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SHORT CIRCUIT CURRENT LIMIT CONTROL

The scientific and practical relevance of improving the functioning of credit limit short – circuit (short circuit), formulated the goal and objectives of research. As a solution proposed research and the way to manage complex limitation of short circuit currents in electricity supply production systems under the reactor – controlled shunt. The algorithm of the system reactor – controlled shunt. For the first time the schemes cause – effect relationships occurrence of short – circuit currents – Figure Ysikavy according to ISO 9004.

Key words: *short-circuit current; reactor; Ishikawa; IS0 9004 performance; limitations; fuse; controlled shunt; reduced losses.*

У зв'язку зі зростанням рівнів та кількості струмів короткого замикання, існують проблеми, пов'язані з підвищенням ефективності методів та засобів обмеження струмів короткого замикання, які є актуальними у контексті розвитку енергетичного сектору України. Проблеми ускладнюються тим, що в системах електропостачання виробничих систем є значна кількість устаткування, яку необхідно замінити за умовами короткого замикання і устаткування з відпрацьованим терміном служби або значною зношеністю, а промисловість не забезпечує потреби виробничих систем в електроустаткуванні. Тому питання про спосіб вирішення цих проблем, повинне вирішуватися на основі техніко-економічного аналізу. Ключовим аспектом тут є інтенсифікація темпів зменшення витрат електроенергії у виробничих системах електропостачання, що може бути досягнуто шляхом впровадження нових або з підвищеною ефективністю існуючих методів та

засобів обмеження струмів короткого замикання. Присутня наукова та практична актуальність вдосконалення функціонування засобів обмеження струмів короткого замикання, сформульована мета та завдання наукового дослідження. В якості рішення уперше запропоновано та досліджено спосіб управління обмеження струмів короткого замикання у виробничих системах електропостачання з використанням струмообмежуючого реактора з керованим шунтом. Розроблено алгоритм дії системи "реактор - керований шунт". Вперше побудовано схему причинно-наслідкових зв'язків виникнення струмів КЗ у виробничих системах електропостачання - використовуючи діаграму "аналізу кореневих причин" Ісікава, відповідно до ISO 9004. Запропонований спосіб обмеження струмів КЗ в виробничих системах електропостачання і обладнання для його реалізації за схемою "реактор – керований шунт", яка повністю компенсує всі недоліки, що виникають при обмеженні струмів КЗ в виробничих системах електропостачання за схемою обмеження "реактор - нерегульований шунт". Слід також зазначити, що обмеження струмів КЗ в виробничих системах електропостачання за схемою "реактор - керований шунт" має певні суттєві переваги перед іншими існуючими на сьогоднішній день засобами обмеження струмів КЗ, а отримані нові науково-обгрунтовані теоретичні і практичні результати, що дають підстави для подальшого розвитку нових методів і засобів обмеження струмів КЗ в системах електропостачання виробничих систем з урахуванням усіх особливостей, а результати проведення повномасштабного експерименту з незначною похибкою підтвердили математичну модель системи "реактор - не керований шунт".

Ключові слова: *струм короткого замикання; реактор; Ісікава; IS0 9004; ефективність; обмеження; запобіжник; керований шунт; зниження втрат.*

1. Introduction

Amid growing levels of short-circuit currents, issues related to increasing the efficiency of methods and means of limiting short-circuit currents are central in the context of development of Ukraine's energy sector. A key factor here is intensifying pace of decreasing electricity losses in power supply production systems (PSPS), which could be achieved through implementation of new and improved efficiency of existing methods and means of limiting short circuit currents.

Studies indicate that addressing the issue of reducing electricity losses in the absence of short circuit currents in the PSPS calls for new approaches. This is due to an ongoing increase in the efficiency of the means and methods of limiting short circuit currents used today, as well as broad application of fundamentally new means and methods of limiting short circuit currents – devices controlling the means of limiting short circuit currents, built on decision theory [1].

The analysis of existing means and methods of limiting short circuit currents shows that, by increasing the efficiency of short circuit currents limiting devices based on decision theory, it is possible to reduce the costs of maintenance of short circuit current limiting equipment through reduced losses in the absence of short circuit currents, i.e. deliver actual energy saving while limiting short circuit currents in the PSPS [2].

To reduce the impact of short circuit (s/c) currents on the power supply system, various means and methods are developed and applied, allowing limiting magnitude, as well as their duration.

2. Aim and objectives of the study

The study aims to increase the efficiency of the means of short circuit current limiting devices in the production systems by optimizing their operation modes.

To achieve this goal, the following objectives are addressed:

- analysis of methods and means of limiting SC currents in the PSPS;
- developing a controlled shunt reactor suite based on decision theory;
- building the algorithm of controlled shunt reactor suite operation based on the decision theory.

3. Solution to the task at hand

During operation of the PSPS of industrial facilities, short circuits occur frequently, leading to disturbances in the normal operation of electrical installations and possible disruption of electricity supply to consumers. Based on the main cause and effect relationships of the occurrence of short circuit currents, we are able to build a scheme of cause and effect relationships of the occurrence of short circuit currents (Ishikawa iteration scheme), according to ISO 9004 presented in Fig. 1.

Short circuits in electrical installations have the following consequences: damage to electrical equipment, wear and tear on circuit breakers, lowered voltage in the grid, fires and other damages. In its physical nature, the SC current is a continuous random process. The totality of characteristics describing the probable nature of the various parameters and conditions of short circuits are the probable characteristics of short circuits in an electrical installation.

In order to reduce the impact of short circuit currents on electrical equipment, various methods and means of limiting short circuit currents have been proposed and used [2, 3]. Taking into account the specific character of PSPS development, as well as technical and economic characteristics, fundamentally new means of limiting the short circuit current are being developed and investigated, allowing to limit the magnitude of the short circuit current as well as its duration.

The benefits and disadvantages of the existing methods and means of limiting the short circuit current are also being analysed.

As we know, the most common means of limiting short circuit currents in 6-10 kV grids in Ukraine are unregulated single and dual linear concrete reactors. They differ in their structural design, as well as technical and economic characteristics and parameters. GOST 18624-73 offers a general classification of reactors for different purposes.

Along with the existing methods and means of limiting the short circuit currents decision theory also has its application. Let us consider a decision-making method that can be based on pattern recognition theory, whose application allows us to recognize the normal, pre-emergency and emergency operation modes of power supply of production systems.

To resolve the problem of increasing the efficiency of the short circuit current limiting devices, we suggest a suite and a method of controlling the limitation of the short circuit currents in the PSPS according to the controlled shunt reactor scheme, whereby the inductive resistance is switched on and off automatically in the event of short circuit current [4].

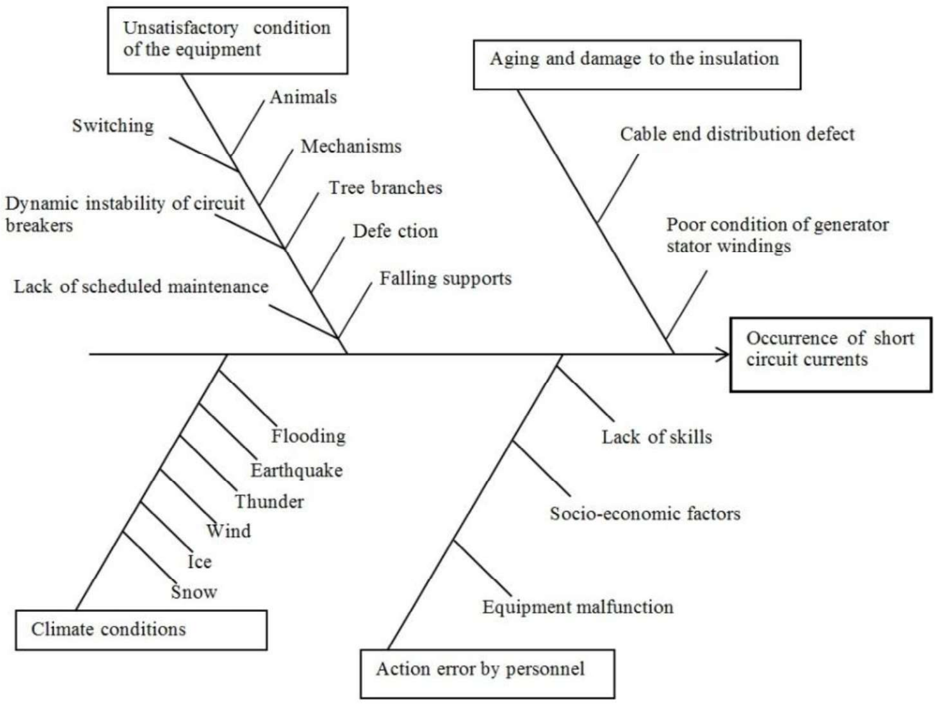

Fig. 1. Scheme of cause and effect relationships of short circuit currents.

The device’s operation principle is to compare the measured current with the reference value and to form a control signal that affects the inductive resistance.

Fig. 2 shows a structural diagram of a short – circuit current limiting device. A current-limiting resistance (current – limiting reactor) 2, shunted with a high – speed switching element *3,* is included in the section of the electric system *1*. A current measuring unit *4* connected to the analyzer *5* is connected to the electric system, whose control output of which through the device *6 is* connected to the control input of the high – speed switching element *3*.

Under normal conditions, device *3* (shunt inductance) passes current and have a parallel connection of the inductance and the switching element with resistance lower than the inductance resistance.

In emergency mode, information from the current measuring unit *4 is* fed to the analyzer *5*. In case of the current change $\Delta I_p \geq \delta I$, the control point mode is emergency mode, and the device *6* generates a control signal that turns off the switching unit *3*, while the inductive resistance *2* limits the short – circuit current accordingly.

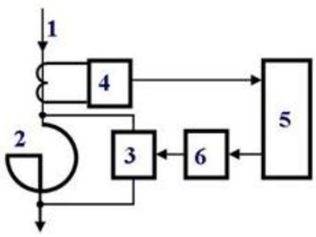

Fig. 2. Shows a structural diagram of a short – circuit current limiting device.

Periodically in time segments $\Delta t = T/N$, where N is the number of control points (Fig. 3), the value of the actual current of the electric network I_{ca} is measured at control points over the monitoring time interval T. Further the discrepancy ΔI_t between the actual I_F and the set (reference) current I_{cr} for a controlled time interval T is determined, i.e.

$$\Delta I_т = \sqrt{\sum_{t=1}^{n} (I_F - I_{cr})^2} ,$$

where I_{cr} is a value that accounts for the conditions for starting the electromotive load.

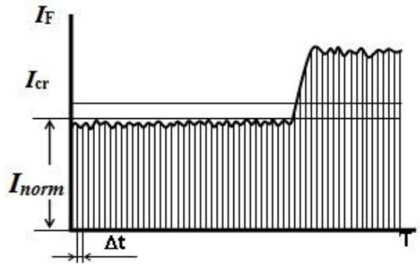

Fig. 3. Schedule current of the electric network.

If $\Delta I_t \geq \delta I$ (where the value δI, is the setting determined by the operating mode), a control action is formed that disconnects the switching unit. The algorithm limiting the s/c current is shown in Fig. 4.

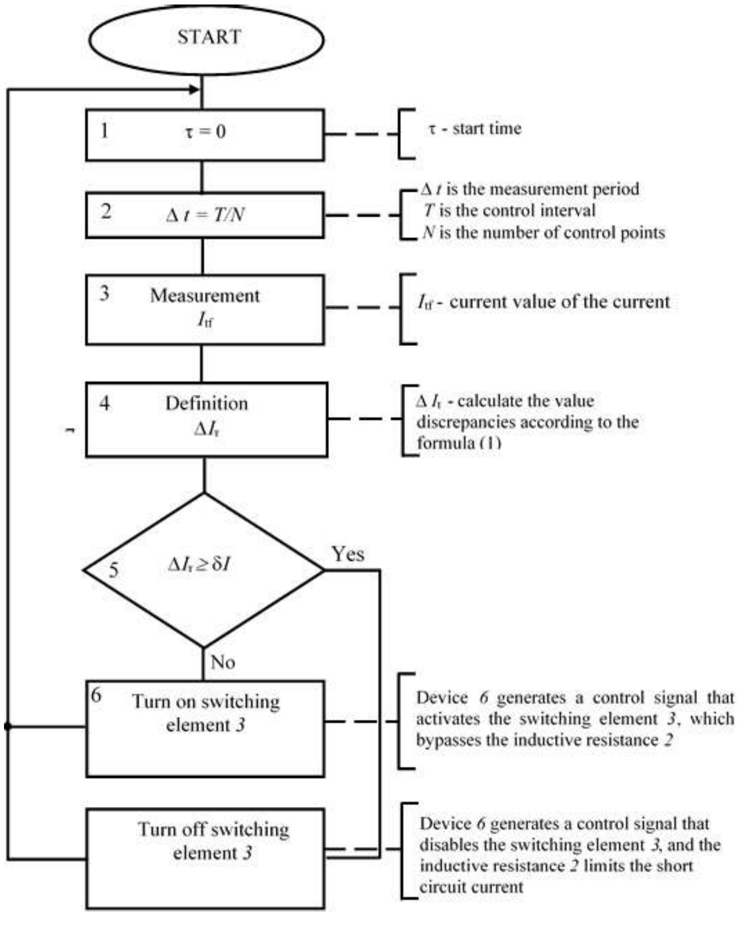

Fig. 4. Algorithm of the analyzer operation.

The proposed method of limiting short circuit currents in the PSPS and the suite for its implementation under the controlled shunt reactor scheme fully compensates for all the disadvantages that occur when limiting short circuit currents in the PSPS under the unregulated shunt reactor scheme [3].

It should also be noted that the limitation of short circuit currents in the PSPS under the controlled shunt reactor scheme has certain advantages over other means of limiting short circuit currents, in particular:

- room for further development and improvement of this system of limitation of short circuit currents;
- performance and reliability;
- compliance with energy-saving requirements;
- ability of collecting and proper use of currents statistics in the PSPS.

Economic rationale for the proposed solution

The economic effect of introducing the proposed automatic s/c current control device is determined in accordance with the following methodology.

After installing the device on a 6 – 35 kV network, the total active power losses in three – phase groups of reactors should decrease as follows [2]:

$$\Delta P_{Э\Sigma} = (1 - 1/K_2)\sum_{i=1}^{n} 3\Delta P_{Hi}(I_{Mi}^2 / I_{Hi}^2),\ \text{kW},$$

where $K_2 = R_p(1+K_1)^2/(X_p K_1)$; $K_1 = R_{\text{device}}/X_p$; $I_м = I_{\text{device}} + I_p$; $I_м$ is over current; P_H is nominal losses in the reactor; X_p is reactance of the reactor; R_p is the resistance of the reactor; R_device is the resistance of the s/c current control device; I_p is the current going through the reactor; I_device is current going through the s/c current control device.

Reactive losses at $R_\text{device} \le X_\text{p}$ are almost completely eliminated and the total technical effect will be

$$\Delta Q_{E\Sigma} = \sum_{i=1}^{n} 3I_{мi}^2 X_{\text{p}i} \cdot 10^{-3}, \text{kVAr}.$$

Annual energy savings are mostly determined based on the "losses time":

$$\tau_a=(0.124\ T_{\text{ma}}/10^4)^2\ 8760,\ \text{h/year};$$

$$\tau_\text{p}=(0.124 \cdot T_{\text{mr}}/10^4)^2\ 8760,\ \text{h/year};$$

where T_ma, T_mr are the maximum number of using active and reactive loads, respectively.

In this case, annual energy savings from installing a short – circuit current control device will be (in kW·h and kVAr·h, respectively):

$$\Delta W_{S\Sigma} = \Delta P_{S\Sigma}\tau_a$$

$$\Delta V_{S\Sigma} = \Delta Q_{S\Sigma}\tau_p.$$

In accordance with the single – rate tariffs currently used in Ukraine, only the actual energy consumption is billed at the rates established for classes 1 and 2 of industrial consumers with connected capacity of $S_c \geq 750$kV·A. Based on the tariff structure, direct savings in cost terms for a short – circuit current limiting control device installed in reacted lines can be presented as

$$S = (\alpha \Delta W_{S\Sigma} + \gamma \Delta V_{S\Sigma})10^{-2} = (\alpha \Delta P_{S\Sigma} \tau_a + \gamma \Delta Q_{S\Sigma} \tau_p)10^{-2},$$

where α_{min}, α_{max} are active energy coefficients; γ_{min}, γ_{max} are reactive energy coefficients.

4. Conclusions

Existing devices and methods for limiting the short – circuit currents have a number of significant drawbacks:

– single use of work, requiring fuse replacement after burnout;

– electric arc at the time of burnout, which is a conductor of short – circuit currents;

– insufficient operational reliability;

– unstable current – time characteristics;

– limited application in terms of rated currents and rated voltages;

– no option of external control, such as by automatic reclosers of the protected circuit.

The device for short – circuit current limitation control designed by the authors, where the inductance is switched on and off automatically when a short – circuit current occurs, has none of the above drawbacks.

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