DISTRIBUTION NETWORK EVENTS ANALYSIS WITH TOOLS PROVIDED BY MODERN SYSTEMS OF DIGITAL PROTECTION

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INTRODUCTION

During first half of 2002, first digital protection systems have been introduced in the company for the distribution of electrical energy, Elektrodistribucija Beograd. They have offered new possibilities in the relay protection systems application, testing and exploitation. Very important feature of digital protection is the ability for detailed analysis of different network events. In the last four years two transformer substations employing new digital protection systems have been built and energized, TS Vinca 35/10 kV and TS Borca 35/10 kV. This paper represents analysis of several network events that occured in the area supplied from aforementioned substations. Data and analysis of the events shown here are available due to the implementation of the digital protection systems.

TS VINČA 35/10 kV

During reconstruction of the Vinča transformer substation complete primary equipment, secondary equipment and auxiliary DC and AC supply have been replaced. Substation contains two Dy5, 35/10kV transformers, one 8MVA and the other 4MVA. Power system network on the 10kV side is isolated, and on the 35kV side is grounded in the source substations. There are seven 35kV bays and eight 10kV bays. Second phase expansion has been planned in the future that will include grounding of the 10kV star point of the transformers through the resistor. Installed circuit breakers are vacuum type. The substation has been energized in the fall of 2004. That is the first substation in the company where the digital protection has been applied. It consists of digital protection and control units installed in each feeder and transformer bay in the 10kV and 35kV switchgear and monitoring units in the tiebreak, service transformer and auxiliary supply bays. Every unit is connected to the station computer via communications network through which all measurements, alarms, indications and commands are routed. Network uses RS485 interface and operates on the standard IEC 60870-5-103 communications protocol. Station computer is powered by UPS system, it has monitor and printer and modem through which the communication with Control center is executed.

TS BORČA 35/10 kV

This substation is completely new object, built in the fast growing part of the city in order to compensate for the strong rise in the electrical power consumption mostly due to the great number of newly built family housing. It contains seventeen 10kV bays, four 35kV bays and two 8MVA power transformers. It has been energized in the summer of 2005. Digital protection system in this substation is almost identical to the protection system employed in the TS Vinča. It comprises digital protection

and control units installed in every 10kV and 35kV feeder and transformer bay and digital monitoring units installed in tiebreak, service transformer and auxiliary supply bays. Every unit is connected to the IEC 60870-5-103 communications network and station computer. Alarms, indications, measurements and commands are sent over the network and station computer through modem communicates with control center.

NETWORK EVENTS

Aforementioned digital protection and monitoring systems enabled detailed analysis of the events that occurred in that part of the high voltage network. Four events are represented here, two for each substation.

TS Vinča

First event that we talk about happened in TS Vinča on the 1st of December 2003 in the 35kV feeder bay H07. The isolation breakdown occurred on the cable head and earth fault developed on the C phase. By using software for fault analysis and data stored in the relay protecting the feeder, we can see the time sequence of the fault and check the value of any variable in the system (picture 1).
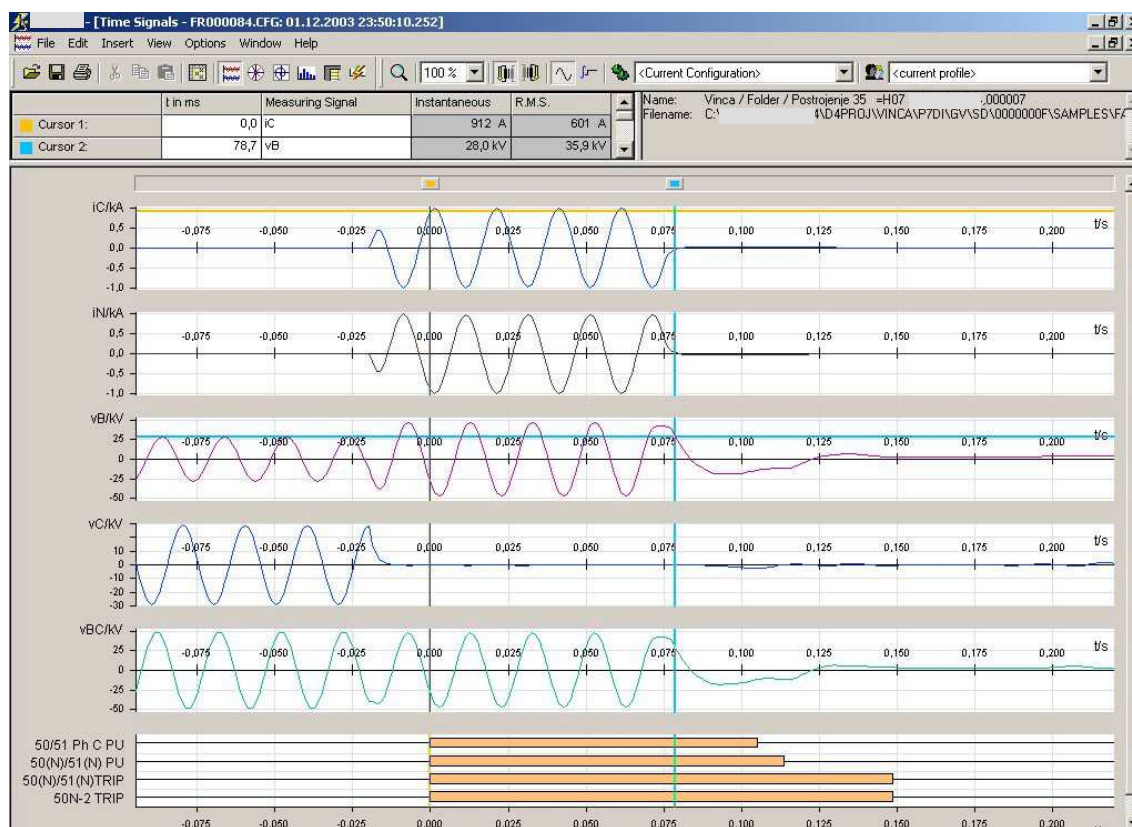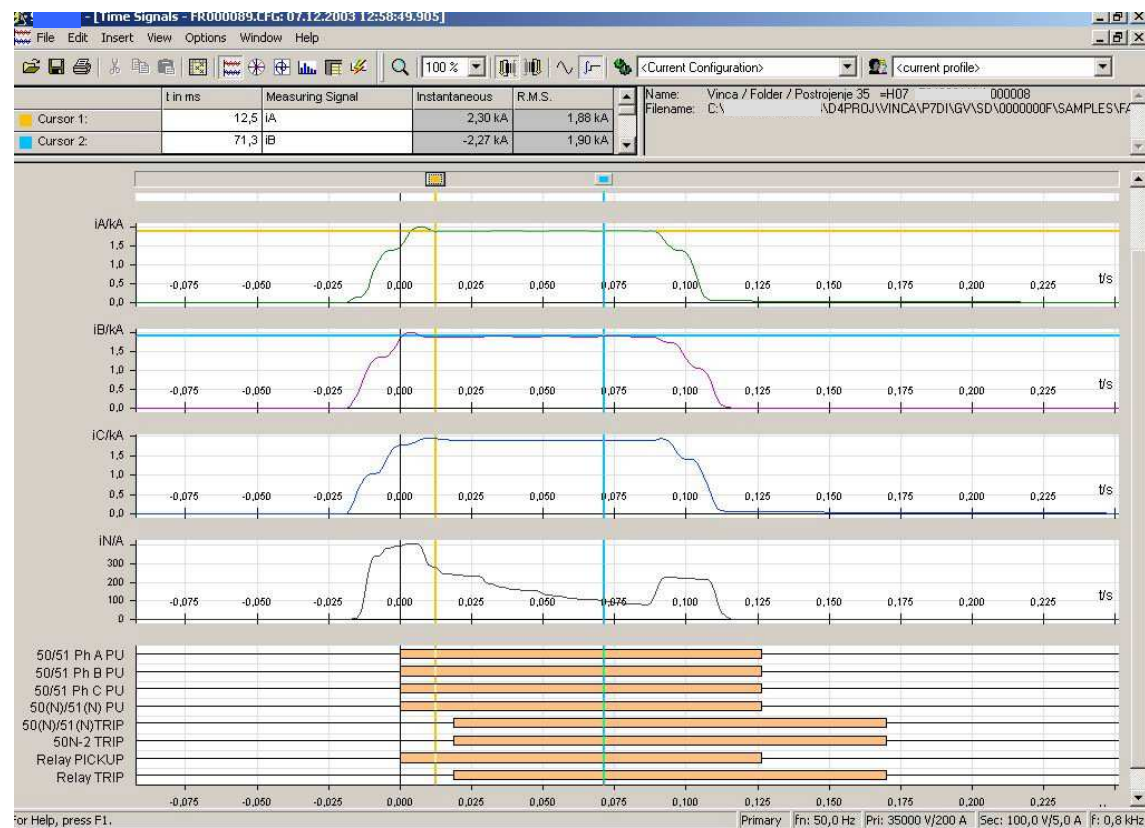

Picture 1

This program packet enables straightforward summary of voltage and current time signals in the faulty and healthy phases as well as relay protection activity diagram. We can see clearly the loss of voltage in the C phase, raised voltage in the healthy phase and the moment of circuit breaker contacts opening, i.e. fault clearance. Any variable value in any moment of the time record can be read out using two available cursors. Picture 2 represents over current relay trip log record for this fault. From trip log it is possible to analyze the event and protection relay performance even more thoroughly.

Number	Indication	Value	Date and time
00301	Power System fault	5 - ON	01.12.2003 23:48:30.113
00302	Fault Event	6 - ON	01.12.2003 23:48:30.113
00501	Relay PICKUP	ON	0 ms
01761	50(N)/51(N) O/C PICKUP	ON	0 ms
01765	50N/51N picked up	ON	0 ms
01834	50N-1 picked up	ON	0 ms
02785	79 - Auto-reclose is dynamically BLOCKED	ON	5 ms
01764	50/51 Phase C picked up	ON	15 ms
01810	50-1 picked up	ON	15 ms
01831	50N-2 picked up	ON	15 ms
00511	Relay GENERAL TRIP command	ON	15 ms
01791	50(N)/51(N) TRIP	ON	15 ms
01833	50N-2 TRIP	ON	15 ms
02863	79 - Lockout	ON	23 ms
00533	Primary fault current Ia	0,00 kA	40 ms
00534	Primary fault current Ib	0,00 kA	40 ms
00535	Primary fault current Ic	0,69 kA	40 ms
01764	50/51 Phase C picked up	OFF	124 ms
01810	50-1 picked up	OFF	124 ms
01765	50N/51N picked up	OFF	137 ms
01834	50N-1 picked up	OFF	137 ms
01761	50(N)/51(N) O/C PICKUP	OFF	137 ms
01831	50N-2 picked up	OFF	137 ms
00301	Power System fault	5 - OFF	01.12.2003 23:48:30.258

Picture 2

In the picture 3, time sequence for three-phase short circuit can be seen. The fault occurred in the same bay, H07 when earthing disconnect mechanical failure lead to energized busbars being directly grounded. RMS values of the currents are shown on the diagrams.
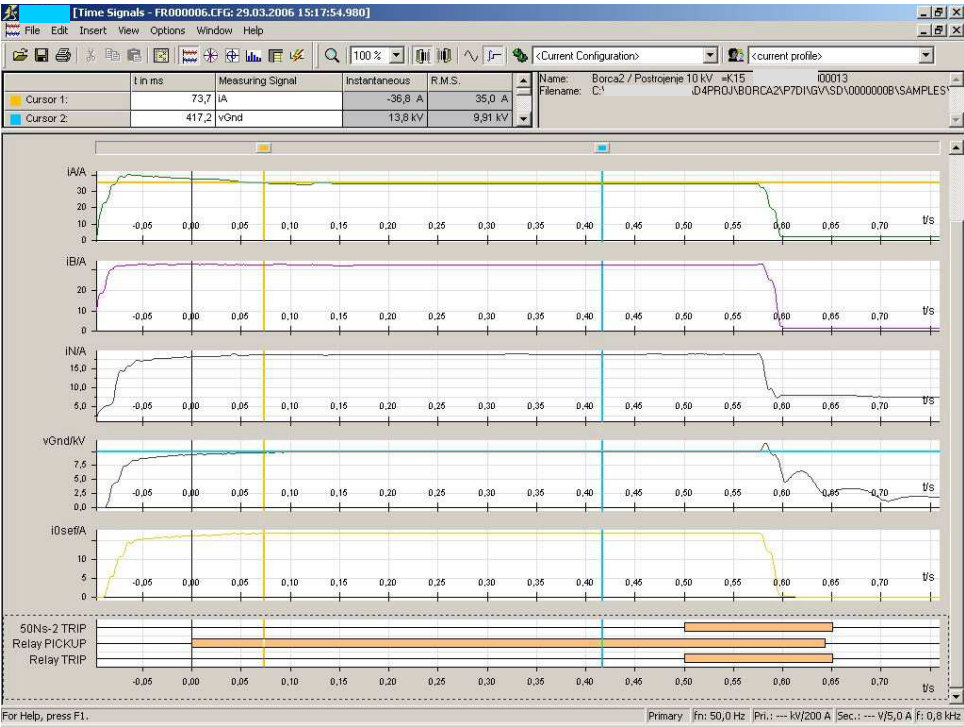

Picture 3

Picture 4 shows trip log record with exact time sequence, event duration and short circuit current values.

| Number	Indication	Value	Date and time
00301	Power System fault	7 - ON	07.12.2003 12:58:49.998
00302	Fault Event	8 - ON	07.12.2003 12:58:49.998
00501	Relay PICKUP	ON	0 ms
01761	50(N)/51(N) O/C PICKUP	ON	0 ms
01765	50N/51N picked up	ON	0 ms
01762	50/51 Phase A picked up	ON	0 ms
01763	50/51 Phase B picked up	ON	0 ms
01764	50/51 Phase C picked up	ON	0 ms
01810	50-1 picked up	ON	0 ms
01834	50N-1 picked up	ON	0 ms
01831	50N-2 picked up	ON	0 ms
01800	50-2 picked up	ON	10 ms
00511	Relay GENERAL TRIP command	ON	18 ms
01791	50(N)/51(N) TRIP	ON	18 ms
01833	50N-2 TRIP	ON	18 ms
01831	50N-2 picked up	OFF	24 ms
01765	50N/51N picked up	OFF	29 ms
01834	50N-1 picked up	OFF	29 ms
02785	79 - Auto-reclose is dynamically BLOCKED	ON	35 ms
02863	79 - Lockout	ON	35 ms
00533	Primary fault current Ia	1,89 kA	44 ms
00534	Primary fault current Ib	1,91 kA	44 ms
00535	Primary fault current Ic	1,89 kA	44 ms
01765	50N/51N picked up	ON	105 ms
01834	50N-1 picked up	ON	105 ms
01800	50-2 picked up	OFF	114 ms
01765	50N/51N picked up	OFF	126 ms
01762	50/51 Phase A picked up	OFF	126 ms
01763	50/51 Phase B picked up	OFF	126 ms
01764	50/51 Phase C picked up	OFF	126 ms
01810	50-1 picked up	OFF	126 ms
01761	50(N)/51(N) O/C PICKUP	OFF	126 ms
01834	50N-1 picked up	OFF	126 ms
00301	Power System fault	7 - OFF	07.12.2003 12:58:50.133

Слика 4

TS Borča

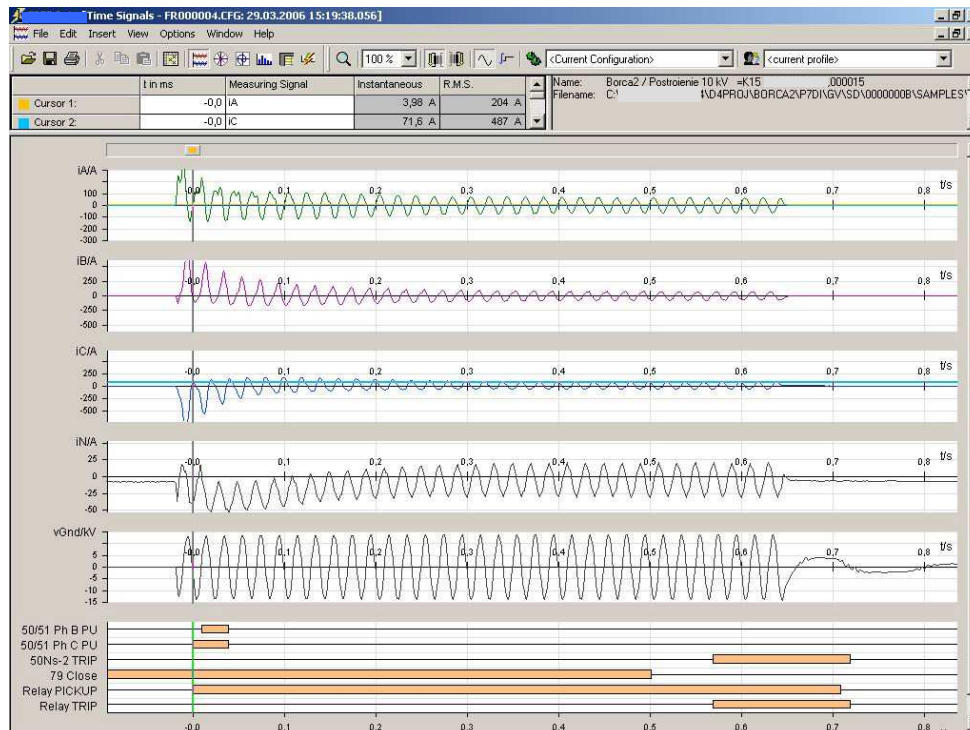Event described here occurred on the 10kV feeder bay K15 in this substation.

Picture 5
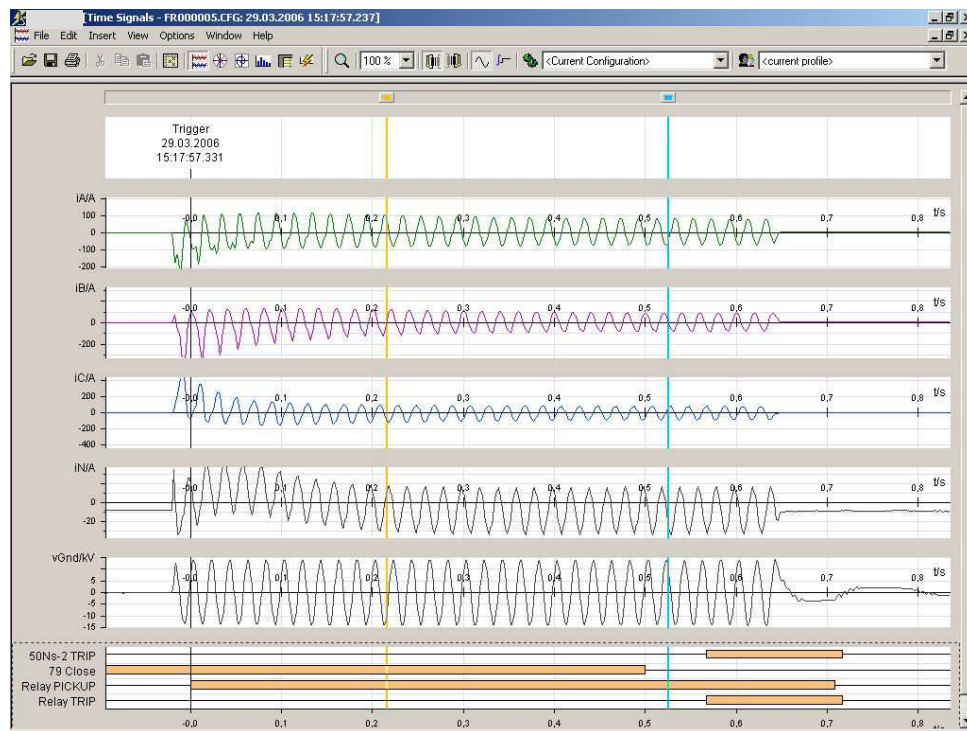
Picture 6

Picture 7

The fault developed as a multiple short circuit probably caused by tree branch contacting overhead line. Due to the fact that the 10kV power network in this substation is isolated, and that short circuit path involved high fault resistance, sensitive earth fault element of the protection relay picked up and

tripped. The relay started auto-reclose sequence. Picture 5 depicts initial fault and protection reaction with set time delay. Picture 6 shows continued fault after circuit breaker closed following first dead-time, and picture 7, second auto-reclose cycle and final breaker opening. Picture 8 shows trip log record for this event.

| Number	Indication	Value	Date and time
	- [Trip Log - 000013 / 29. 3.2006 15:17:55.078 - Borca2 / Postrojenje 10 kV / =K15 /		
00301	Power System fault	13 - ON	29.03.2006 15:17:55.078
00302	Fault Event	13 - ON	29.03.2006 15:17:55.078
00501	Relay PICKUP	ON	0 ms
01215	64 displacement voltage pick up	ON	0 ms
01221	50Ns-2 Pickup	ON	0 ms
01224	50Ns-1 Pickup	ON	0 ms
01276	Sensitive Gnd fault in forward direction	ON	0 ms
00511	Relay GENERAL TRIP command	ON	500 ms
01223	50Ns-2 TRIP	ON	500 ms
02801	79 - in progress	ON	505 ms
00533	Primary fault current Ia	0,03 kA	522 ms
00534	Primary fault current Ib	0,03 kA	522 ms
00535	Primary fault current Ic	0,03 kA	522 ms
01215	64 displacement voltage pick up	OFF	643 ms
01221	50Ns-2 Pickup	OFF	643 ms
01224	50Ns-1 Pickup	OFF	643 ms
02878	79-A/R single phase reclosing sequence	ON	655 ms
02844	79 1st cycle running	ON	655 ms
02851	79 - Close command	ON	2154 ms
00302	Fault Event	14 - ON	29.03.2006 15:17:57.331
00501	Relay PICKUP	ON	2253 ms
05165	46-1 picked up	ON	2253 ms
01215	64 displacement voltage pick up	ON	2320 ms
01221	50Ns-2 Pickup	ON	2320 ms
01224	50Ns-1 Pickup	ON	2320 ms
01276	Sensitive Gnd fault in forward direction	ON	2320 ms
05165	46-1 picked up	OFF	2433 ms
00511	Relay GENERAL TRIP command	ON	2820 ms
01223	50Ns-2 TRIP	ON	2820 ms
00533	Primary fault current Ia	0,05 kA	2850 ms
00534	Primary fault current Ib	0,06 kA	2850 ms
00535	Primary fault current Ic	0,06 kA	2850 ms
01215	64 displacement voltage pick up	OFF	2961 ms
01221	50Ns-2 Pickup	OFF	2961 ms
01224	50Ns-1 Pickup	OFF	2961 ms
02845	79 2nd cycle running	ON	2973 ms
02851	79 - Close command	ON	29.03.2006 15:19:38.052
00302	Fault Event	15 - ON	29.03.2006 15:19:38.150
00501	Relay PICKUP	ON	29.03.2006 15:19:38.150
01761	50(N)/51(N) O/C PICKUP	ON	29.03.2006 15:19:38.150
01764	50/51 Phase C picked up	ON	29.03.2006 15:19:38.150
01810	50-1 picked up	ON	29.03.2006 15:19:38.150
05165	46-1 picked up	ON	29.03.2006 15:19:38.150
01763	50/51 Phase B picked up	ON	29.03.2006 15:19:38.160
05159	46-2 picked up	ON	29.03.2006 15:19:38.169
01763	50/51 Phase B picked up	OFF	29.03.2006 15:19:38.189
01764	50/51 Phase C picked up	OFF	29.03.2006 15:19:38.189
01810	50-1 picked up	OFF	29.03.2006 15:19:38.189
01761	50(N)/51(N) O/C PICKUP	OFF	29.03.2006 15:19:38.189
05159	46-2 picked up	OFF	29.03.2006 15:19:38.189
01215	64 displacement voltage pick up	ON	29.03.2006 15:19:38.218
01221	50Ns-2 Pickup	ON	29.03.2006 15:19:38.218
01224	50Ns-1 Pickup	ON	29.03.2006 15:19:38.218
01276	Sensitive Gnd fault in forward direction	ON	29.03.2006 15:19:38.218
05165	46-1 picked up	OFF	29.03.2006 15:19:38.370
00511	Relay GENERAL TRIP command	ON	29.03.2006 15:19:38.718
01223	50Ns-2 TRIP	ON	29.03.2006 15:19:38.718
02785	79 - Auto-reclose is dynamically BLOCKED	ON	29.03.2006 15:19:38.724
02863	79 - Lockout	ON	29.03.2006 15:19:38.724
00533	Primary fault current Ia	0,05 kA	29.03.2006 15:19:38.739
00534	Primary fault current Ib	0,05 kA	29.03.2006 15:19:38.739
00535	Primary fault current Ic	0,05 kA	29.03.2006 15:19:38.739
01215	64 displacement voltage pick up	OFF	29.03.2006 15:19:38.858
01221	50Ns-2 Pickup	OFF	29.03.2006 15:19:38.858
01224	50Ns-1 Pickup	OFF	29.03.2006 15:19:38.858
00301	Power System fault	13 - OFF	29.03.2006 15:19:38.871

Picture 8

Simultaneously same event was recorded by the relay in the neighboring bay K02. The fault is correctly filed as a sensitive ground fault in reverse direction as can be seen in the trip log on the picture 9.

Number	Indication	Value	Date and time
00301	Power System fault	28 - ON	29.03.2006 15:17:55.084
00302	Fault Event	28 - ON	29.03.2006 15:17:55.084
00501	Relay PICKUP	ON	0 ms
01215	64 displacement voltage pick up	ON	0 ms
01277	Sensitive Gnd fault in reverse direction	ON	0 ms
01215	64 displacement voltage pick up	OFF	643 ms
00301	Power System fault	28 - OFF	29.03.2006 15:17:55.737

Trip Log - 000028 / 29. 3.2006   15:17:55.084 - Borca2 / Postrojenje 10 kV / =K02 /

Picture 9

Another event from this substation happened when the circuit breaker in the K01 bay closed onto a short circuit between phases B and C. Time diagrams are shown on the picture 10 and trip log extract on picture 11.
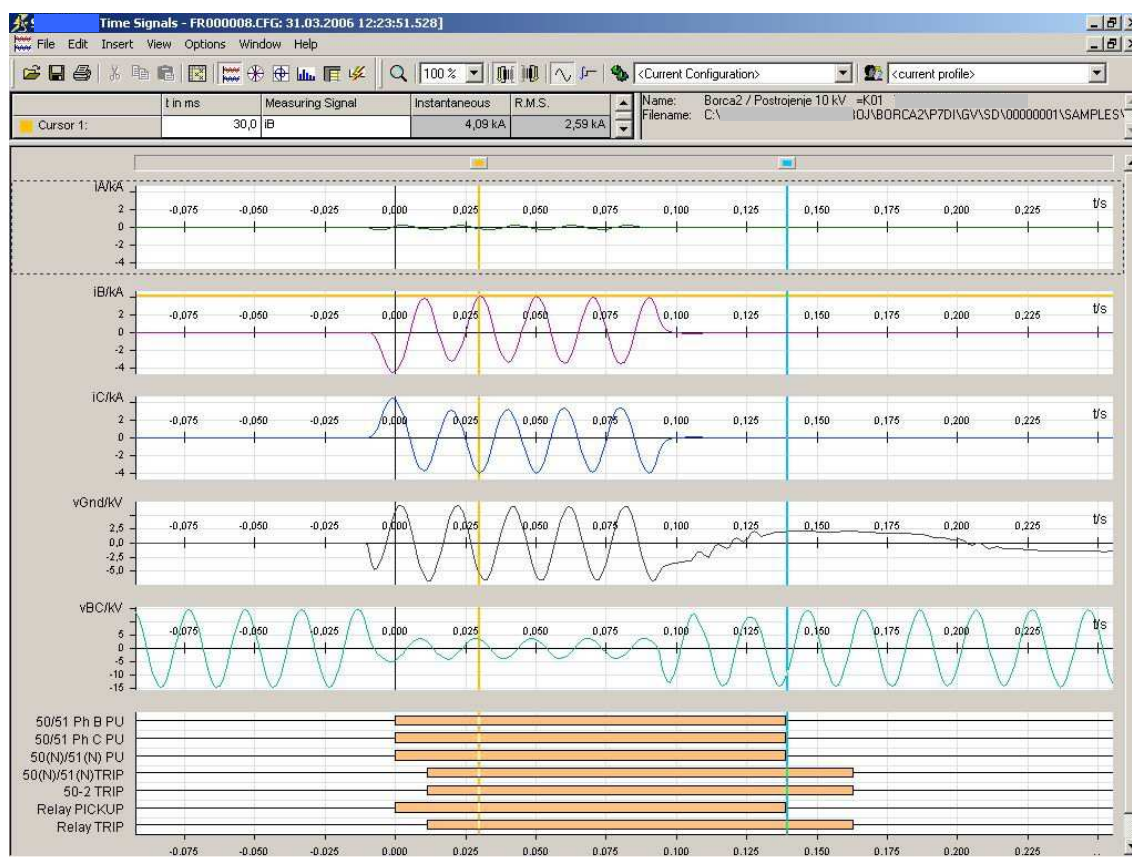
Picture 10

The time diagrams show 180 degrees angle between currents in the faulty phases while the current in the healthy phase is below nominal value. Као што се са дијаграма види струје у фазама у квару су у контрафази, док је струја у здравој фази незнатна. At the same time voltage between shorted phases decreased and neutral point voltage reached roughly nominal phase to ground value. Picture 11 shows trip log extract from the transformer bay K04 protection relay for this event. It can be seen that the feeder relay sent a signal to the transformer relay in order to lock-out the busbar protection.

[Trip Log - 000088 / 31. 3.2006 12:23:51.620 - Borca2 / Postrojenje 10 kV / =K01 /]

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Number	Indication	Value	Date and time
00301	Power System fault	88 - ON	31.03.2006 12:23:51.620
00302	Fault Event	110 - ON	31.03.2006 12:23:51.620
00501	Relay PICKUP	ON	0 ms
01761	50(N)/51(N) O/C PICKUP	ON	0 ms
01763	50/51 Phase B picked up	ON	0 ms
01764	50/51 Phase C picked up	ON	0 ms
01810	50-1 picked up	ON	0 ms
05165	46-1 picked up	ON	0 ms
05159	46-2 picked up	ON	0 ms
01800	50-2 picked up	ON	12 ms
00511	Relay GENERAL TRIP command	ON	12 ms
01791	50(N)/51(N) TRIP	ON	12 ms
01805	50-2 TRIP	ON	12 ms
05165	46-1 picked up	OFF	22 ms
05159	46-2 picked up	OFF	22 ms
00533	Primary fault current Ia	0,15 kA	40 ms
00534	Primary fault current Ib	2,59 kA	40 ms
00535	Primary fault current Ic	2,52 kA	40 ms
01215	64 displacement voltage pick up	ON	97 ms
01221	50Ns-2 Pickup	ON	97 ms
01224	50Ns-1 Pickup	ON	97 ms
01276	Sensitive Gnd fault in forward direction	ON	97 ms
05165	46-1 picked up	ON	119 ms
05159	46-2 picked up	ON	119 ms
01800	50-2 picked up	OFF	130 ms
01215	64 displacement voltage pick up	OFF	130 ms
01221	50Ns-2 Pickup	OFF	130 ms
01224	50Ns-1 Pickup	OFF	130 ms
01763	50/51 Phase B picked up	OFF	140 ms
01764	50/51 Phase C picked up	OFF	140 ms
01810	50-1 picked up	OFF	140 ms
01761	50(N)/51(N) O/C PICKUP	OFF	140 ms
05165	46-1 picked up	OFF	140 ms
05159	46-2 picked up	OFF	140 ms
00301	Power System fault	88 - OFF	31.03.2006 12:23:51.772

Picture 11

Trip Log - 000064 / 31. 3.2006 12:23:51.623 - Borca2 / Postrojenje 10 kV / =K04 /

Number	Indication	Value	Date and time
00301	Power System fault	64 - ON	31.03.2006 12:23:51.623
00302	Fault Event	64 - ON	31.03.2006 12:23:51.623
00501	Relay PICKUP	ON	0 ms
01761	50(N)/51(N) O/C PICKUP	ON	0 ms
01763	50/51 Phase B picked up	ON	0 ms
01764	50/51 Phase C picked up	ON	0 ms
01810	50-1 picked up	ON	0 ms
01800	50-2 picked up	ON	10 ms
01852	50-2 BLOCKED	ON	28 ms
01215	64 displacement voltage pick up	ON	67 ms
01278	Sensitive Gnd fault direction undefined	ON	67 ms
01215	64 displacement voltage pick up	OFF	115 ms
01800	50-2 picked up	OFF	120 ms
01763	50/51 Phase B picked up	OFF	130 ms
01764	50/51 Phase C picked up	OFF	130 ms
01810	50-1 picked up	OFF	130 ms
01761	50(N)/51(N) O/C PICKUP	OFF	130 ms
00301	Power System fault	64 - OFF	31.03.2006 12:23:51.760

Picture 12

CONCLUSION

This paper is describing new tools emerging with introduction of the digital relay protection in "Elektrodistribucija Beograd". Relay protection personnel, when using these new technologies is able to configure, test and check relay protection systems in much shorter time. At the same time it is much easier to understand and predict behavior of the distribution network in normal and fault conditions.