FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 3, N° 1, 2006, pp. 15 - 26

PROTECTION OF DISTRIBUTIVE POWER TRANSFORMERS AND THE PROFESSIONAL RISK

UDC 368.025.61

Vladica Aleksić[1], Zoran Stajić[2], Milan Radić[2]

[1]Electric Power Distribution Company, Vranje
[2]Faculty of Electronic Engineering, Niš

Abstract. *This paper considers the correlation between the operation of distributive power transformers' protection systems and the level of professional risk in distributive substations. The main functional segments of a typical substation of 110/35/10 kV and its operation have been described. Also, the typical protection systems of three-winding distributive power transformer 110/36.75/10.5 kV, 31.5/31.5/10.5 MVA have been mentioned. Special attention has been paid to the reserve earth-fault protection system, which is identified as the cause of a serious problem in the parallel operation of two distributive power transformers. Besides the argumentation of the applied protection system inadequacy, some suggestions for revision of certain technical recommendations are given. The acceptance of these suggestions will make the operation of distributive substations more reliable and safe, decreasing the level of professional risk, at the same time.*

Key Words: *Professional Risk, Power Transformer, Parallel Operation, Protection System*

INTRODUCTION

Due to the existence of numerous conductive parts at the high-level voltage, a distributive substation can be considered as a working environment with an extremely high professional risk level. Even under the normal operating conditions, the equipment in the substation presents a permanent source of potential danger for the personnel. In situations when an electrical fault occurs in the substation or somewhere in the distributive network connected to the substation, the level of potential danger and the possibility of accidents additionally increase. The standard approach to decreasing the professional risk in the substation is closely connected with the engagement of specially educated and well trained employees, and, moreover, with strict respect of all the rules related to the use of protective working equipment and standard operating procedures.

Received November 25, 2005

It has to be mentioned that different types of electrical protective systems, which are, in the first place, intended for the protection of power system components, also play a significant role in decreasing the professional risk and potential danger in the distributive substations. Considering the fact that both the protective system set-up and its implementation are strictly defined through the valid technical regulation and recommendations, it is hard to believe that in some cases the protective systems may have a negative effect on the level of the professional risk thus increasing rather than decreasing the possibility of accidents. However, such situations are known in practice, indicating that the technical recommendations can be improved in some segments by introducing certain changes. Problems in parallel operation of two distributive power transformers 110/35/10 kV, 31.5/31.5/10.5 MVA, noticed in the substation "Bujanovac," and caused by implementation of an inadequate reserve earth-fault protection system, are good examples of the previously mentioned facts.

1. DESCRIPTION OF TYPICAL DISTRIBUTIVE SUBSTATION 110/35/10 KV

Distributive substations are points in a large electrical power transmission network where high-level voltage is transformed into medium-level voltage, suitable for some industrial consumers supply, and for further transformation and distribution to the low-voltage end consumers. The most important element in each distributive substation is a distributive power transformer, which makes an interconnection among two or three different voltage level networks. The structure of such distributive substations is usually very complex, including switchgear equipment, meters, protective and communication systems, which allows the control of the substation under different operating conditions.

A typical disposition of the substation 110/35/10 kV is shown on the one-pole scheme in Figure 1. Usually, there are two distributive power transformers in substations of this type, and they can operate either independently or in parallel which is more often. Each transformer has three windings, which are connected to the corresponding bus system.

High voltage bus system (110 kV) is fed through the incoming 110 kV transmission line, which can be either of radial type or a part of the closed 110 kV ring electrical network. High-voltage winding of the transformer is always wye-connected, forming the neutral point, which is directly earthed. Terminals of the high-voltage winding are connected to the 110 kV bus.

Medium-voltage winding of a transformer in the substation of this type is also wye-connected, but its neutral point is always earthed via low impedance, whose purpose is to limit the earth-fault currents. It is important to point out that both the transformers have common grounding impedance, as shown in Figure 1. The terminals of the medium-voltage winding are connected to the 35 kV bus. Each transformer feeds its own 35 kV bus, but closing the separating circuit breaker in medium-voltage bus system, two transformers can be put into parallel operation. Several outgoing power transmission lines (usually 4 to 6) are also connected to the 35 kV bus system, feeding the 35 kV network which is always of radial type.

The third winding of the power transformer (10.5 kV "low" voltage winding) is always delta-connected, and its purpose is to provide the electrical power supply at the 10 kV voltage level, but it also acts as the compensating winding, amending the performance of the transformer under unbalanced load operation conditions. Low-voltage winding terminals are connected to the 10.5 kV bus system, feeding more outgoing power transmission lines (up to 30) of radial type.

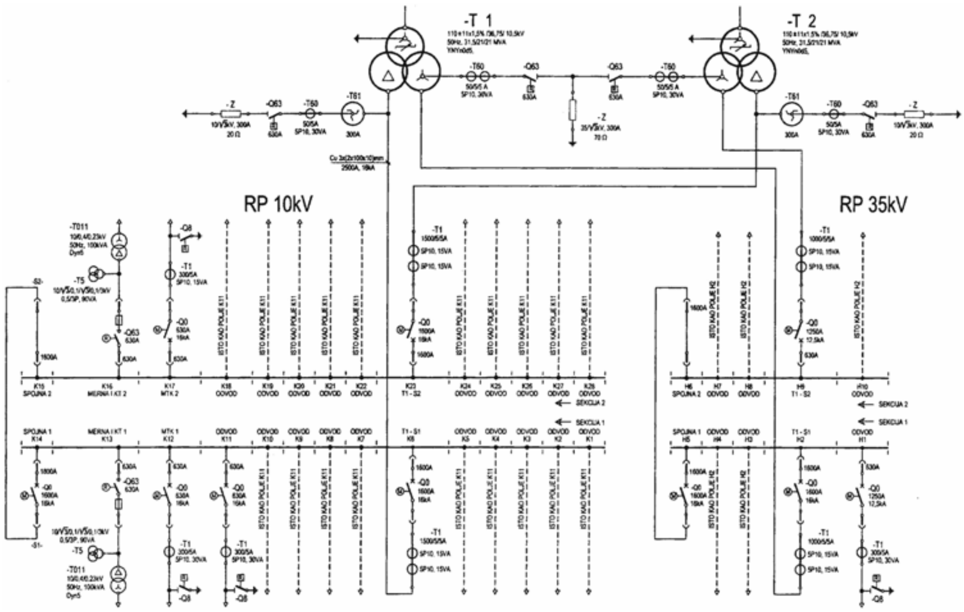

Fig. 1 Typical Disposition of Substation 110/35/10 kV

The main purpose of the substation is to provide reliable and continuous electric power supply for consumers connected to the distributive network. In certain situations, e.g., when a fault in the distributive network occurs, it is necessary to interrupt the power supply until the fault is removed. Continuous operation under fault conditions may lead to damaging or complete destruction of distribution system components and electrical apparatus in supplied consumer, but is also recognized as a source of great risk and danger for human health and life. Thus, each distributive substation has to be provided with different protective systems, whose purpose is to recognize any significant fault emerging in the distributive network or in the substation, and to induce forced disconnection of power supply in a reasonable short time interval. It is desirable that the protective system acts as selectively as possible, disconnecting only the part of distributive network hit by the fault, and leaving the rest of the system in normal operation. Since they represent the components of the distribution system most liable to a fault, the transmission lines have to be equipped with their own protective system. In the case that any of the outgoing radial transmission lines is hit by some kind of electrical fault, its protective relay should cause opening of the outgoing circuit-breaker and disconnection of transmission line from the bus system. The other outgoing transmission lines stay connected to the bus and the power supply of the greatest part of the consumers is uninterrupted.

In some situations, an electrical fault may occur at the bus system, or inside the distributive power transformer. These elements have their own protective systems that react in cases of more serious faults and thus cause forced disconnecting of transformer from the bus system, leaving a large number of consumers without power supply. It is important to notice that the basic bus system protection and transformer protection also act as a reserve protective system of the outgoing transmission lines, in the case that basic protection of the transmission line hit by electrical fault does not react for some reason.

2. Protection of Three-Winding Distributive Power Transformers 110/36.75/10.5 kV

According to the Serbian Electric Power Distribution Company's technical recommendations [3], the protection of distributive power transformers 110/36.75/10.5 kV includes:
- Basic protection of internal faults
- Reserve protection
- Over-load protection
- Over-voltage protection
- Other protection

All the mentioned types of distributive power transformer protections are very complex, and they are presented in the literature ([1], [3]) with detailed explanations. This paper pays special attention to one sub-system of the reserve protection system applied to the three-winding distributive power transformers 110/36.75/10.5 kV.

In general, the distributive power transformer reserve protection should cause the disconnection of the transformer in the case that the basic transformer protection fails, as well as in the case of failure of the bus system or an outgoing transmission line basic protection. The reserve protection consists of:
- reserve over-current protection $RI_1>$
- reserve shortcut-current protection (bus system protection ZS, and protection of circuit-breaker failure ZOP)
- reserve earth-fault protection $RI_0>$

For the purpose of the analysis which will be made in this paper, it is very important to clarify the operation of the three-winding transformer reserve earth-fault protection system.

3. Reserve Earth-Fault Protection System

The reserve earth-fault protection at the high-voltage side of the transformer is not realized as a separate existing unit, because its function is already included in the reserve over-current protection $RI_1>$ and the protection of unbalanced load.

At the low voltage side of the transformer (10 kV and 35 kV), the reserve earth-fault protection system is installed, serving at the same time as the reserve earth fault protection of outgoing transmission lines, and as the basic earth-fault protection of the bus. The main features of this protection are presented in Technical Recommendation TP-4a1 (1), which says:

If neutral point of network is earthed via low impedance, two types of reserve earth fault protection have to be installed:
1. Reserve earth-fault protection RZZ> which reacts in case that basic protection system on some of the outgoing transmission lines hit by earth-fault fails.
2. High-impedance reserve earth-fault protection RZV>, which reacts if an earth-fault across high impedance appears.

Measuring relay of reserve earth-fault protection RZZ> or RZV> is single-phase overcurrent relay which is connected to the terminals of current transformer secondary winding. This current transformer has turns ratio 50/5 A or 100/5 A and is mounted between neutral terminal of power transformer and separating switch in front of grounding impedance Z_E .

Technical Recommendation TP4a-1 also defines current and time adjustments of measuring relays RZZ> and RZV>:

Measuring relay of the reserve earth-fault protection RZZ> has to be adjusted to react if the earth-fault current greater or equal than 30A occurs during the time interval between 0.2 seconds and 3 seconds. Reaction of relay RZZ> causes disconnection of the distributive power transformer at both primary and secondary side.

According to the original version of Technical Recommendation TP4a-1, which was valid till June 2004, the measuring relay of high-impedance reserve earth-fault protection RZV> had to be adjusted to react if the earth fault current greater or equal to 2A occurred during the time interval of 60 seconds. In case that substation is included in the distant control system, a high-impedance earth-fault is just signalized while the power transformer continues with operation. Otherwise, reaction of relay RZV> causes disconnection of the distributive power transformer at both primary and secondary side.

4. Problems Related to Distributive Power Transformers Protection

The main purpose of the protective system is to provide fast, reliable and selective disconnection from the distributive electrical network of an element hit by electrical fault. A well-realized protective system will act only when a real fault occurs, disconnecting as few consumers as possible from the power supply, leaving the rest of the distributive system in normal operation. Under certain circumstances, the protective systems may operate unselectively, or even worse, they may cause forced disconnection of the electrical network elements without any real reason, which is called false reaction. Normally, such situations can be avoided if the protective system has been realized in accordance with the strict rules which are scientifically-based and practically-tested.

The Technical Recommendations of the Serbian Electric Power Distribution Company are expected to be a coherent set of rules whose strict implementation leads to the proper operation of protective systems in distributive substations. However, the practice has shown that these recommendations are incompatible is some segments, and that the reserve earth-fault protection of distributive power transformer 110/36.75/10.5 kV when realized in strict accordance with them, may have false reactions under the normal operating conditions in the substation. A good example is the false reaction of the reserve earth-fault protection in the transformer substation "Bujanovac" 110/35/10 kV, 2×31.5/31.5/10.5 MVA.

4.1. Description of problem with parallel operation of transformers in the substation "Bujanovac"

In the "Bujanovac" transformer substation 110/35/10 kV, 2×31.5/31.5/10.5 MVA there are two three-winding distributive power transformers, whose rated parameters are given in Table 1.

Table 1 Rated parameters of power transformers

	Transformer 1	Transformer 2
Type	TP-8302-31.5	TP-0102-31.5
S_n [MVA]	31.5 / 31.5 / 10.5	31.5 / 31.5 / 10.5
U_n [kV]	110 / 36.75 / 10.5	110 / 36.75 / 10.5
I_n [A]	165.3 / 494.9 / 577.4	165.3 / 494.9 / 577.4
u_k [%]	$u_{k12} = 12.05/10.78/10.0$ $u_{k23} = 1.52$ $u_{k13} = 6.12/5.69/5.47$	$u_{k12} = 12.23/10.94/10.18$ $u_{k23} = 3.44$ $u_{k13} = 8.77/7.65/7.42$
connection	YNyn0d5	YNyn0d5

Medium-voltage terminals of each transformer are connected to the 35 kV bus divided into two sections via separating switch. Since the separating switch is always closed in normal regimes, the transformers are always in parallel operation. It is also important to mention that the third winding of one transformer has to be loaded, supplying consumers connected to the 10 kV bus with electric power. Although all known technical demands related to the parallel operation of transformers have been fulfilled, in normal operation of substation "Bujanovac" some unexpected problems often appeared.

It was noticed that reserve earth-fault protection system reacted very frequently, disconnecting one of the transformers from the common bus. Knowing that large electrical consumption is supplied from this distributive substation, and that parallel operation of the transformers is always necessary, the transformer left in operation was usually seriously overloaded. As a consequence, its over-current protection reacted after some period of time, disconnecting the transformer and leaving the consumers completely without supply.

High-impedance reserve earth-fault protection RZV> should react in case that a high-impedance earth-fault occurs on some of the outgoing transmission lines connected to the common 35 kV bus, and the basic earth fault protection of transmission line affected by earth-fault fails. In such case, both of transformers should be disconnected, because their secondary windings are connected to the same 35 kV bus. The fact that second distributive transformer stayed in operation for some time, indicated the possibility of reserve earth-fault protection system false reacting.

4.2. Analysis of the problem

In order to explain the reason of reserve earth-fault protection system false reacting, it is necessary to consider parallel operation of distributive power transformers at the 35 kV bus in terms of technical recommendations TP-6 and TP-4a1 which were valid at the moment when the problem has been noticed for the first time (2002.).

According to the technical recommendation TP-6 ([4]), if a continuous parallel operation of two distributive power transformers is predicted, both of neutral points have to be grounded via common low impedance, as shown in Figure 2. From Figure 2 it is obvious that current transformers CT1 and CT2, which are intended for the supply of the reserve earth-fault protection measuring relays RZZ> and RZV>, have to be placed into the conductor connecting neutral points of power transformers in parallel operation. In further analysis, some specific features of transformers in parallel operation have to be taken into account.

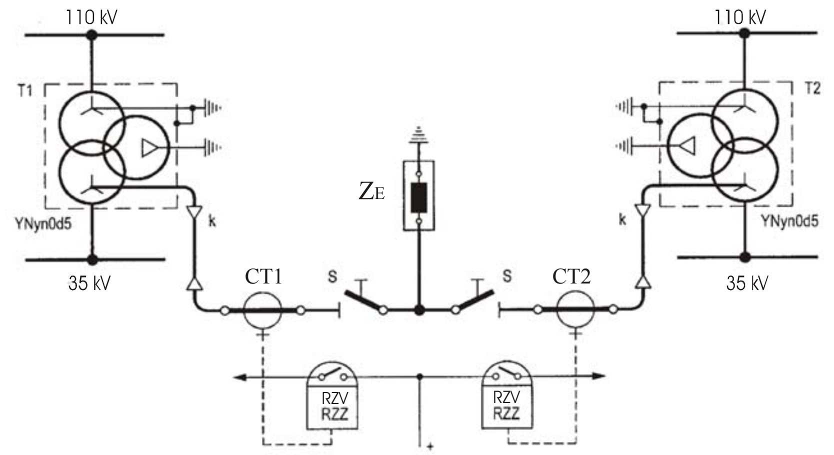

Fig. 2 Grounding of Neutral Points at 35 kV Voltage Level in Parallel Operation

The starting point in our analysis is the fact that when two or more transformers are in parallel operation, certain balancing currents will flow through the transformer windings and through the bus ([5], [6]. This is symbolically presented in Figure 3.

The values of the balancing currents are determined by short-circuit impedance of each power transformer, bus impedance, and the difference between transformer secondary voltages. Theoretically, if all conditions for parallel operation are totally fulfilled, and if primary phase voltages and electrical loads in each phase of secondary winding are totally symmetrical, the balancing current per phase will be equal to zero. In real parallel operation, certain deviations from these ideal conditions are unavoidable and allowed, which causes the appearance of the balancing currents in transformers windings. These currents exist even when transformers operate in parallel under no-load conditions, and they can increase when transformers are loaded.

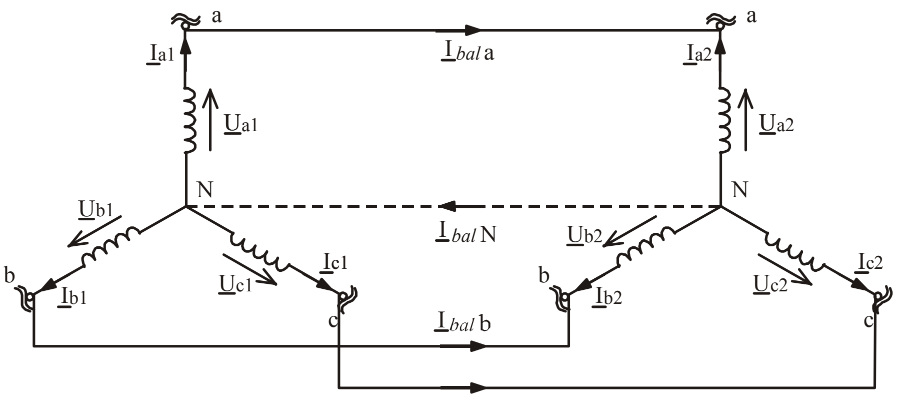

Fig. 3 Balancing Currents in Parallel Operation of Two Transformers

If the neutral points of the transformers in parallel operation are electrically connected, corresponding balancing current $I_{bal\mathrm{N}}$ may flow through the conductor connecting the neutral points. The instantaneous voltage occasions, the load conditions, and the impedance of the connecting line determine this current. Consequently, this current can vary in time, and may be expressed as:

$$\underline{I}_{bal\mathrm{N}} = \underline{I}_{bal\,\mathrm{a}} + \underline{I}_{bal\,\mathrm{b}} + \underline{I}_{bal\,\mathrm{c}} \qquad (1)$$

Observing Figures 2 and 3, it can be noticed that balancing current $I_{bal\mathrm{N}}$ will flow through primary windings of current transformers CT1 and CT2, intended for detecting an earth-fault current. Consequently, the corresponding current will flow though the secondary windings of the current transformers and through the coils of measuring relays RZZ> and RZV>. Under certain operating conditions, balancing current $I_{bal\mathrm{N}}$ can reach the value of 2A during the period of 60s, thus causing the reaction of relay RZV>. As it is impossible that both of RZV> relays have strictly equal reactions, even when their adjustments are equal, one of them reacts first, disconnecting one of the transformers. At the same moment, the balancing current that exists only during the parallel operation disappears. Being not excited anymore, second relay RZV> will allow for a normal autonomous operation of the second power transformer.

Many tests conducted in TS "Bujanovac" have shown that the values of the balancing current between the neutral points of the transformers in parallel operation are in the range $I_{bal\mathrm{N}} = (1.5 - 2.5)$ A. It is obvious that this balancing current can cause false reacting of the reserve earth-fault protection system whose measuring relay RZV> is set to react at the 2A.

4.3. Inadequacy of the Applied Protection System

In the previous section, the balancing current is identified as the main reason of the reserve earth -fault protection system false reacting. Taking into consideration only the range of the balancing current values, measured in real operation of TS "Bujanovac", it could be concluded that the recommended adjustment of relay RZV> was not proper. At first sight, it seems that the described problem can be easily resolved by simple change of relay RZV> reacting current to a higher value. However, the problem of the reserve earth-fault protection operation is much more complicated, and neglecting of its hidden aspects may lead to dangerous regimes of the transformer operation. Further analysis shows that the false reacting explained in the text above is not the only problem caused by inappropriate terms of technical recommendations.

Suppose that the transformers are in parallel operation and that a high-impedance earth-fault occurs on some of the outgoing 35kV transmission lines. As a direct consequence, an earth-fault current I_E occurs, flowing through ground and grounding impedance Z_E (Figure 4).

If the basic earth-fault protection of the transmission line for some reason does not react, the reserve protection system should react, disconnecting transformers after 60 seconds. From Figure 4, it is obvious that the earth fault is fed by both the transformers, and that the earth-fault current can be expressed as:

$$\underline{I}_{\mathrm{E}} = \underline{I}_{\mathrm{E1}} + \underline{I}_{\mathrm{E2}} \qquad (2)$$

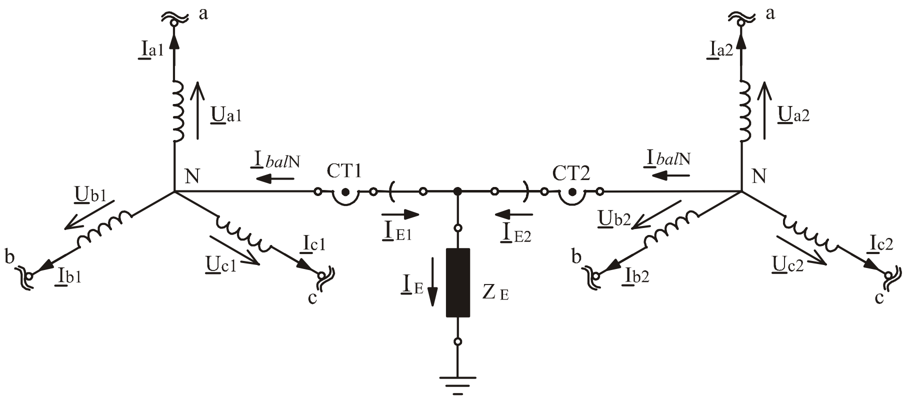

Fig. 4 Transformer Currents During an Earth-fault in Parallel Operation

Through the primary windings of the current transformers flow currents $\underline{I}_{CT1}$ and $\underline{I}_{CT2}$ which consist of neutral balancing current $\underline{I}_{balN}$ and earth fault current components $\underline{I}_{E1}$ and $\underline{I}_{E2}$. According to Figure 4, it can be written:

$$\underline{I}_{CT1} = \underline{I}_{E1} - \underline{I}_{balN} \tag{3}$$

$$\underline{I}_{CT2} = \underline{I}_{E2} + \underline{I}_{balN} \tag{4}$$

Considering equations (3) and (4,) it is clear that if the current transformers are placed in accordance with the controversial recommendation, protective relays RZV> connected to the secondary windings of current transformers CT1 and CT2 do not get the proper information about the real value of earth-fault current I_E. It is obvious that the actual value of earth-fault current $\underline{I}_E$ may overcome the value adjusted on relays RZV> but they will not react, since currents through their coils are much lower than I_E . The final consequence is that the reserve earth-fault protection system cannot operate properly, although is installed and implemented in complete accordance with the related technical recommendations TP-4a1 and TP-6.

4.4. Suggested Technical Solution and Changes in Technical Recommendations

After detecting the essential problem causing false reactions of the reserve earth-fault protection system and thorough the analysis performed in order to find out the most appropriate solution (7), a suggestion for revision of technical recommendations TP-4a1 and TP-6 is given to the Serbian Electric Power Delivery Company. The suggested technical solution predicts a change of position where current transformer of measuring relay RZV> has to be mounted in order to prevent false reaction of the reserve earth-fault protection. According to this solution, current transformers CT1 and CT2 should be displaced from the line connecting the neutral points of the power transformers, and put into serial connection with grounding impedance Z_E. With such position, the flow of balancing current I_{balN} through primary windings of current transformers would be avoided. Also, a new position of the current transformers would ensure proper and reliable functioning of the reserve earth-fault protection system, because measuring relays RZV> would get accurate information about the value of the earth-fault current.

In June 2004, a couple of months after the authors had suggested revision of controversial technical recommendations, the Working group of Serbian Electric Power Delivery company made certain changes in Technical Recommendation TP-4a1 ([2]). However, these changes were not in accordance with the previously described solution.

Technical recommendation TP-4a1 valid at this moment says that the measuring relay of high-impedance reserve earth-fault protection RZV> has to be adjusted to react if an earth fault current greater or equal to 4A occurs during the time interval of 20 seconds. Also, the implementation of an additional relay with purpose of blocking the false reaction of the reserve earth-fault protection due to the balancing current in parallel operation, has been suggested.

It is obvious that the conditions for false reacting of the reserve earth fault protection system in the "Bujanovac" substation will not be fulfilled in terms of new rules, and the problem seems to be solved by making such a change. However, false reaction is just one segment of this otherwise complex problem. Considering the analysis presented in section 4.3. of this paper, it is clear that implementation of new rules to the adjustment of relays RZV> will lead to further decrease of protection system reliability in case that the high-impedance earth-fault occurs.

In that sense, corresponding Technical Recommendations will have to be changed once more in order to eliminate the above-mentioned deficiency.

5. Correlation between Protection of Power Transformers and Professional Risk

Protection systems play a significant role in the process of electric power distribution and their main purpose is to ensure a reliable and safe operation of the distributive system. Considering the influence that the power transformers protection systems have on the levels of the professional risk in substations, it can be expected that their implementation contributes to the safety of working process, decreasing the possibility of accidents and professional injures. However, in certain cases, when protection systems are not adequate and do not operate properly, their implementation has quite opposite consequences to the level of professional risk that the employees in substations are exposed to.

The basic task of the electric power distribution system is to provide continuous and reliable power supply for its consumers. Any fault causing forced disconnecting of some part of the system leads to the situation that some consumer groups stay without supply. This is absolutely undesirable and opposite to the mentioned task of the electric power distribution system. During periods of the interrupted power supply, employees in substations are exposed to high psychic pressure, especially in the situations when the supplied consumers have sensitive nature and must not be left without electric power supply for a long time. If interruptions in the power supply are caused by false reaction of the protection systems and happen frequently, the things get even worse because the employees lose their trust in the protection system capabilities.

It is also known that, after forced disconnecting, every reconnection to the power supply exposes the power system components to high tension, and shortens their operating life limited by the defined number of the allowed work cycles. The possibility of failures and damages on the power system components is greatest during the transient regimes, when a component is being disconnected from the distribution system or when it is reconnected. Failure of these components is usually accompanied with great damage and dangerous explosions that can have terrible consequences for health and life of the employees. Knowing that most of accidents and work injuries that have ever happened in substations are related to the process of disconnecting or reconnecting of power system components, it is quite clear that false reacting of the power transformers protection systems and frequent manipulations of the switchgear contribute to an enormous increasing of the professional risk.

Under these conditions, some of the employees could try to solve the problem by different improvisations, or by simply re-adjusting the measuring relays included in the protection system to react at a higher value of the measured parameter. This approach is completely wrong, because it leads to a more dangerous situation that the protection system does not react in the case of a real fault and allows the transformer operation under irregular conditions. If such a situation lasts long enough, serious damages and destruction of the power system components may appear. Also, there is a possibility that some of the exposed conductive parts in substation or even out of it, come to a voltage potential different from zero, threatening the life of people who could get in contact with them.

These facts clearly indicate that the problem of an inadequate reserve earth-fault protection system of the power transformers in parallel operation must not be neglected. On the contrary, it deserves serious considerations and further changes in the technical recommendations that define realization and implementation of this kind of protection systems.

REFERENCES

1. "Protection of power transmission lines 10 kV, 20 kV and 35 kV", Technical recommendation TP-4a1, Serbian Electric Power System – Direction for distribution of electrical energy, Belgrade, May 2001.
2. "Protection of power transmission lines 10 kV, 20 kV and 35 kV", change of Technical recommendation TP-4a1, Serbian Electric Power System – Direction for distribution of electrical energy, Belgrade, June 2004.
3. "Protection of distributive power transformers in 35/10(20) kV and 110/x kV substations", Technical recommendation TP-4b, Serbian Electric Power System – Direction for distribution of electrical energy, Belgrade, May 2001.
4. "Grounding of neutral points in electric power distributive networks 110 kV, 35 kV, 20 kV, 10 kV and 0.4 kV", Technical recommendation TP-6, Serbian Electric Power System – Direction for distribution of electrical energy, Belgrade, May 2001.
5. Kalić Đ. "Transformers", The Institute for School Books and Teaching Aids, Belgrade, 1991.
6. Vukić Đ., Milkić Ž., Stajić Z. "Transformers - solved problems", Faculty of Electrical Engineering, Pristina, 1998.
7. "Parallel operation of transformers 110/35/10 kV, 31.5/31.5/10.5 MVA – problem analysis with suggestions of technical solutions", Study, Faculty of the Occupational Safety, Nis, 2003.

ZAŠTITA DISTRIBUTIVNIH ENERGETSKIH TRANSFORMATORA I PROFESIONALNI RIZIK

Vladica Aleksić, Zoran Stajić, Milan Radić

U radu se razmatra odnos između načina rada sistema zaštite distributivnih energetskih transformatora i nivoa profesionalnog rizika u distributivnim trafo-stanicama. Opisani su glavni funkcionalni delovi i rad tipične trafo-stanice 110/35/10 kV. Navedeni su tipični sistemi zaštite koji se primenjuju kod tronamotajnih transformatora 100/36.75/10.5 kV snage 31.5/31.5/10.5 MVA. Posebna pažnja je posvećena radu sistema rezervne zemljospojne zaštite koji je identifikovan kao uzrok pojave ozbiljnih problema pri paralelnom radu dva energetska transformatora. Osim toga što je argumentovana neadekvatnost ovog sistema zaštite, date su sugestije za izmenu odgovarajućih tehničkih preporuka kojima se definiše način realizacije sistema rezervne zemljospojne zaštite. Uvažavanje ovih sugestija dovešće do pouzdanijeg i bezbednijeg rada energetskih transformatora u distributivnim trafo-stanicama 110/35/10 kV, što će istovremeno za posledicu imati smanjenje nivoa profesionalnog rizika.

Ključne reči: *profesionalni rizik, sistem zaštite, energetski transformator, paralelan rad*