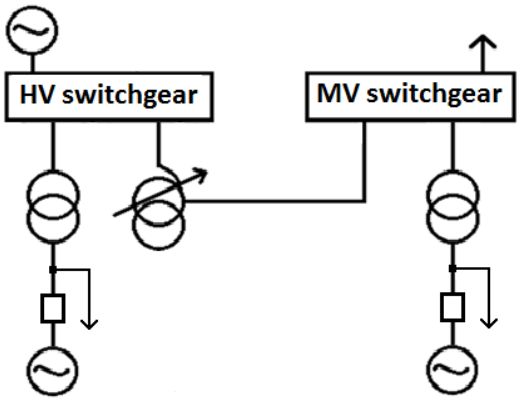

Figure 2. Power plant simplified block diagram with connection power autotransformer.

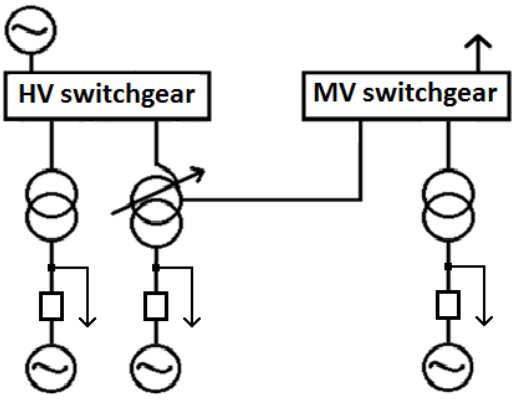

Figure 3. Power plant simplified block diagram with generator power autotransformer.

2. Algorithm of the power autotransformer choice

For a choice of the autotransformer it is necessary to calculate power flows between switchgears; to define an operation mode of the power autotransformer and the most loaded winding: the common, series, low-voltage winding.

The power autotransformer has such operation modes: the autotransformer, the transformer, the combined. In case of the autotransformer modes the side of LV is opened, there is a power flow from HV side on MV side or from MV side on HV side. In case of the transformer modes: power flow from LV side on HV side or from HV side on LV side when opened MV side; from LV side on the MV side or from MV side on LV side when opened HV side; from LV on the sides of MV and HV or from the sides of MV and HV on LV side. In the combined mode all three windings participate in power flow. In the first case power flow goes on the side of MV or from MV, in the second – on the side of HV or from HV. As an example the power flows of the combined modes is shown (figures 4-7).

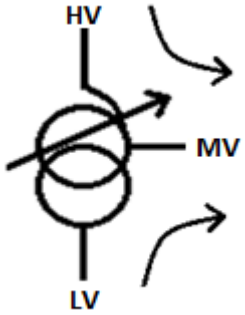

Figure 4. Power flows on the side of MV of the combined mode.

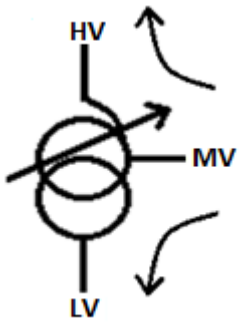

Figure 5. Power flows from the side of MV of the combined mode.

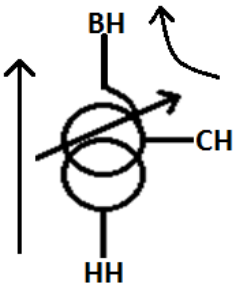

Figure 6. Power flows on the side of HV of the combined mode.

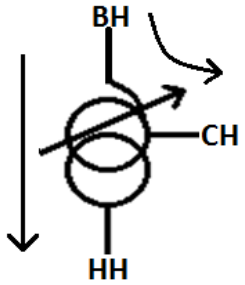

Figure 7. Power flows from the side of HV of the combined mode.

After mode identification it is necessary to make calculation of the demanded rated power for the following formulas [1]:

$$S_{calc} = \max\{S_c, S_S, S_{LV}\},$$

where S_C –power flow on the common winding
S_S – power flow on the series winding
S_{LV} –power flow on the low-voltage winding

$$S_{rate} \geq \frac{S_{calc}}{k_{co\_ratio}},$$

where k_{co_ratio} – co-ratio of an autotransformer coefficient is defined as

$$k_{co\_ratio} = \frac{U_{HV} - U_{MV}}{U_{HV}}$$

Calculation of the required power rating of the power autotransformer will be:
for the autotransformer modes:

$$S_{rate} \geq \frac{S_{C(S)}}{k_{co\_ratio}} \text{ or } S_{rate} \geq S_{MV} = S_{HV}$$

for the transformer modes:

$$S_{rate} \geq \frac{S_{LV}}{k_{co\_ratio}}$$

for combined modes:
in case of a power flow on the side of MV or from the side of MV:

$$S_{rate} \geq \frac{\sqrt{P_{LV} + k_{co\_ratio} \cdot P_{HV}{}^2 + Q_{LV} + k_{co\_ratio} \cdot Q_{HV}{}^2}}{k_{co\_ratio}}$$

in case of a power flow on the side of HV or from the side of HV:

$$S_{rate} = \max\left(\sqrt{P_{LV} + P_{MV}{}^2 + Q_{LV} + Q_{MV}{}^2} \cdot k_{co\_ratio}, S_{LV}\right).$$

The selected autotransformer needs to be checked on loading of a low-voltage winding [3]:

$$S_{LV} \leq S_{LV\_rate}$$

3. The program development for the power autotransformer choice

The program development for research of operation modes of the power autotransformer is carried on Electric Power Systems' Department of Power Engineering Institute of National Research Tomsk Polytechnic University. This development will allow selecting the autotransformer set both on substation, and on power station.

The program is written in the Delphi programming language. The choice of the Delphi programming language is caused by that this programming language allows to create the convenient interface and mobility, for example, buttons, functions of saving, comparing, the dropdown list were used [2, 4].

The program consists of some windows: the description, input of basic data, results, check and literature.

The description window contains the name of the program, assignment, the executed functions, data on the developer and the research supervisor.

In the input of basic data window (figure 8) lines for input of powers and voltages are created. Lines for voltages have the dropdown list with rated values of networks voltages to which the autotransformer [3] is connected. The user needs to enter values of the active and reactive powers and the side voltages and to press the Calculation button. Check of input of all parameters and powers balance with submission of specific information to the user is created in the program.

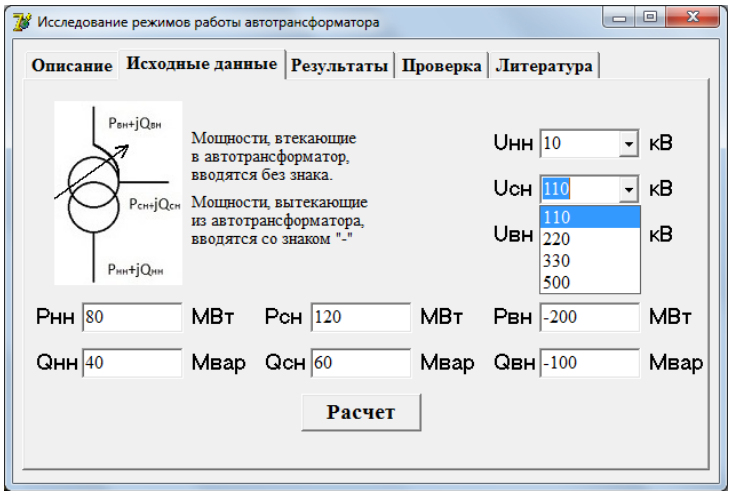

Figure 8. Input of basic data window.

After clicking of the "Calculation" button there is a transition to the results window (figure 9). In this window the next information are shown: the basic data, power autotransformer operation mode (transformer, autotransformer, combined); values of an autotransformer co-ratio coefficient; required power rating and power of the most loaded autotransformer winding. Results can be saved in the txt file form. By the "Back" button it is possible to return to the window of basic data in case of faulty action (input of parameters). When clicking the "Further" button there will be a transition to the check window.

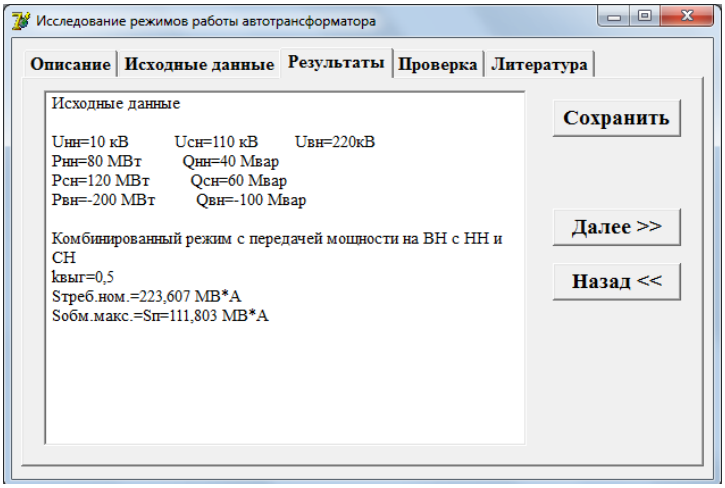

Figure 9. Result window.

The check window of the power autotransformer choice is shown on a figure 10. The check is carried out on voltages, power rating of a low-voltage winging, power rating of the autotransformer. At lines in the left part of a window catalog data of the power autotransformer are entered. When clicking the "Check" button comparing of catalog data with the estimated is made. If any value doesn't correspond to necessary conditions, in the right window the message on inappropriate parameter and on the wrong choice of the autotransformer will be displayed. If all values correspond to conditions, the message on a right choice of the autotransformer will be displayed. In a window of check there is a Reference manual button opening the reference manual with catalog data of autotransformers [3].

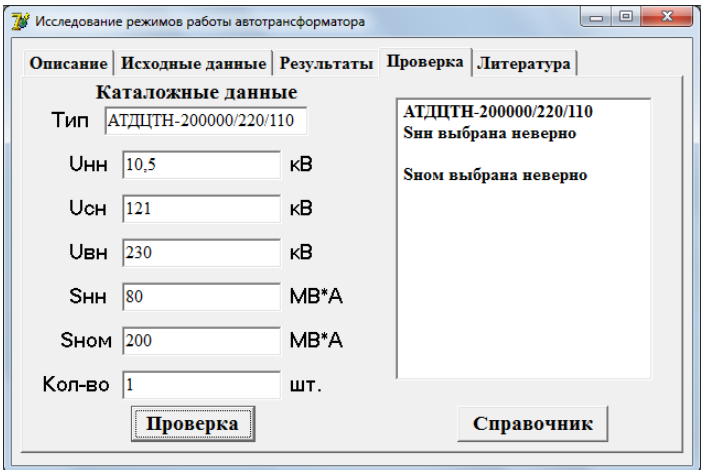

Figure 10. Check window.

In the literature window a list of the used sources is shown. Also there is a "Help" button in case of which clicking the document with methodical material on this subject opens.

4. Conclusion

The provided material contains the concentrated presentation of operation modes and algorithm of the power autotransformer choice, one of the main electric equipment participating in process of electrical power supply of customers including an oil and gas field. On this basis the program allowing on according to the entered data for the autotransformer is developed:

1. to define the most loaded winding;
2. to determine an operation mode by power transmission;
3. to calculate the required power rating;
4. to save calculated data in the file form;
5. to check correctness of the autotransformer choice;
6. to study reference methodical material on this subject.

Now operation on implementation of the developed program for educational and research tasks in TPU is carried.

References

[1] Vasilyev A A, Kruchkov I P, Nayashkova E F and Okolovich M N 1990 *Electric part of stations and substations* (Moscow: Energoatomizdat) p 576
[2] Kultin N B 2007 *Programming bases in Delphi 7* (St. Petersburg: BHV-St. Petersburg)
[3] Neklepayev B N 1989 *Electric part of power plants and substations. Reference materials for course and degree design* (Moscow: Energoatomizdat) p 608
[4] Homonenko A D 2005 *Work with databases in Delphi* (St. Petersburg: BHV-St. Petersburg)