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MODELING OF OPERATING CONDITIONS OF THE MEDIUM VOLTAGE NETWORK EARTH FAULT PROTECTION

Викладено результати комп'ютерного симулювання режимів роботи захисту від мережі середньої напруги. Швидка оцінка цих режимів може бути метою обчислювальної системи KSAZ, розробленої інститутом електроенергетики Познанської політехніки. Результати досліджень можна показати різними способами. У цій статті результати подано у комплексній площині.

In this paper, the computer simulation results of operating conditions of the medium voltage (MV) network earth-fault protection are presented. A fast on-line assessment of these conditions can be aided by the computing system KSAZ (Protection Analysis Computer System) developed in the Institute of Electric Power Engineering, Poznań University of Technology. The results of research can be shown in a few ways. In the paper the results on the complex plane are presented.

Introduction. A large quantity of high-resistance faults in overhead lines, different ways of neutral point grounding in rural MV networks, low level of decisive signals, are only few reasons which caused the development of new earth fault protections [1, 2, 3]. In Polish Elecrical Power Distributions, relays based on admittance criteria turned out to be most effective ones [4]. The software package KSAZ [5,6] became the tool enabling the appropriate choice and correct settings of the earth fault protections. In Fig. 1. the structure of the KSAZ program is shown.

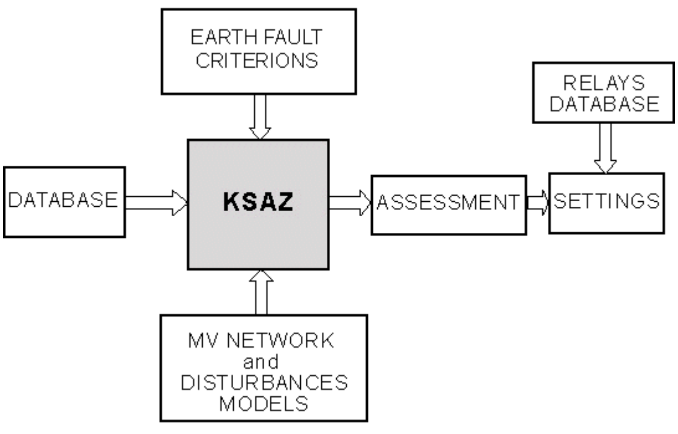

Fig. 1. Block diagram of the system KSAZ

In order to analyse the phenomena accompanying the earth-faults MV network model and the disturbances model were created. The scheme of the compensated network is shown in Fig. 2. Among others, earth-fault capacitances (C_0) and conductances (G_0), fault point resistance (R_F), zero-sequence measuring components (U_0, I_0 filters), neutral point grounding system with active/reactive forcing arrangement, were taken into consideration.

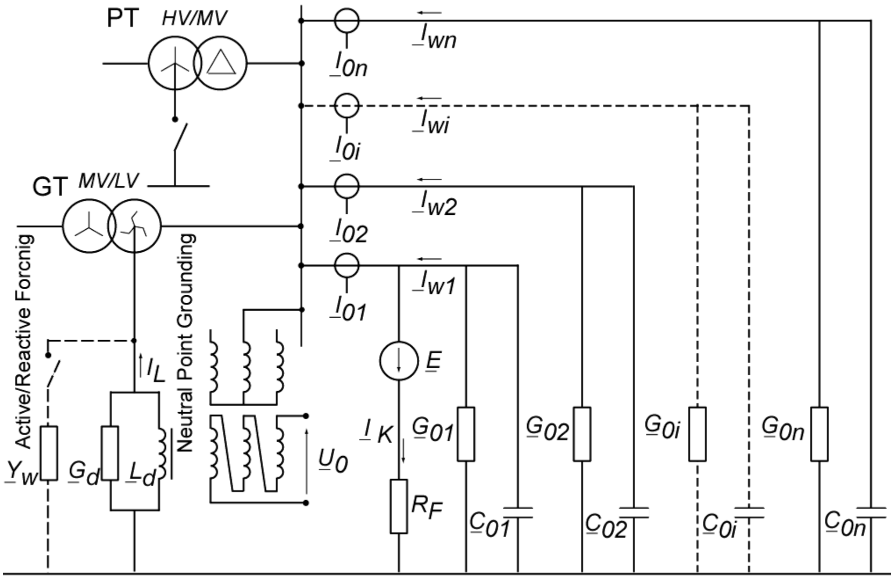

Fig. 2. The MV network model used in program KSAZ

Parameters of analysed MV network. The parameters of the MV network computed by the KSAZ application refer to a hypothetic 110/15 kV substation (GPZ – Main Switching Point). The are close to parameters in Polish electric power distribution companies. In a typical GPZ both sections operate as compensated networks equipped with the devices for the zero-sequence resistive current forcing (AWSCz). For the greater transparency the analyses have been carried out for the GPZ with the single bus. The values are given in Table 1.

Table 1

Parameters of the GPZ under consideration

Network rated voltage	15 kV	
The compensated network		
Coefficient of earth-fault curent compensation s	5 %	
Earth-fault zero-sequence capacitance of the network I_{ps}	100 A	
Zero-sequence resistive current forcing by arrangement AWSCz I_{AWSCz}	15 A	
Coils:	2	
- coil 1	60–120 A	hook 3 (90 A)
- coil 2	15–30 A	hook 5 (15 A)

In basic configuration, the section under consideration operates as the overcompensated network with coefficient of the earth fault compensation *s* falling between acceptable limits in Poland. The AWSCz device is efficient and forces the flow of the additional 15 A real component when the earth fault occurs. The results presented in successive parts of the paper are also related with simulation of the failed operation of the AWSCz device.

Basic parameters of the tested overhead line are shown in Table 2. In the line, the measuring current transformer in the form of the Holmgreen network with the ratio of 200/5 [A/A] has been installed. The coefficient A for the analysed line is equal to 15. The coefficient A is defined as a share of earth-fault capacitive current of the line in total earth-fault capacitive current of the network.

Table 2

Parameters of the tested line

Earth-fault zero-sequence capacitance of the line I_{pl}	15 A
Measuring current transformer (CT)	Holmgreen
CT ratio	200 A/ 5 A
CT error current	30 mA

Moreover, the following assumptions have been made in calculations:

- setting value U_{on} is equal to 15 V for voltage-conditioned criterions,
- safety coefficient k_b – 1.1,
- sensitivity coefficients k_c are equal to 1.5 for metallic faults and 1.3 for resistive faults for overcurrent criteria.

Analysis of the fault resistance influence on operating conditions of earth-fault relays. In the KSAZ application the effectiveness of an earth fault protection is principally determined by the range of the detectable earth fault resistances in the network configuration with given earth fault circuit and measurement circuit parameters [7]. In Fig. 3 we show the results of the analysis carried out for four values of simulated fault resistance R_F testing operating conditions of the admittance RYGo relay. Case 3A refers to the metallic fault. In the case 3B fault resistance value is equal to 100 Ω, in 3C – 1 kΩ and in case 3D – 2 kΩ.

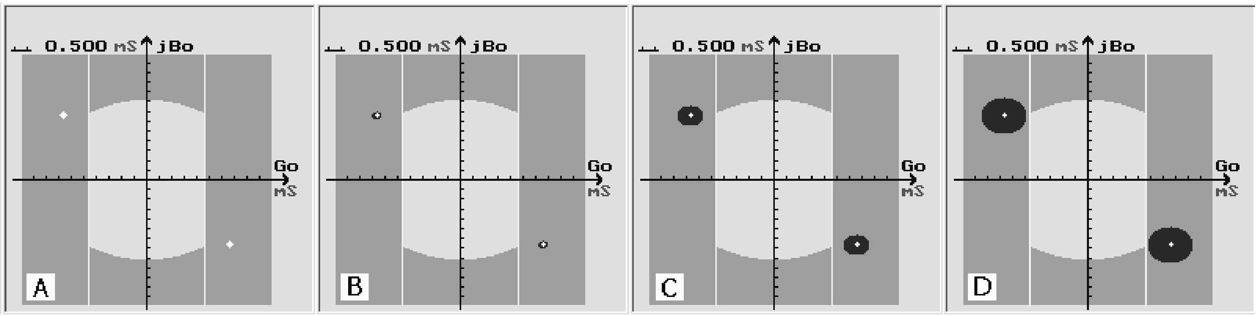

Fig. 3. Results of analysis of the fault resistance influence on operating conditions of RYGo protection in the examined line

Green colour in the figure represents the area of the activity of criterion for the setting value, calculated by the KSAZ program, grey colour reperesents the area of no activity. On the outer part of the yellow outline there is the area of the activity for start-up value of chosen earth-fault relay. White points surrounded by the red ones represent working points. The radius of the red circle defines the uncertainty zone and is proportional to the measurment current of the measuring current transformer. All admittance criterions are always combined with the network zero-sequence voltage (U_0) condition requirements. In this case, the range of detected fault resistance is determined by U_0 voltage start-up value.

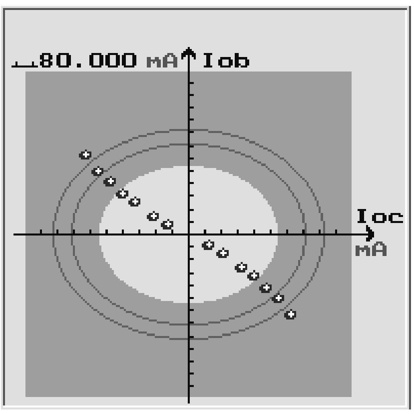

Fig. 4. Arranging of measuring points on complex plane for overcurrent relay for different values of the fault resistance

In the Fig. 4, the results of similar analysis for overcurrent criterion are presented. The highest value of detected fault resistance R_F of 70 Ω merely. On the complex planes for the single simulation two points are symmetrically placed, because all analysed criterions are undirectional.

Analysis of the coefficient s influence on operating conditions of earth-fault relays. The KSAZ program allows to smooth the change of value of the earth-fault current compensation coefficient s. The results of combined admitance YGo criterions analysis are shown in Fig. 5. The analysis have been done for simulated fault resistance R_F equal to 1 kΩ. On the left panel (Fig. 5A) R_F and U_0 values are marked. Additionally, paticular criterions are represented on the top. Yellow letters on red background represent conditions of the activity. The right panel (Fig. 5B) shows collective results, both for undercompensated network (negative values); as well as for the overcompensated one.

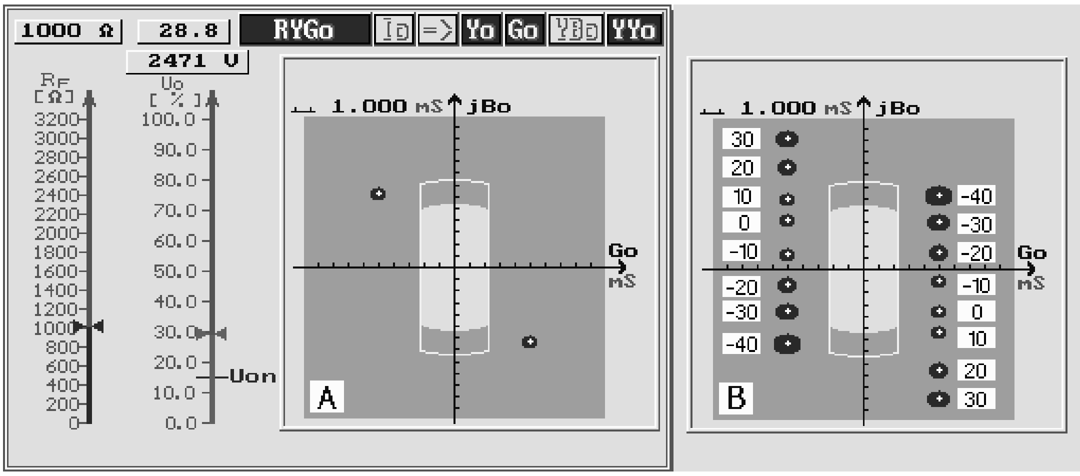

Fig. 5. Analysis of operating conditions for admittance criterion YGo for different values of earth-fault current compensation coefficient s [%] (on the right diagram in the white squares)

Analysis of the active forcing devices influence on operating conditions of relays. With software package KSAZ the changes in configuration can allow simulation of the failed operation of the AWSCzs devices. In Fig. 6 are presented the results of the analysis of operating conditions for admittance criterion YGo for different values of zero-sequence resistive current forcing by AWSCz. Low value of current I_{AWSCz} may cause ‘dropping out’ from the area of activity. Due to missing of the AWSCz, many criterions (f.e. the active-power based criterion) as well as the conductance criterion G_0 failed to work. The results shown in Fig. 6 concern the simulation for the earth-fault current compensation coefficient s value of 5 %. Higher overcompensation of the network can result not only in the increment in the current value at the fault location but also in the higher sensitivity of the Yo> criterion. Effectiveness of criterions belonging to the admittance family is additionally increased in the combined criterions, mainly in the YGo one.

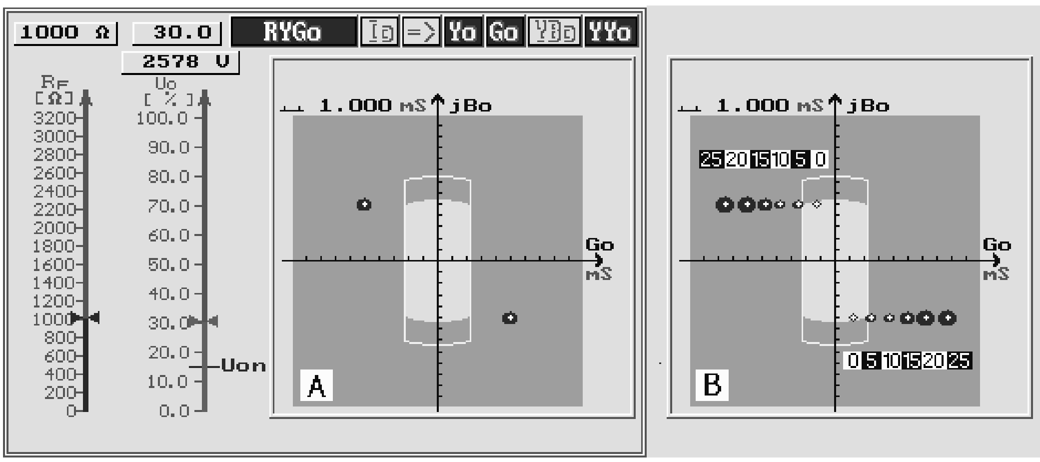

Fig. 6. Analysis of operating conditions for admittance criterion YGo for different values of zero-sequence resistive current forcing by AWSCz (on the right diagram values are recorded in the white and blue squares)

In the KSAZ system, analysis are carried out for both the *computed start-up value* and the *currently set value*. Such approach makes possible the sensitivity margin assessment. In all figures the outer part of the yellow outline represented the area of the activity for currently set value of chosen relay. In reported example the conductance module setting is constant and is equal to 2.3 mS while the module Yo> setting is equal to 7.5 mS. The start-up value computed by KSAZ is equal to 5.25 mS. If the AWSCz device is forcing the active current component of 5 A only in the earth fault network, Yo> module for setting 7.5 mS is in the blocking area, the device is still able to act with the start-up value computed by KSAZ.

Analysis of the coefficient A influence on operating conditions of earth-fault relays. The issue of the sensitivity margin assessment is remarkable also in the analysis of the influence of earth-fault zero-sequence capacitance current I_{pl} of tested line on operating conditions of RYGo relay. In the Fig. 7, the values of I_{pl} current are given in the upper left top corner. For described simulation these numbers mean both current value in ampers as well as coefficient A in percent. For line-to-earth capacitive current of 15 A the currently setting value of Y0> module is close to start-up value computed by the KSAZ program. The change of chosen line coefficient A can be caused by switching of other lines connected to the bus of the medium voltage. Many earth fault criterions are very sensitive in a such case and lost good operating conditions. However, the combined admittance criterions still remain in the area of activity.

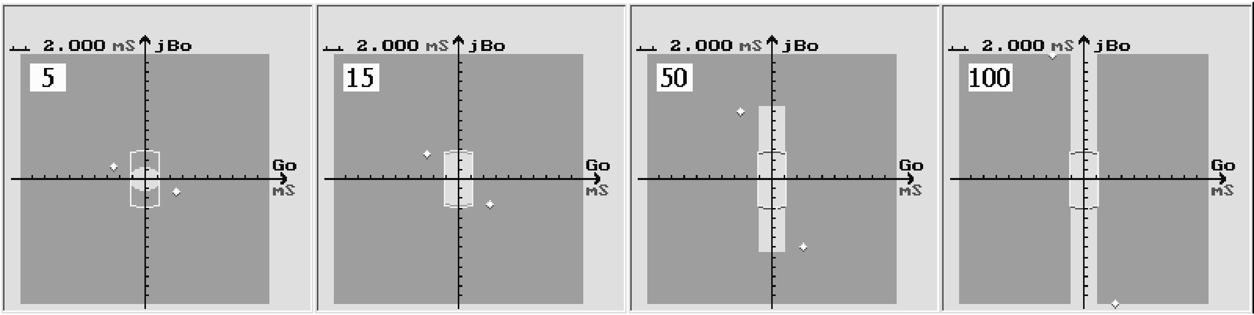

Fig. 7. Analysis of operating conditions for admittance criterion YGo for different values of earth-fault zero-sequence capacitance current of tested line (on the diagrams values are recorded in the white squares)

Summary. The results of analysis supported by the KSAZ application are presented in the paper. The KSAZ package makes a wide scope of types of earth-fault analysis available, the ones for typical MV substation and overhead line are only shown *on complex plane*. Analysing procedures taking into account of variance in the earth-fault parameters, real time configuration of the distribution substation, as well as the effects of error measuring circuit of zero-sequence currents, the voltage of natural asymmetry of the network, the effect of the resistance in the fault point on the selectivity and sensitivity of the earth fault protections, were all implemented in this program.

Modeling of MV network and modeling of earth fault disturbances allowed appropriate choice of earth fault protection, computing of setting values, assessment of sensitivity margin and assessment of operating conditions of some MV devices (f.e. active forcing arrangment).

In view of these results we can conclude; that admittance criterions, particularly combined criterion YGo, are the most efficient ones, both for high-resistance faults, as well as in time varying exploitation conditions and network configurations.

In response to the network reconfiguration (lines switching operations, swith-off grounding transformer, etc.), the KSAZ interface allows rapidly to compute setting parameters, and the results obtained that way can be used as a starting point for the real time setting of the contemporary digital protection systems. Such approach opens a possibility of using described application to aid settings determination in adaptive protections.

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WIND FARM OPERATION DURING IMPORTANT DISTURBANCES IN ELECTRIC POWER SYSTEM

Викладено окремі результати модельних досліджень динамічних режимів електроенергетичних систем для областей з високим насиченням вітроелектричних станцій. В дослідженнях використано програмне забезпечення GE – PSLF. Моделювання виконано для енергосистеми Польщі. Показано переваги нових рішень для роботи вітрових електростанцій під час виникнення системних збуджень, викликаних короткими замиканнями. Визначена роль взаємодії пристроїв FACTS типу SVC. Відзначено все ще актуальну проблему неконтрольованого збільшення потужності приєднаних вітрових електростанцій у режимах електроенергетичних систем.

In the paper, the selected results of simulation studies on the electric power system’s dynamic conditions in the area with high density of the wind farms are presented. In simulations, the GE – PSLF software package has been used. The computing models of Polish power system have been applied. The advantages of new solutions for the wind power plants operation during system’s disturbances due to faults have been shown. The role of the co-operating SVC-type FACTS devices has been indicated. The still existing threat to the system operation due to the uncontrolled increase in the power of connected wind farms has been underlined.

Introduction. The plans of the Polish power system include the connection of both the individual wind power plant and the wind farms of some hundreds MW. Due to such *status quo*, the transmission system operators (OSP) and the distribution system operators (OSD) are forced, following the West European operators [1], to develop the detailed requirements concerning the wind farms (FW) to be integrated [2]. The requirements are necessary to provide the safe operation of the national power system (KSE) under the normal and disturbed operation conditions.

The farm wind operation during disturbances could result in important variations in the KSE grid operation conditions, especially in the areas of high density of the wind farms. In versions existing up to