

ALARM PROCESSING IN A POWER SYSTEM BY HUMAN EXPERT

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Preliminary notes

Emergence of failure within a power system is an unwanted situation when certain parts of the network become separated from the other parts unaffected by this failure. Relay protection system has the task of isolating the sections that are faulty. By activating the protection an alarm is sent to the substation and the dispatch centre. Alarms in the dispatch centre come in the short period of time which can confuse the dispatcher and lead him towards making an error. The proper approach and selection of methods for analysing alarms are both very essential for locating the faulty section. There are two well-known methods for analysing failures; one is a method of finger printing and the other a method of hypothesis. The analysed alarms were the ones in the TS 35/10 kV Istok detachment from the rest of the power system. The aim of this paper is to analyse the alarms that have occurred in the dispatch centre during the 35/10 kV Istok detachment by using the finger print method and the method of hypothesis. The results have been found and the cause of section 35/10 kV Istok failure from the rest of the power system. The given results have confirmed the unit and the cause of the TS 35/10 kV Istok detachment from the rest of the power system.

Keywords: *alarm analysis, finger print method, hypothesis method, relay protection*

Čovjekova analiza alarma u elektroenergetskom sustavu

Prethodno priopćenje

Pojava kvara je neželjena situacija u elektroenergetskom sustavu prilikom čega se određeni dijelovi mreže odvajaju od ostatka koji nije zahvaćen kvarom. Sustav relejne zaštite ima zadatak izoliranja dionica koje se nalaze u kvaru. Aktivacija određene zaštite šalje alarm u trafostanicu i dispečerski centar. Alarmi u dispečerski centar dolaze u kratkom vremenu što može dispečera zbuniti i navesti na pogrešku. Pravilan pristup i odabir metode za analiziranje alarma vrlo su bitna stvar za lociranje dionice u kvaru. Poznate su dvije metode za analiziranje kvara a to su metoda niza i metoda hipoteza. Analizirani su alarmi koji se pojavljuju prilikom odvajanja TS 35/10 kV Istok od ostatka elektroenergetskog sustava. Cilj ovog rada je analiziranje alarma koji su se pojavili u dispečerskom centru prilikom ispada TS 35/10 kV Istok metodom niza i metodom hipoteza. Dobiveni rezultati su utvrdili dionicu i uzrok ispada TS 35/10 kV Istok od ostatka elektroenergetskog sustava.

Cljučne riječi: *analiza alarma, metoda niza, metoda hipoteza, relejna zaštita*

1 Introduction

This paper describes the fault diagnosis problem faced by operators and the requirements met by the human expert. Faults in substations alarm the power system operator by triggering a response on event recorders, mimic diagrams in the control rooms and/or the graphic displays of SCADA system. These indications can normally provide means for evaluating the seriousness of the disturbance. In addition they will assist the system operator and/or the supervisor of a manned substation, to plan the necessary steps for the restoration of supplies. If restoration is not possible by automated switching, then there is no other choice but to alarm the responsible crew for monitoring the situation and initiate repairs. Depending on the location and seriousness of the fault, system security may be reduced for considerable time.

Taking into consideration all these procedures the following should be pointed out:

- The consequences of some faults may be very serious for consumers serviced by the substation affected by the fault.
- The distance of substations is sometimes an additional problem being far from test laboratories where the maintenance team is normally based.
- Substation faults are quite rare and therefore full time employment of an expert based at a manned substation is not justifiable.
- The experts in order to analyse the fault require certain information about the equipment to be involved in the emergency which is time consuming

to be obtained (e.g. search through manuals), causing additional delays.

- If the substation is manned there are some fundamental simple tests which could be carried out very easily by a non-expert technician (e.g. the supervisor of the substation).

It can therefore be justified to use an expert system implemented on a low-cost microcomputer permanently installed in the substation and continuously monitoring all necessary protection and control functions. The microcomputer system could operate on-line linked with the SCADA system in addition to the other signals required for solving of the problem and/or off-line when the substation is manned.

Fault in the power system (PS) activates the relay protection system that isolates the faulty section. A certain protection is activated by sending a local signal (an alarm) to a transformer substation (TS) and a remote one to the dispatch centre. In the dispatch centre the alarms are visible through the SCADA system which alongside having a possibility of remote management, measurement and control, also has a chronological events recorder (CER). The alarms that reach the dispatch centre are visible in the CER and are retained there. The alarms coming from the TS are related to the primary and secondary part of the TS. A wide range of alarms includes: signalling the position of circuit breakers (CB) and disconnectors, that is how they switch on, activate and trip a certain protection, signalling the detachment of certain automatic CBs in the secondary transmission, the detachment of certain devices in the secondary transmission, as well as some seemingly unimportant

alarms such as opening substation doors. At the moment of failure all these alarms appear on the CER screen and fold one onto the other so that the last apparent alarm is the latest activated within the network. Everything is fine as long as the number of alarms and situations in the network are simple. When hundreds of alarms appear within the short period of time the thing gets complicated and it is difficult to find the faulty unit and its cause, which disables operator's reaction to establish the initial operation state in the network, and can thus be misled towards making an error [3]. Due to these kinds of situations we are using the methods for analysing the alarms. The two standard ones are used: a finger print method [1] and a hypothesis method. The finger print method is used when we have a small number of alarms and when there is a situation with easily determinable unit and cause of the failure. We use this method when we know the facts, information and when we logically move towards the goal. The hypothesis method is used in the case of a wider number of alarms and situations where we cannot be 100 % certain about the unit and cause of the malfunction [1]. It is used for different types of problems, with unknown facts and information and thus we start from the hypothesis. During the TS 35/10 kV Istok detachment the incoming alarms in the dispatch centre were analysed with both finger print and hypothesis methods.

The point of this entire analysis is the right usage of both methods on a specific example of TS 35/10 kV Istok detachment from the rest of the distribution network.

2 Finger print and hypothesis method

The basic idea behind this method is to provide an expert with the necessary information and interaction in order to make a fault diagnosis through the substation alarms in a very friendly environment. The main task of the method is to replace the troubleshooting manuals of substation equipment and human expertise in substation fault diagnosis and alarm processing with a user-friendly computer environment and to take advantage of the user's accumulated experience.

The very notion of analysing alarms includes a wide spectrum of techniques with the same goal: to present to the operator organized and coordinated information about the events at the PS. We have contemporary, intelligent techniques as well as some traditional ones which we are going to touch upon as well. The alarm analysis (fault diagnosis) is done by the operators in the control centre, as well as by the protection engineers.

The alarm analysis can be done in three different time periods: immediately, short term or long term [4]. We are going to show the short term analysis done by the finger print method and the hypothesis method and thus show the situations operators face, where they have to do an immediate analysis.

An event assumes a change done by the operator on the overall network topology to do certain tasks for the network maintenance (supply from the other feeder, a shutdown, inserting another transformer), as well as changing the circuit state which is activated either due to the relay protection influence or the detachment of the PS section affected by the fault.

All the information about the daily events are presented in the dispatcher reports. We open the CER list based on these reports, and analyse the received alarms and finally make conclusions. These events might be just a temporary fault after it has been shut down by the protection system. The automatic reconnection (AR) returns a certain section of the network after a short or long pause back to its initial state. After that we establish the proper functioning of the relay protection system. In certain situation we wait for this true reconnection of the system in order to determine the direction of the fault (cable network).

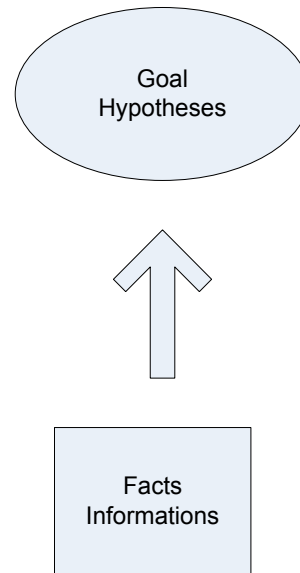


Figure 1 Block diagram of the finger print method

In order to analyse the alarms coming into the dispatcher centre we have to primarily know the way a relay protection functions, its parameters, as well as the network and energy flow which supply certain TS.

The analysis itself is based on several steps: the right approach, choosing the method, knowledge of the aforementioned notions, logical conclusions and experience. This analysis is far from simple and trite, even though it might look so at first glance. When a certain complex fault appears the CER screen can pick up as much as several hundreds or even thousands of alarms within a couple of minutes. A person trying to analyse and determine the order of fault within the PS might reach the limits of his/her capabilities. In order to capture all the variables in the analysis we have to take into consideration the incoming phone calls from the field, and accept the possibility of redundant alarms as well as the lack of individual alarms. CER is the strongest authority for proving the alarm analyses, alongside all the other tools we can use while analysing the alarms such as phone alerts from the field or local signals withheld in the TS used for the further analysis. CER is placed within the SCADA system and can be overviewed for any substation which has the remote communication equipment, used for remote management, control and measurements. Changing the protection parameters can also be done remotely. CER shows various kinds of signals coming from the network both from the primary and secondary part of TS. When a complex event occurs, an operator

simply does not have time to do the analysis. He uses trial and error method to put network in initial state and thus isolate the fault. A finger print method and hypothesis method are the two traditional methods for analysing the alarms coming from the TS. The pattern method got its name from the way in which alarms come to the control centre. They fold one onto the other so that the uppermost alarm is the last one that occurred. The finger print method uses concluding in advance. It starts by assembling the information, which is used as a basis for the logical conclusions. For example, if $X = \text{a frog}$ then $X = \text{green}$. The conclusion begins with familiar facts which are sources for new facts by using certain rules, and this process is continued till the coveted goal is reached, see Fig. 1. Expert systems [2] rarely use these kinds of conclusions. There is a drawback to this kind of prejudging, because we start with the information or facts we often do not possess and therefore we cannot reach logical conclusions.

The hypothesis method is actually an alternative approach for analysing alarms appearing within a network and TS. The finger print method is used when we have a fairly clear situation and up to several hundred alarms, while the hypothesis method is used in complex situations and hundreds and thousands of alarms. We also use it when we cannot be 100 % sure what has happened. We simply attach a certain level of probability to each hypothesis so that the overall sum equals 1. The number of hypotheses can come up to as high as ten. While browsing through the CER some of the hypotheses will drop off leaving the remaining 2 or 3. Forming inter-hypothesis is a risky thing and it is not used when analysing alarms. The hypothesis method is the way alarm processors function when they are replacing a human in dealing with complex situations and big PSs while analysing alarms.

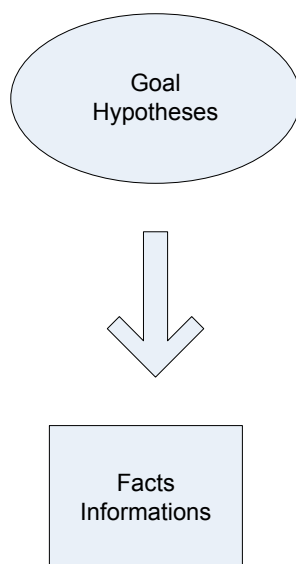


Figure 2 Block diagram of the hypothesis method

Alarm processors emerged in the late 1980s primarily in the USA, Germany and Japan [5]. Their function is based on the hypothesis method, an algorithm and knowledge base. Knowledge bases are similar to databases but they include experience information.

The second category of problems is the ones where we do not know the information or facts so we start from the hypothesis which we are trying to prove by getting information to support this hypothesis. This is shown by Fig. 2. This conclusion method is also used in the expert system and is called a reverse conclusion. The reverse conclusion starts with a goal that needs to be proven. The reverse conclusion refers to the way of thinking in the hypothesis method.

The simplified algorithm scheme of the automatized method in the hypothesis used by the alarm processor (an expert system) is shown in Fig. 3 [1].

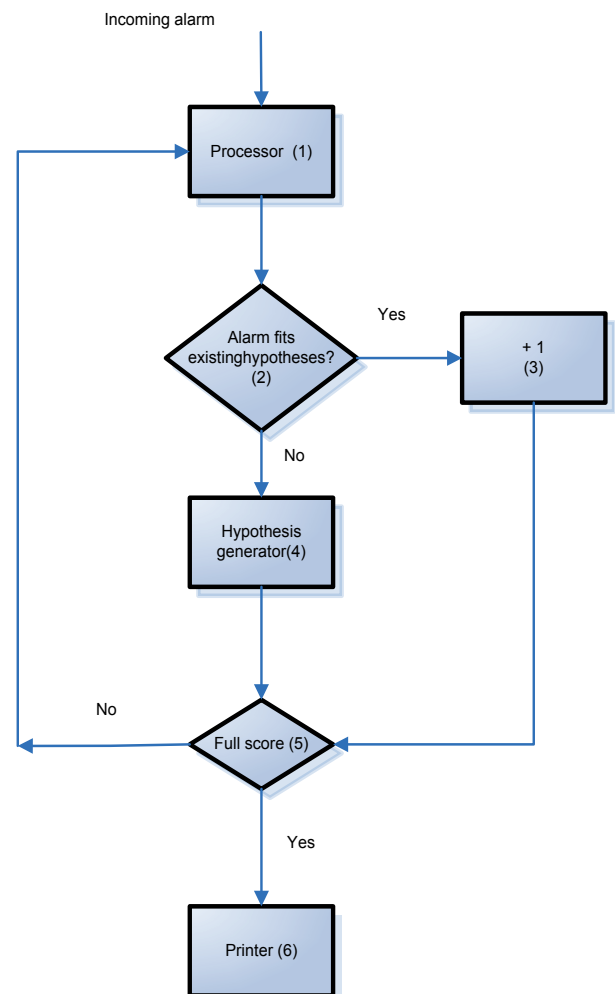


Figure 3 A simplified algorithm used in the alarm processor

The oncoming alarms come to the processor (1), followed by being checked if they match some of the hypotheses (2). If the match occurs, the hypothesis is given one point, thus gaining advantage over other hypotheses. The hypothesis/es then go to the evaluation stage (5) which checks if it is 100 % correct, meaning if it has the maximum number of points and in that order it is finally printed. When the hypothesis is printed, its corresponding alarms are printed out as well. If the oncoming alarm does not correspond to any hypothesis (2), a new hypothesis has to be generated. This newly created hypothesis now has a set of alarms which are immediately recognizable while forming the hypothesis, only they have to be compared to the ones that came in.

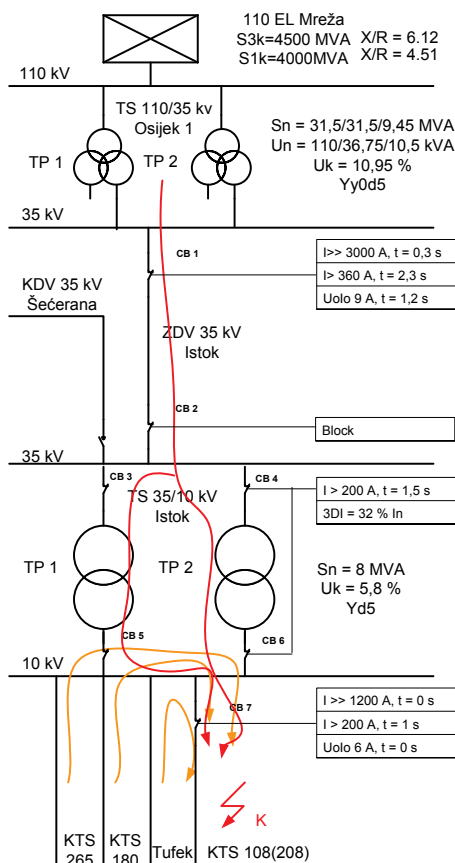


Figure 4 35 kV section of the DP Elektroslovanija network

11.2.2010	08:19:34.807	ISTOK	10	108/208	RAST UZEM	Međupoložaj 00
11.2.2010	08:19:34.344	ISTOK	10	108/208	RAST VOD	ISKLJUCEN
11.2.2010	08:19:34.340	ISTOK	10	108/208	RAST VOD	Stanje kvara 11
11.2.2010	08:17:55.594	ISTOK	10	108/208	RAST S 1	ISKLJUCEN
11.2.2010	08:17:55.564	ISTOK	10	108/208	RAST S 1	Međupoložaj 00
10.2.2010	21:30:25.818	ISTOK	10	TUFEK	PREKIDAC	UKLJUCEN
10.2.2010	21:30:25.815	ISTOK	10	TUFEK	PREKIDAC	Stanje kvara 11
10.2.2010	21:29:57.064	ISTOK	10	KTS 180	PREKIDAC	UKLJUCEN
10.2.2010	21:29:57.055	ISTOK	10	KTS 180	PREKIDAC	Stanje kvara 11
10.2.2010	21:29:25.577	ISTOK	10	KTS 265	PREKIDAC	UKLJUCEN
10.2.2010	21:29:25.570	ISTOK	10	KTS 265	PREKIDAC	Međupoložaj 00
10.2.2010	21:29:11.299	ISTOK	NAPON AC NA SABIRNICAMA			POVRATAK
10.2.2010	21:28:53.429	ISTOK	35	ZDV OS 1	PREKIDAC	UKLJUCEN
10.2.2010	21:28:53.426	ISTOK	35	ZDV OS 1	PREKIDAC	Međupoložaj 00
10.2.2010	21:28:20.208	OSK 1	35	ISTOK	PREKIDAC	UKLJUCEN
10.2.2010	21:28:20.195	OSK 1	35	ISTOK	PREKIDAC	Stanje kvara 11
10.2.2010	21:27:48.387	ISTOK	10	TUFEK	PREKIDAC	ISKLJUCEN
10.2.2010	21:27:48.378	ISTOK	10	TUFEK	PREKIDAC	Stanje kvara 11
10.2.2010	21:27:33.912	ISTOK	10	KTS 180	PREKIDAC	ISKLJUCEN
10.2.2010	21:27:33.907	ISTOK	10	KTS 180	PREKIDAC	Stanje kvara 11
10.2.2010	21:27:17.159	ISTOK	10	KTS 265	PREKIDAC	ISKLJUCEN
10.2.2010	21:26:41.017	ISTOK	35	ZDV OS 1	PREKIDAC	ISKLJUCEN
10.2.2010	21:26:15.915	OSK 1	35	APU DEF	PRESTANAK	
10.2.2010	21:26:15.906	OSK 1	35	Z. KRATKOSPojNA	PRESTANAK	
10.2.2010	21:26:15.902	OSK 1	ISPRAVLJAC ACDC 220V			POVRATAK
10.2.2010	21:26:15.803	OSK 1	35	ISTOK	PREKIDAC	ISKLJUCEN
10.2.2010	21:26:15.791	OSK 1	35	ISTOK	PREKIDAC	Stanje kvara 11
10.2.2010	21:26:15.754	OSK 1	35	APU DEF	UPOZ	
10.2.2010	21:26:15.743	OSK 1	35	Z. KRATKOSPojNA	ISK	
10.2.2010	21:26:15.646	OSK 1	ISPRAVLJAC ACDC 220V			ISPAD
10.2.2010	21:26:15.527	ISTOK	10	Z. KRATKOSPojNA	PRESTANAK	

10.2.2010	21:26:15.512	ISTOK	NAPON AC NA SABIRNICAMA			NESTANAK
10.2.2010	21:26:15.492	ISTOK	10	108/208	PREKIDAC	ISKLJUCEN
10.2.2010	21:26:15.488	ISTOK	10	108/208	PREKIDAC	Međupoložaj 00
10.2.2010	21:26:15.444	ISTOK	10	Z. KRATKOSPojNA	ISK	
10.2.2010	21:26:15.426	ISTOK	10	108/208	PREKIDAC	UKLJUCEN
10.2.2010	21:26:15.420	ISTOK	10	108/208	PREKIDAC	Međupoložaj 00
10.2.2010	21:25:42.409	ISTOK	35	KDV SEC	PREKIDAC	ISKLJUCEN
10.2.2010	21:25:42.406	ISTOK	35	KDV SEC	PREKIDAC	Stanje kvara 11
10.2.2010	21:25:03.902	ISTOK	35	ZDV OS 1	PREKIDAC	UKLJUCEN
10.2.2010	21:25:03.899	ISTOK	35	ZDV OS 1	PREKIDAC	Međupoložaj 00
10.2.2010	21:24:19.626	ISTOK	35	ZDV OS 1	RAST S 1	UKLJUCEN
10.2.2010	21:24:19.172	ISTOK	35	ZDV OS 1	RAST S 1	Stanje kvara 11
10.2.2010	21:14:42.755	OSK 1	35	ISTOK	PREKIDAC	UKLJUCEN
10.2.2010	21:14:42.743	OSK 1	35	ISTOK	PREKIDAC	Stanje kvara 11
10.2.2010	20:56:06.724	ISTOK	10	TUFEK	PREKIDAC	UKLJUCEN
10.2.2010	20:56:06.721	ISTOK	10	TUFEK	PREKIDAC	Stanje kvara 11
10.2.2010	20:55:38.458	ISTOK	10	KTS 180	PREKIDAC	UKLJUCEN
10.2.2010	20:55:38.456	ISTOK	10	KTS 180	PREKIDAC	Stanje kvara 11
10.2.2010	20:54:45.668	ISTOK	10	KTS 265	PREKIDAC	UKLJUCEN
10.2.2010	20:54:45.661	ISTOK	10	KTS 265	PREKIDAC	Međupoložaj 00
10.2.2010	20:54:23.789	ISTOK	10	TP 2	PREKIDAC	UKLJUCEN
10.2.2010	20:54:23.785	ISTOK	10	TP 2	PREKIDAC	Međupoložaj 00
10.2.2010	20:54:15.927	ISTOK	NAPON AC NA SABIRNICAMA			POVRATAK
10.2.2010	20:53:56.047	ISTOK	10	TP 1	PREKIDAC	UKLJUCEN
10.2.2010	20:53:56.038	ISTOK	10	TP 1	PREKIDAC	Stanje kvara 11
10.2.2010	20:53:32.875	ISTOK	10	KTS 265	PREKIDAC	ISKLJUCEN
10.2.2010	20:53:32.875	ISTOK	10	KTS 265	PREKIDAC	Stanje kvara 11
10.2.2010	20:53:30.055	ISTOK	35	TP 2	PREKIDAC	UKLJUCEN
10.2.2010	20:53:30.055	ISTOK	35	TP 2	PREKIDAC	Međupoložaj 00
10.2.2010	20:53:15.660	ISTOK	35	TP 1	PREKIDAC	UKLJUCEN
10.2.2010	20:53:15.646	ISTOK	35	TP 1	PREKIDAC	Međupoložaj 00
10.2.2010	20:52:43.043	ISTOK	10	KTS 180	PREKIDAC	ISKLJUCEN
10.2.2010	20:52:43.028	ISTOK	10	KTS 180	PREKIDAC	Stanje kvara 11
10.2.2010	20:52:24.778	ISTOK	35	KDV SEC	PREKIDAC	UKLJUCEN
10.2.2010	20:52:24.775	ISTOK	35	KDV SEC	PREKIDAC	Međupoložaj 00
10.2.2010	20:52:11.265	ISTOK	10	TUFEK	PREKIDAC	ISKLJUCEN
10.2.2010	20:52:11.256	ISTOK	10	TUFEK	PREKIDAC	Stanje kvara 11
10.2.2010	20:51:58.577	ISTOK	35	TP 1	PREKIDAC	ISKLJUCEN
10.2.2010	20:51:58.566	ISTOK	35	TP 1	PREKIDAC	Međupoložaj 00
10.2.2010	20:51:32.616	ISTOK	10	TP 1	PREKIDAC	ISKLJUCEN
10.2.2010	20:51:16.291	ISTOK	35	TP 2	PREKIDAC	ISKLJUCEN
10.2.2010	20:51:16.283	ISTOK	35	TP 2	PREKIDAC	Međupoložaj 00
10.2.2010	20:50:54.248	ISTOK	10	TP 2	PREKIDAC	ISKLJUCEN
10.2.2010	20:50:54.242	ISTOK	10	TP 2	PREKIDAC	Stanje kvara 11
10.2.2010	20:50:41.470	ISTOK	35	ZDV OS 1	RAST S 1	ISKLJUCEN
10.2.2010	20:50:41.092	ISTOK	35	ZDV OS 1	RAST S 1	Stanje kvara 11
10.2.2010	20:50:21.191	ISTOK	35	ZDV OS 1	PREKIDAC	ISKLJUCEN
10.2.2010	20:50:21.189	ISTOK	35	ZDV OS 1	PREKIDAC	Međupoložaj 00
10.2.2010	20:49:15.379	OSK 1	35	APU DEF	PRESTANAK	
10.2.2010	20:49:15.371	OSK 1	35	Z. KRATKOSPojNA	PRESTANAK	
10.2.2010	20:49:15.357	OSK 1	ISPRAVLJAC ACDC 220V			POVRATAK
10.2.2010	20:49:15.266	OSK 1	35	ISTOK	PREKIDAC	ISKLJUCEN
10.2.2010	20:49:15.255	OSK 1	35	ISTOK	PREKIDAC	Stanje kvara 11
10.2.2010	20:49:15.217	OSK 1	35	APU DEF	UPOZ	
10.2.2010	20:49:15.206	OSK 1	35	Z. KRATKOSPojNA	ISK	
10.2.2010	20:49:15.111	OSK 1	ISPRAVLJAC ACDC 220V			ISPAD
10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPojNA	PRESTANAK	
10.2.2010	20:49:14.948	ISTOK	10	108/208	PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA			NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208	PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPojNA	ISK	

Figure 5 KRD alarms

3 Results

The events of February 10, 2010 and the failure at feeder KTS 108/208 when the entire TS 35/10 kV Istok became detached from the rest of the network. TS 35/10 kV Istok has the ability of supplying itself from TS 110/35 kV Osijek 1 and TS 35/10 kV Šećerana. At the moment of the fault TS 35/10 kV Istok was supplied from TS 110/35 kV Osijek 1.

The arrows show the direction of the energy flow at the point of the fault at feeder 10 kV 108/208 as illustrated in Fig. 4.

The finger print analysis is used for analyzing a smaller number of alarms, which in our case was not an easy way out. The supply scheme of the TS Istok with its corresponding protection adjustments is shown in Fig. 4. In order to determine the fault section and its cause, CER was the only reliable tool. The initial analysis point, shown in Fig. 5, moves from bottom upwards. This method is called a bottom-upwards method.

At 20:49:14,901 a short-circuit protection was tripped at TS 35/10 kV Istok causing the shutdown of the CB in feeder 10 kV 108/208 at 20:49:14,984. An alarm appears at 20:49:14,984 to signal the termination of short-circuit protection and thus eliminating the fault. At 20:49:15,206 a short-circuit protection is activated at TS 110/35 kV Osijek 1, by shutting down the feeder 35 kV Istok at 20:49:15,266. It is followed by the alarm signalling the termination of the short-circuit protection at 20:49:15,371 meaning that the fault has been eliminated. At 20:50:21,191 the operator shuts down a CB at TS 35/10 kV Istok in feeder 35 kV ZDV OS 1. After that at 20:50:54,242 he turns off the disconnecter at the same feeder, followed by the turnoff of the 10 kV transformer 2's CB at 20:50:54,248, and shortly after that at 20:51:16,291 turning off the 35 kV CB at transformer 2. At 20:51:32,616 the operator turns off 10 kV CB at transformer 1, followed by turning off 35 kV CB on transformer 1 at 20:51:58,577. After that at 20:52:11,265 it unburdens the 10 kV bus by switching off the feeder 10 kV Tufek. After this operation is done at 20:52:24,778, a 35 kV feeder Šećerana CB is turned on, thus supplying the voltage to 35 kV bus at TS 35/10 kV Istok. After this point at 20:52:43,043 the operator turns off 10 kV feeder KTS 180 CB which continues unburdening the 10 kV bus at TS 35/10 kV Istok. It turns on the 35 kV transformer 1 CB at 20:53:15,660, and shortly after that the 35 kV CB in transformer 2 at 20:53:30,055 and by doing so it puts both transformers into a neutral state. At 20:53:32,875 operator turns off the 10 kV feeder KTS 265 CB and this unburdens the 10 kV bus at TS 35/10 kV Istok. At 20:53:56,047 the operator turns on the 10 kV CB at transformer 1 thus supplying the voltage at 10 kV bus. At 20:54:23,789 the operator turns on 10 kV CB transformer 2 bringing the voltage to 10 kV bus, and at the same time putting both transformers into a parallel work. At 20:54:45,668 he turns on the feeder 10 kV KTS 265 CB, and shortly after that at 20:55:38,458 turns on the feeder 10 kV CB KTS 180. After that at 20:56:06,724 he turns on the feeder 10 kV Tufek's CB and by doing so it finishes the loading of the 10 kV bus at TS 35/10 kV Istok. Feeder 10 kV 108/208 has not been turned on so far. Furthermore at 21:14:42,755, feeder 35 kV Istok in

TS 110/35 kV Osijek 1 is turned on. At 21:24:19,626 a disconnecter is turned on, followed by a CB at 21:25:03,902, feeder 35 kV ZDV OS 1 in TS 35/10 kV Istok. This means that at that point TS 35/10 kV is supplied from TS 35/10 kV Šećerana, but also from TS 110/35 kV Osijek 1. At 21:25:42,409 the operator turns on the feeder 35 kV Šećerana's CB at TS 35/10 kV Istok. The result of this is that now the TS 35/10 kV Istok is supplied from TS 110/35 kV Osijek 1. This leads to the conclusion that there is no failure at 35 kV ZDV OS 1-Istok. Considering the fact that the operator is trying to bring the network into its initial state it turns on the feeder 10 kV 108/208 CB at 21:26:15,426. This action leads to activating the short-circuit protection at 21:26:15,444.

Followed by the protection's order to turn off the feeder 10 kV 108/208 CB which was turned off at 21:26:15,488. Parameters for short-circuit protection feeder 10 kV 108/208 is $I \gg 1200$ A and $t=0$ s, and we can see that from the turning on the feeder 10 kV 108/208 CB to its turn off, 62 ms has passed, which means that the protection was done in accordance with the adjusted values, and the CB's reaction is approximately 50 ms. At 21:26:15,527 an alarm is received "short-circuit protection termination", meaning that the CB has eliminated the fault. At 21:26:15,743 "short-circuit shutdown" alarm appears at TS 110/35 kV Osijek 1 meaning that the protection remained active after eliminating the malfunction at feeder 10 kV 108/208 which caused the feeder 35 kV Istok CB to be turned off at TS 110/35 kV Osijek 1 at 21:26:15,803.

Let us now review the point when the feeder 10 kV 108/208 CB is turned on, which was at 21:26:15,426 and the moment of its turn off, at 21:26:15,492. If we add on a reaction of the switch in approx. 50 ms and the delay time of the short-circuit protection in $t=0$ s it presents an action within the limits of adjustment. Furthermore, if we know that the feeder 35 kV Istok switch at TS Osijek 1 was turned on at 21:26:15,803, and that setting protection at $t=300$ ms was the CB's reaction of additional $t=50$ ms, if we add this mutual time to 21:26:15,426, and that is turning on the feeder 10 kV 108/208 CB, resulting in the time of 21:23:15,803.

This means that the protection has reacted in accordance with the adjustment but randomly because it was awakened after the elimination at the fault at feeder 10 kV 108/208. At 21:26:15,906 an alarm "short-circuit protection shutdown" appears at feeder 35 kV Istok which means that a non-existent failure has been eliminated and the protection activated.

At 21:26:41,017 the operator turns on the feeder 35 kV ZDV OS 1 CB at TS 35/10 kV Istok. After this it unburdens the 10 kV bus at TS 35/10 kV Istok by turning off the CB at feeder 10 kV KTS 265 at 21:27:17,159, a CB at feeder 10 kV KTS 180 at 21:27:33,912 and a CB at feeder 10 kV Tufek at 21:27:48,387. This is followed by turning on the CB at feeder 35 kV Istok at TS 110/35 kV Osijek 1 at 21:28:20,208. After this the operator turns on the feeder 35 kV ZDV OS 1 CB at TS 35/10 kV Istok at 21:28:53,429, thus immediately bringing voltage to 10 kV bus at TS 35/10 kV Istok because both transformers stayed active. He is now starting to burden the 10 kV bus at TS 35/10 kV Istok by turning on the feeder 10 kV KTS 265 CB at 21:29:25,577, followed by 10 kV KTS 180 CB

at 21:29:57,064 and finally turning on the feeder 10 kV Tufek's CB at 21:30:25,815.

There are problems of different category where we do not know the information and facts, so we start from the hypothesis which we are trying to prove by collecting information to support the hypothesis. This kind of conclusion is also used by the expert system and is called a backwards conclusion.

The backwards conclusion starts with establishing a goal which needs to be proven. It relates to the way of thinking included in the hypothesis method. The hypothesis method uses an alarm processor, but also a human when it comes to analysing a larger number of alarms.

Hypothesis can include [4]:

- System faults,
- Protection faults (involving a faulty or no action),
- Malfunctions on the CBs (involving a faulty or no action),
- Telemetry failures (alarm redundancy or deficiency).

The established hypotheses are as follows:

Hypothesis:

- A: Fault at feeder 10 kV ,
 B: Fault at transformer 1 and transformer 2,
 C: Fault at ZDV 35 kV OS 1 – Istok,
 D: Simultaneous faults at 10 kV feeder and 35 kV feeder
 E: Protection false operation.

There were five hypotheses being set, which does not mean there could not have been more. The fewer the hypotheses the faster and more efficient the analysis is, while some trivial hypotheses need to be neglected. The way of analysing is to connect the initial hypothesis with CER which is in the end the proof and solution to the problem.

Some hypotheses will be dropped while CER is sorted and finally there will be a maximum of 3 hypotheses. Hypotheses A, B, C and D refer to the fault location within the system, and the E hypothesis is the protection's false operation (the cause of the event in the facility).

Fig. 5 shows the initial point of analysis by using the hypothesis method. We are trying to put the emergence of a certain number of alarms connected to the protection situation under the establish hypothesis. After activating the short-circuit protection, turning on the VP 10 kV 108/208 CB and activating the hypothesis protection, the hypothesis appears as followed:

A: Fault at feeder 10 kV,

10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:14.948	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA		NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPOJNA	ISK

B: Fault at transformer 1 and transformer 2,

C: Fault at ZDV 35 kV OS 1 – Istok,

D: Simultaneous faults at 10 kV feeder and 35 kV feeder

10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:14.948	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA		NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPOJNA	ISK

E: Protection false operation.

10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:14.948	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA		NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPOJNA	ISK

After activating the short-circuit protection and shut down of the feeder 35 kV Istok.

The hypothesis appears as follows:

A: Fault at feeder 10 kV,

10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:14.948	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA		NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPOJNA	ISK

B: Fault at transformer 1 and transformer 2,

C: Fault at ZDV 35 kV OS 1 – Istok,

D: Simultaneous Faults at 10 kV feeder and 35 kV feeder

10.2.2010	20:49:15.379	OSK 1	35	APU DEF	PRESTANAK
10.2.2010	20:49:15.371	OSK 1	35	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:15.357	OSK 1	ISPRAVLJAC AC/DC 220V		POVRATAK
10.2.2010	20:49:15.266	OSK 1	35	ISTOK PREKIDAC	ISKLJUCEN
10.2.2010	20:49:15.255	OSK 1	35	ISTOK PREKIDAC	Stanje kvara 11
10.2.2010	20:49:15.217	OSK 1	35	APU DEF	UPOZ
10.2.2010	20:49:15.206	OSK 1	35	Z. KRATKOSPOJNA	ISK
10.2.2010	20:49:15.111	OSK 1	ISPRAVLJAC AC/DC 220V		ISPAD
10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:14.948	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA		NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPOJNA	ISK

E: Protection false operation.

10.2.2010	20:49:15.379	OSK 1	35	APU DEF	PRESTANAK
10.2.2010	20:49:15.371	OSK 1	35	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:15.357	OSK 1	ISPRAVLJAC AC/DC 220V		POVRATAK
10.2.2010	20:49:15.266	OSK 1	35	ISTOK PREKIDAC	ISKLJUCEN
10.2.2010	20:49:15.255	OSK 1	35	ISTOK PREKIDAC	Stanje kvara 11
10.2.2010	20:49:15.217	OSK 1	35	APU DEF	UPOZ
10.2.2010	20:49:15.206	OSK 1	35	Z. KRATKOSPOJNA	ISK
10.2.2010	20:49:15.111	OSK 1	ISPRAVLJAC AC/DC 220V		ISPAD
10.2.2010	20:49:14.984	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	20:49:14.948	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	20:49:14.939	ISTOK	NAPON AC NA SABIRNICAMA		NESTANAK
10.2.2010	20:49:14.939	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	20:49:14.901	ISTOK	10	Z. KRATKOSPOJNA	ISK

The above mentioned description refers to Fig. 5 after the protection has been turned off at VP 35 kV Istok. The operator does not know what has happened and he is trying to reverse the network into the initial state by using the trial and error method.

Hypotheses B, C, D are no longer taken into consideration, because they are no longer possible.

Hypothesis now appear as follows:

A: Fault at feeder 10 kV

10.2.2010	21:26:15.527	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	21:26:15.512	ISTOK		NAPON AC NA SABIRNICAMA	NESTANAK
10.2.2010	21:26:15.492	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	21:26:15.488	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	21:26:15.444	ISTOK	10	Z. KRATKOSPOJNA	ISK
10.2.2010	21:26:15.426	ISTOK	10	108/208 PREKIDAC	UKLJUCEN

E: Protection false operation.

10.2.2010	21:26:15.915	OSK 1	35	APU DEF	PRESTANAK
10.2.2010	21:26:15.906	OSK 1	35	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	21:26:15.902	OSK 1		ISPRAVLJAC AC/DC 220V	POVRATAK
10.2.2010	21:26:15.803	OSK 1	35	ISTOK PREKIDAC	ISKLJUCEN
10.2.2010	21:26:15.791	OSK 1	35	ISTOK PREKIDAC	Stanje kvara 11
10.2.2010	21:26:15.754	OSK 1	35	APU DEF	UPOZ
10.2.2010	21:26:15.743	OSK 1	35	Z. KRATKOSPOJNA	ISK
10.2.2010	21:26:15.646	OSK 1		ISPRAVLJAC AC/DC 220V	ISPAD
10.2.2010	21:26:15.527	ISTOK	10	Z. KRATKOSPOJNA	PRESTANAK
10.2.2010	21:26:15.512	ISTOK		NAPON AC NA SABIRNICAMA	NESTANAK
10.2.2010	21:26:15.492	ISTOK	10	108/208 PREKIDAC	ISKLJUCEN
10.2.2010	21:26:15.488	ISTOK	10	108/208 PREKIDAC	Međupoložaj 00
10.2.2010	21:26:15.444	ISTOK	10	Z. KRATKOSPOJNA	ISK
10.2.2010	21:26:15.426	ISTOK	10	108/208 PREKIDAC	UKLJUCEN

The remaining possibilities are the two hypotheses and both of them are correct. Hypotheses A and E were supported by the alarms from the very beginning, and the difference between them is only in the alarms that occurred.

4 Conclusion

Finger print analysis gives solution in the exact form while the hypothesis method leaves more possibilities for the situations with more complexity and lack of information.

The results acquired by analysing the alarms in the PS with the finger print method and the hypothesis method, lead us to equal results as far as the faulty unit and the relay false operation are concerned, the latter being the cause of the unexpected detachment from the rest of the network. We have represented the finger print method and the hypothesis method and both are convenient for future analysing the facility events, in their approach towards the problem. Both methods are simple but their application is very complex. An in-depth analysis has not been done because we were dealing with static relays which do not have a possibility of recording at the very moment of fault. The in-depth analysis refers to the structure of the analysis. The procedure uses the aforementioned methods but also the recorded data from the relay at the moment of the fault. The in-depth analysis

(diagnosis) is the third level of analysing due to its comprehensiveness and there are five possible levels. The fourth and fifth levels take the non-electric influences and telemetry errors into consideration which cannot be used in the current analysis and overall practice.

During the analysis we have excluded the possibility of telemetry error because it would lead us to the state of chaos. The hypothesis method is a traditional technique which has evolved into an intelligent system, opening doors to soft computing and the possibility of using some intelligent methods like fuzzy logics, expert systems and petri nets for analysing PS alarm systems.

5 References

- [1] Gers, J. M.; Holmes, E. J. Protection of Electricity Distribution Networks 2nd Edition, IEE, London, 2004.
- [2] Guan, Y.; Kezunovic, M. Implementing intelligent Techniques for the advanced alarm processing, 15th International conference on Intelligent System Applications to Power Systems, Curitiba, 2009.
- [3] Kezunovic, M.; Guan, Y. Intelligent alarm processing: From data intensive to information rich, 42th Annual Hawaii International Conference on System Science (HICCS 42), Hawaii, 2009.
- [4] McDonald, J. R.; Burt, G. M.; Zielinski, J. S.; McArthur, S. D. Intelligent Knowledge Based system in Electrical Power Engineering, Chapman & Hall, London, 1997.
- [5] Song, Y. H.; Johns, A.; Aggarwal, R. Computational Intelligence Applications to Power Systems, Science press, New York/Beijing, 1996.

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