Application note

Protection settings and secondary testing of intermittent earth fault function

Revision	1.0
Status	Public
Date	24.4.2014
Last saved By	TV
Checked By	JV 14.4.2014

CONTENTS

1 GENERAL

This commissioning and periodic maintenance testing instruction document is a generic one and well applicable for any manufacturer's protection relay featuring an intermittent earth fault protection function.

The aim of the performed secondary testing is to verify that the set intermittent earth fault protection function trips only the faulty feeder in a set operate time and that the function will not cause nuisance starts or trips on background network feeder faults. Testing should also confirm that intermittent earth fault function does not interfere the operation of the regular non-intermittent directional or non-directional earth fault protection in case of non-intermittent earth faults and that the set operation time of intermittent earth fault function does not exceed operation time of busbar residual voltage protection. Additionally proper coordination with other protection functions and especially with the mentioned busbar residual voltage protection function shall be ensured.

This instruction contains two attached folders with simulated transient earth faults on small and medium sized medium voltage networks (PKVerkko) and transient faults on large network (Isoverkko).

2 PROTECTION SETTINGS AND CORDINATION WITH OTHER PROTECTION STAGES

The intermittent earth fault protection shall be cordinated with busbar residual voltage protection in such a way that in case of intermittent earth fault the faulty feeder will be in all cases tripped by intermittent earth-fault protection function prior to residual voltage protection function considering a sufficient safety margin as well. On the other hand, since an intermittent earth fault causes significant network stress the protection trip should be performed as fast as possible.

The strike through time of an intermittent earth fault in a close to resonance tuned network sets the limit for the minimum operate time of an intermittent earth fault protection stage. To ensure a correct protection operation in all cases, the reset time of intermittent earth fault stage shall be set according to the network in question, to such a level that ensures that fault has disappeared and no new strike through is expected after set reset time.

The size of the network is a dominant factor in defining the strike through time interval. In larger network in amperes a less frequent strike troughs can be expected. The following can be presented as a rule of a thumb: in a small / medium size networks (<60A) aprox . 250 - 350ms strike through interval and in a large network (~100A) aprox. 500ms strike through interval is expected*. As a recommended practice it can be stated that the reset time of an intermittent earth fault stage should not be set lower than 450ms to obtain a network independent setting.* Using this reset set value one can be sure that function will not reset too early even in resonance tuned network.

Typically the maximum operate time of the intermittent earth-fault function is dictated by busbar residual voltage protection. If the residual voltage protection is set to very fast tripping it may be necessary to prolong the set value of the same. *As a recommended practice it can be stated that the operation time of an intermittent earth fault stage should be 500ms counting from the first strike through.* In this case the protection tripping requires minimum two strike troughs even in resonance tuned network where strike through happens less frequently. If the residual voltage protection is set to very fast tripping (<1s) it

may be necessary to verify the reset value of the residual voltage protection. In no case shall the residual voltage protection operate time be faster than set intermittent earth fault operate time plus circuit breaker operate time added with reset time of residual voltage protection stage.

If an intermittent earth fault protection start is used to block regular non-intermitten directional earth fault protection, the blocking should be applied for both healthy and faulty feeder relays. In general, if intermittent earth fault protection is not used to block directional earth fault protection, it shall be verified that the operate time of regular directional earth fault protection is longer than set intermittent earth fault protection operate time. It is recommended to block regular directional earth fault protection only to avoid start events of directional earth fault protection during intermittent earth faults (if start events are considered disturbing) or if directional non-intermittent earth fault protection is set to faster operate time than intermittent earth fault protection.

3 SECONDARY TESTING

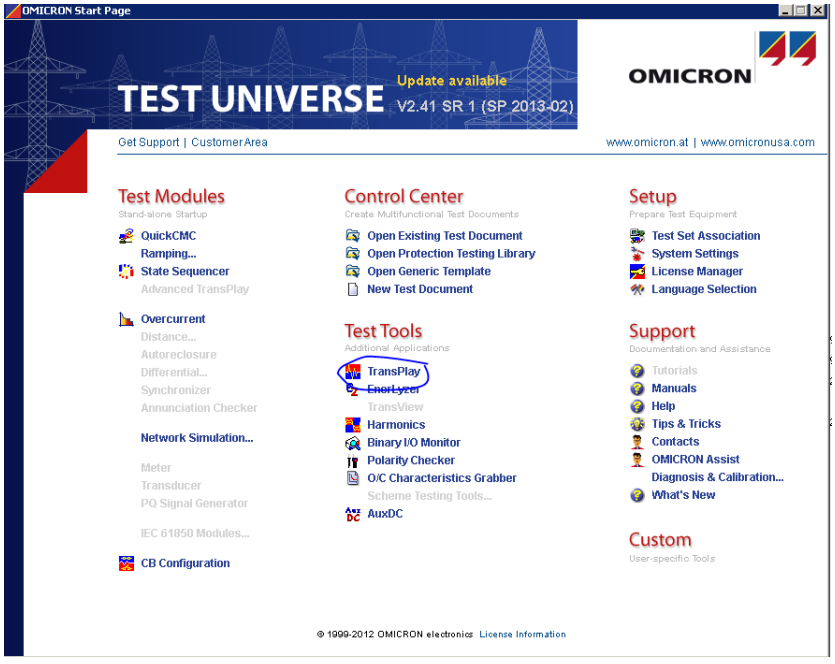
Needed equipment and preliminary data:

- Residual current I0 CT and residual voltage U0 VT ratios of tested feeder
- Size of network in amperes (effects on chosen test files)
- Secondary injection device capable of transplaying at least one current and one voltage channel of transient file recorded with 20kHz sample rate, as an example Omicron or Ponovo type of device.
- Intermittent earth fault transient records of faulty feeder and healthy background network feeder in a close to resonance tuned network as well as strongly over – and undercompensated networks.
- Non-intermittent earth fault record (or simulation of injection device) of a transient earth fault (not intermittent earth fault)

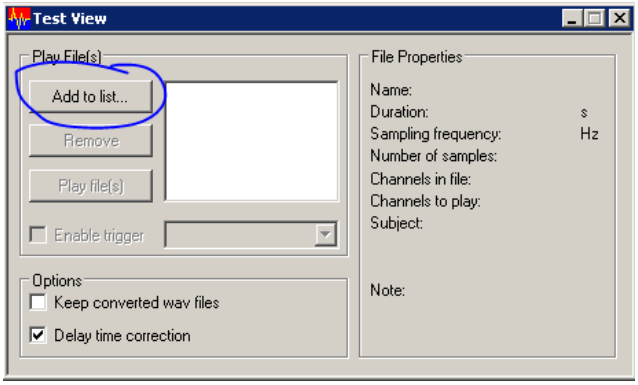
Testing should be carried out with at least three different records for both faulty feeder and for healthy background network feeder cases resulting in a total of six test cases per feeder for intermittent earth fault and an additional test case for verifying that intermittent earth fault protection will not react on non-intermittent earth faults. The additional case is not included in attached files of this document.

Transplay of transient faults can be performed as per following (Omicron):

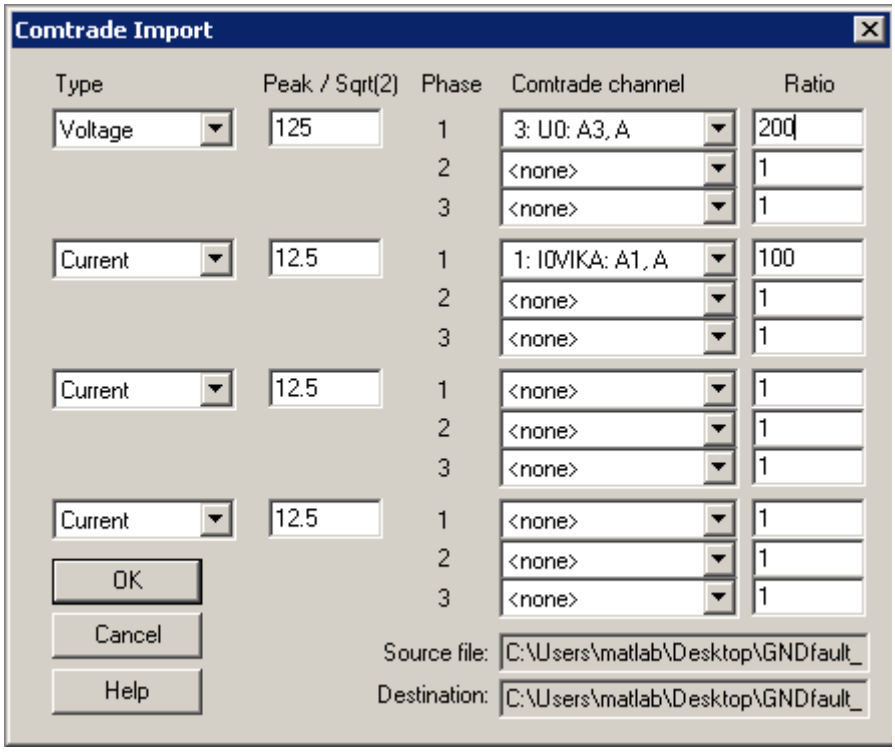
Open Transplay software:



Add files to list:

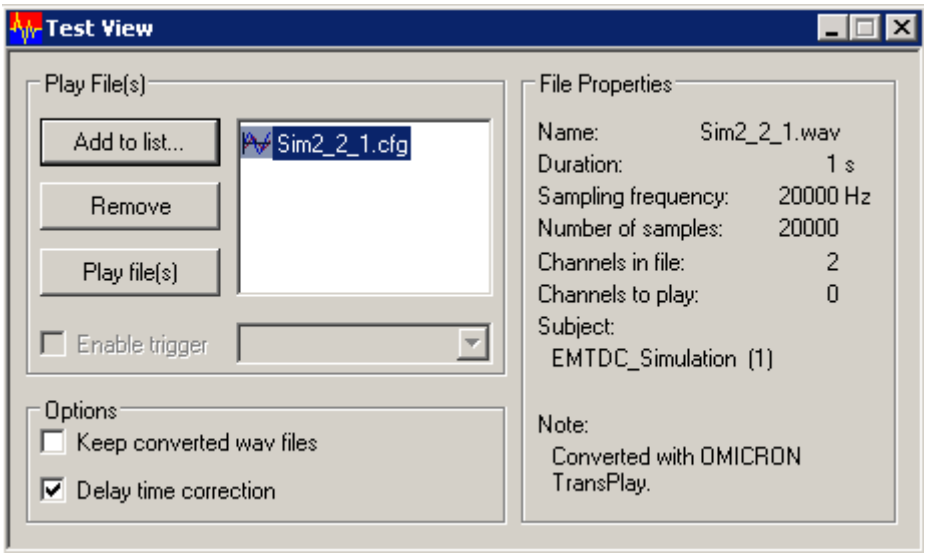


When file is opened a scaling window is presented. Select the channel in which Omicron injects I0 and U0 signals. As the records are scaled to primary values the CT and VT ratios need to be inputted. As an example, if the VT ratio is 20kV / 100V, the scaling factor should be set to 200 and if the CT ratio is 100 / 1, the scaling factor should be set to 100. Additionally injected signal (VIKA or TAUSTA) should be selected. U0 signal remains the same in between test runs.

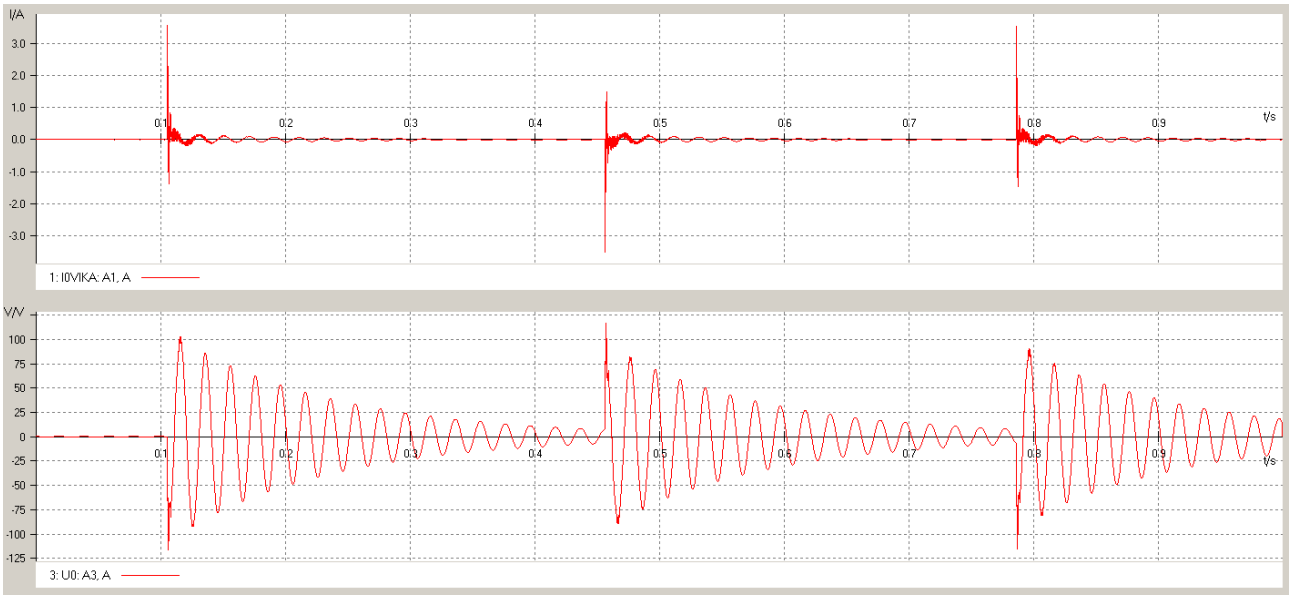


When signals are selected and scaled press ok.

The loaded transient file can be now seen in Test View



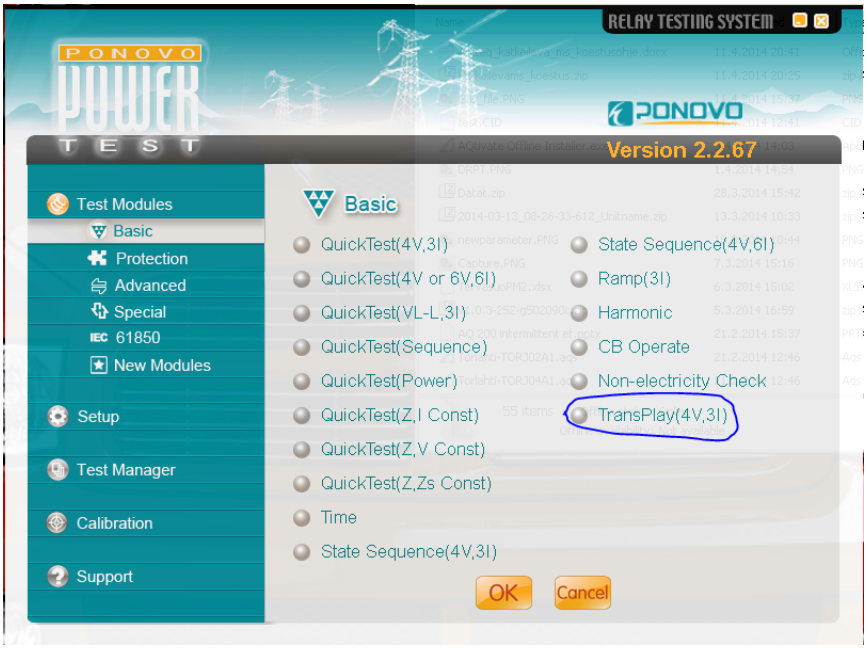
By double clicking the file is displayed in wave form



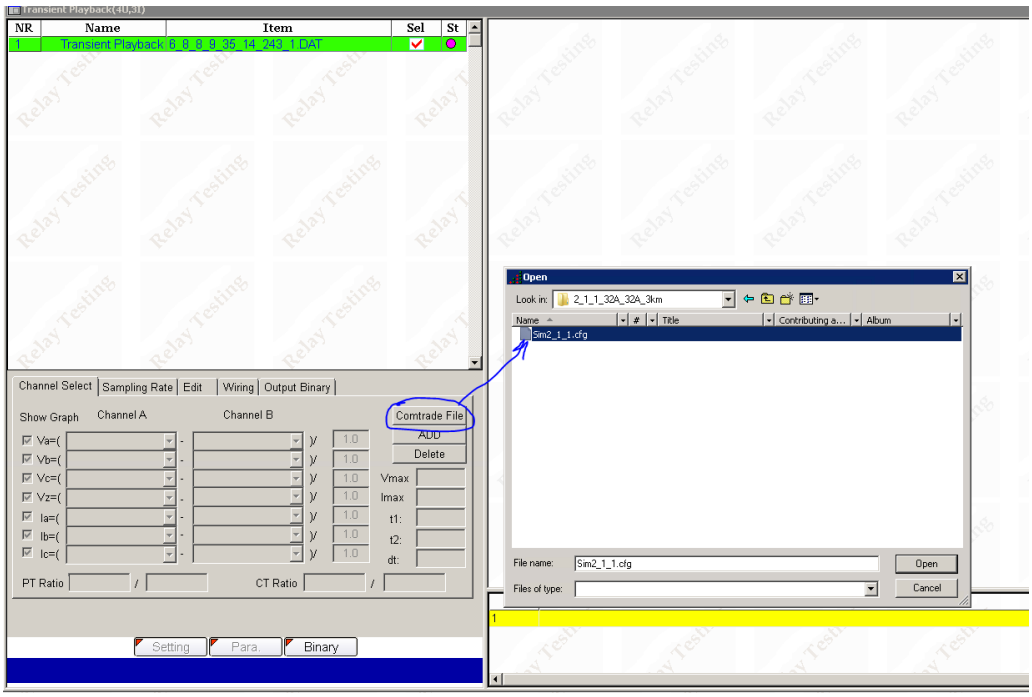
Check using the wave form display that the injected signal is within boundaries of the equipment and that maximum values are not cut out. Using wave form display one can also verify whether record is for faulty feeder or background feeder. In this particular graph above the current and voltage transient spikes are of an opposite directions resulting from faulty feeder case. In case of healthy background feeder the U0 an I0 transient spikes would be of the same direction. (This should be considered also when analyzing relay disturbance records in real fault situations. When performing these test cases it is recommended to get disturbance records from the relay and compare played signals to recorded signals in order to double check that the wiring is correct).

Ponovo Power Test software the transplay is done as follows.

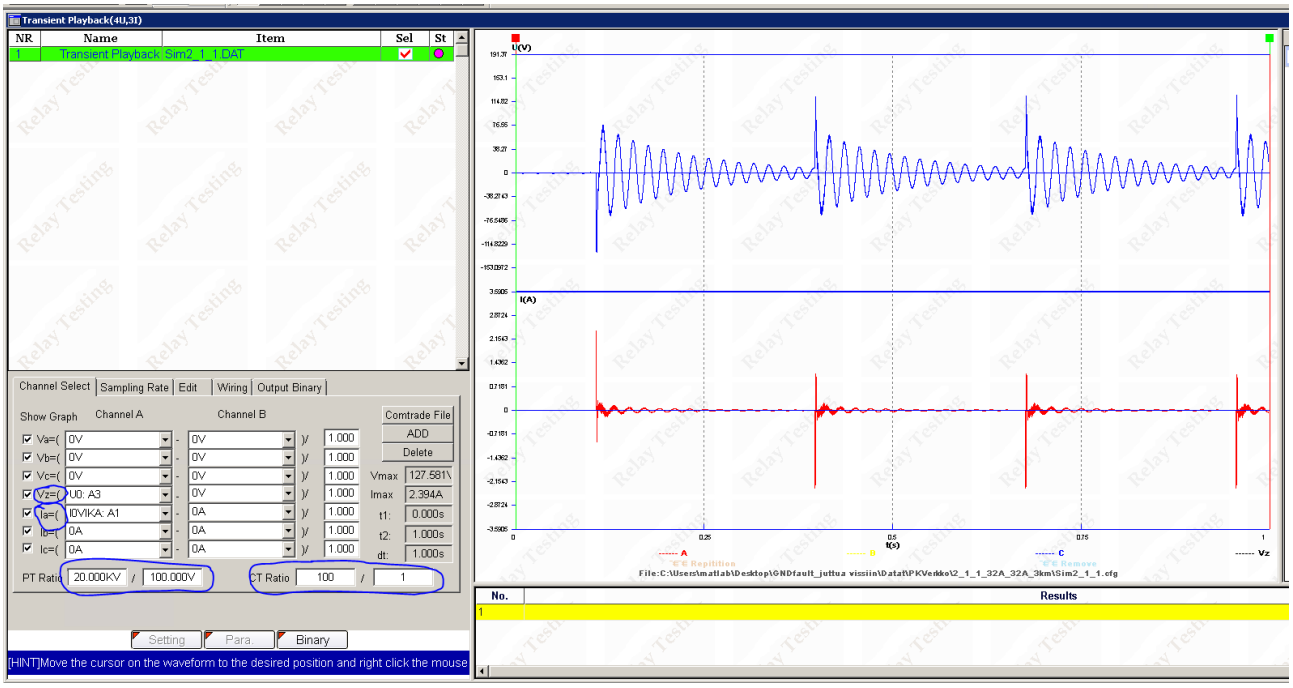
OpenTransPlay(4V3I) Power test software



Select the file to be transplayed



Select the channels to play U0 and I0 records according to wiring in place. Scale the channels according to current and voltage transformers (as per relay settings)



In boht test equpment (Omicron, Ponovo) the file is now ready to be played.

Use of simulated transient records in secondary tests is recommended practice compared to use of records obtained from the field testing as the scaling of signals is only performed in test equipment itself.

Field test data can be also applied for the testing but careful consideration of origin of data is required. Uncertainties are caused by factors such as equipment used for recording, network state during recording and whether recoding is from faulty or background feeder etc. For functional testing a detailed documented simulation data is generic and immune to e.g. measurement accuracy, analogue to digital conversion etc.

It is surely recommended to perform also field testing for the protection but generally the selected protection devices should pass all simulated test cases prior to applying them on expensive field testing. Another reason for usage of simulated test data is that especially in

regular commissioning or maintenance testing it is unpractical and costly to apply field tests of all possible networks states.

3.1 CONTENTS OF TEST CASES

All simulations for both types of networks are done in 20kV nominal voltage. All records contain residual voltage U0 and both faulty feeder and background feeder relay residual currents I0.

Small and medium size network files

File name	Network size	Network tuning point	Fault distance from the station
Sim2_1_1.DAT	32A	98 %	3 km
Sim2_2_2.DAT	32A	130 %	1 km
Sim2_3_3.DAT	32A	72 %	50 m

Large network files

File name	Network size	Network tuning point	Fault distance from the station
Sim1_1_1.DAT	100A	98 %	3 km
Sim1_2_2.DAT	100A	130 %	1 km
Sim1_3_3.DAT	100A	72 %	50 m

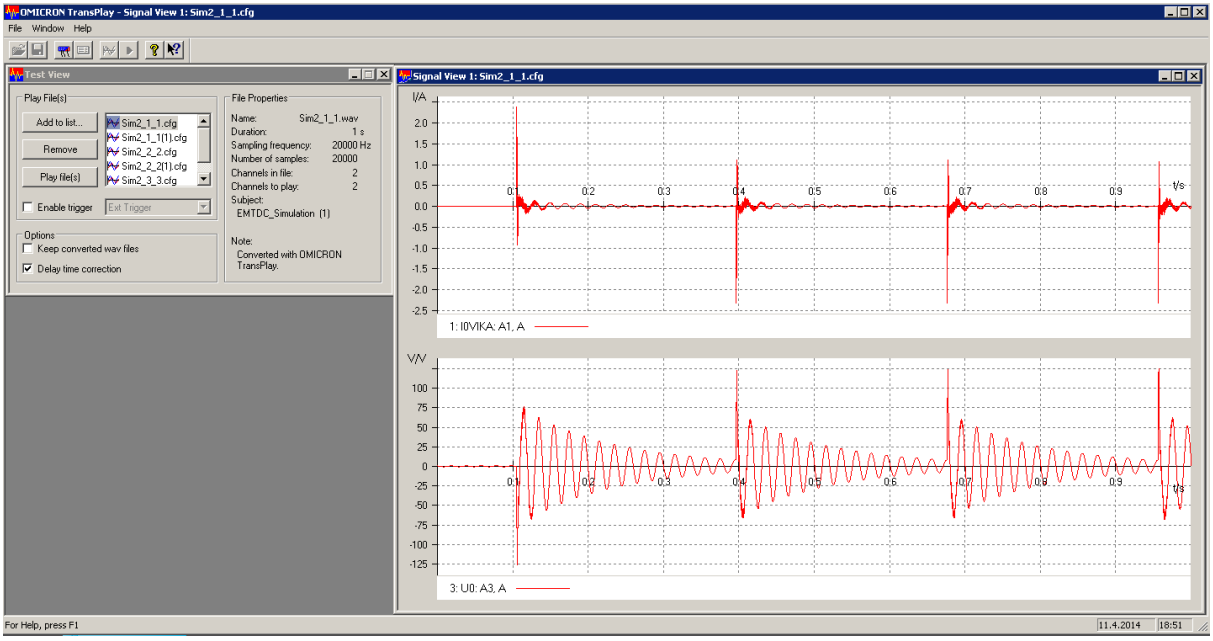
3.2 TESTING OF RELAY IN SMALL AND MEDIUM SIZE NETWORK (< 60A)

Needed files:

PKVerkko folder.

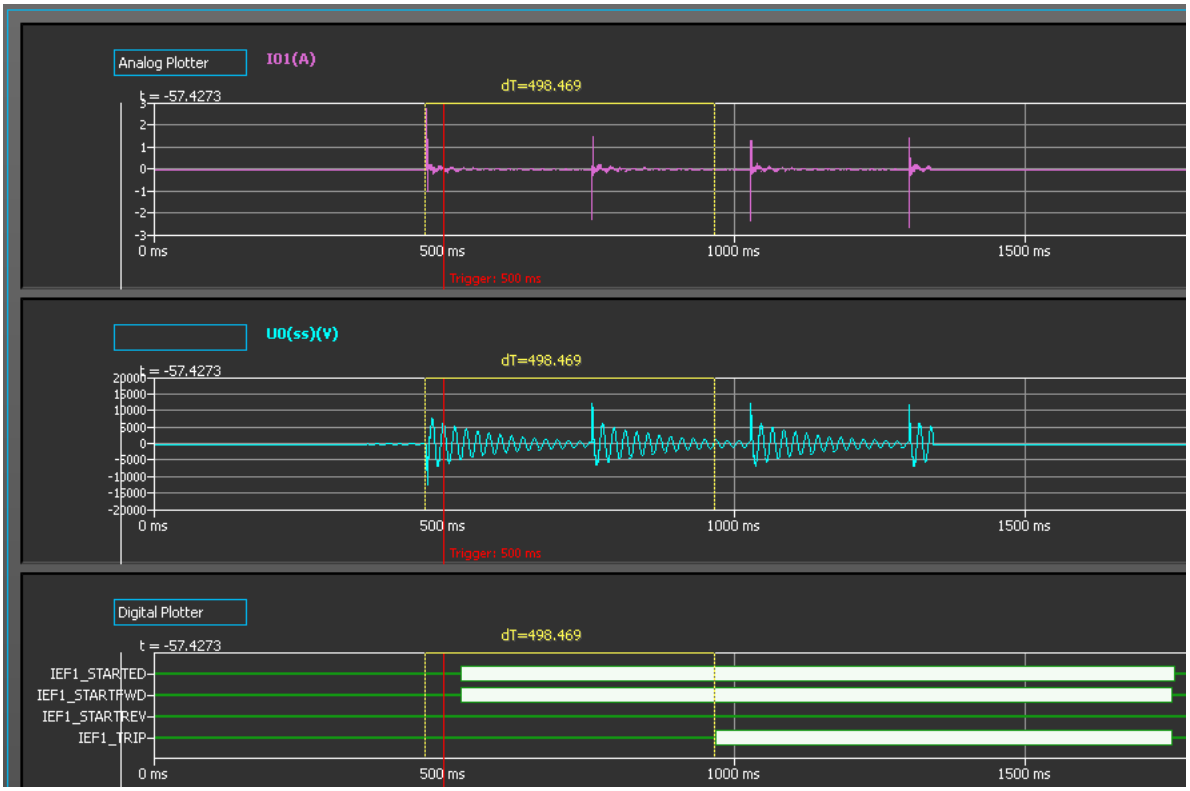
First test case Sim2_1_1.DAT:

Network in close to resonance point, faulty feeder I0VIKA, fault 3km from station.



Actual performance of the relay can be verified using disturbance recorder of the relay.

Disturbance recorder can be triggered e.g. from U0 start. The trip time shall be noted.

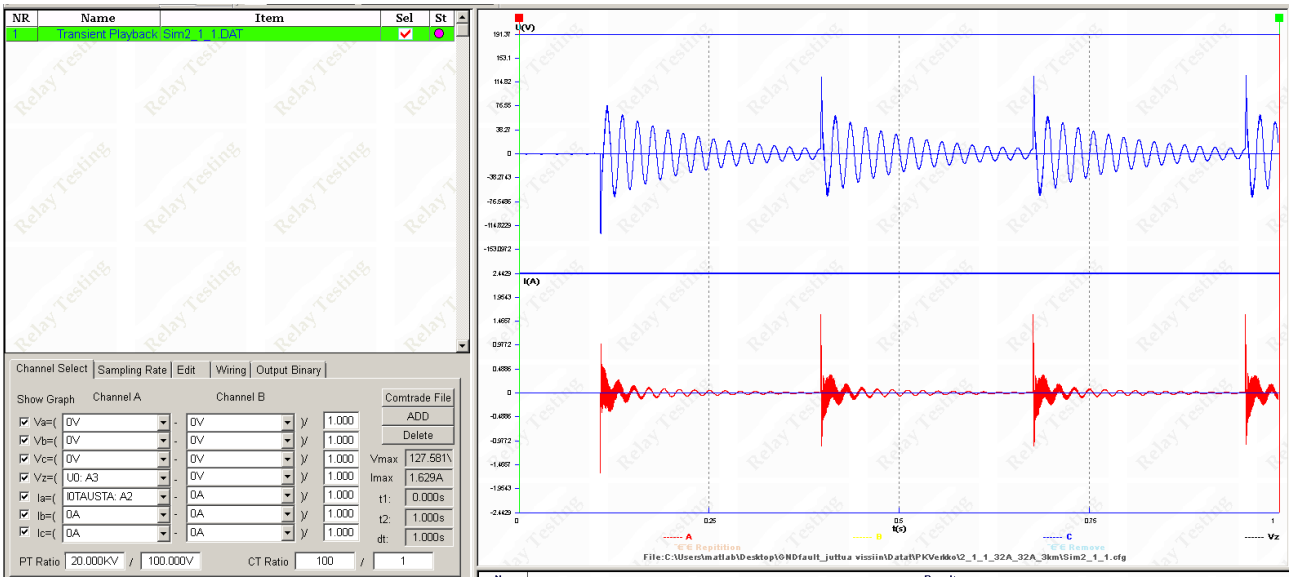


Needed files:

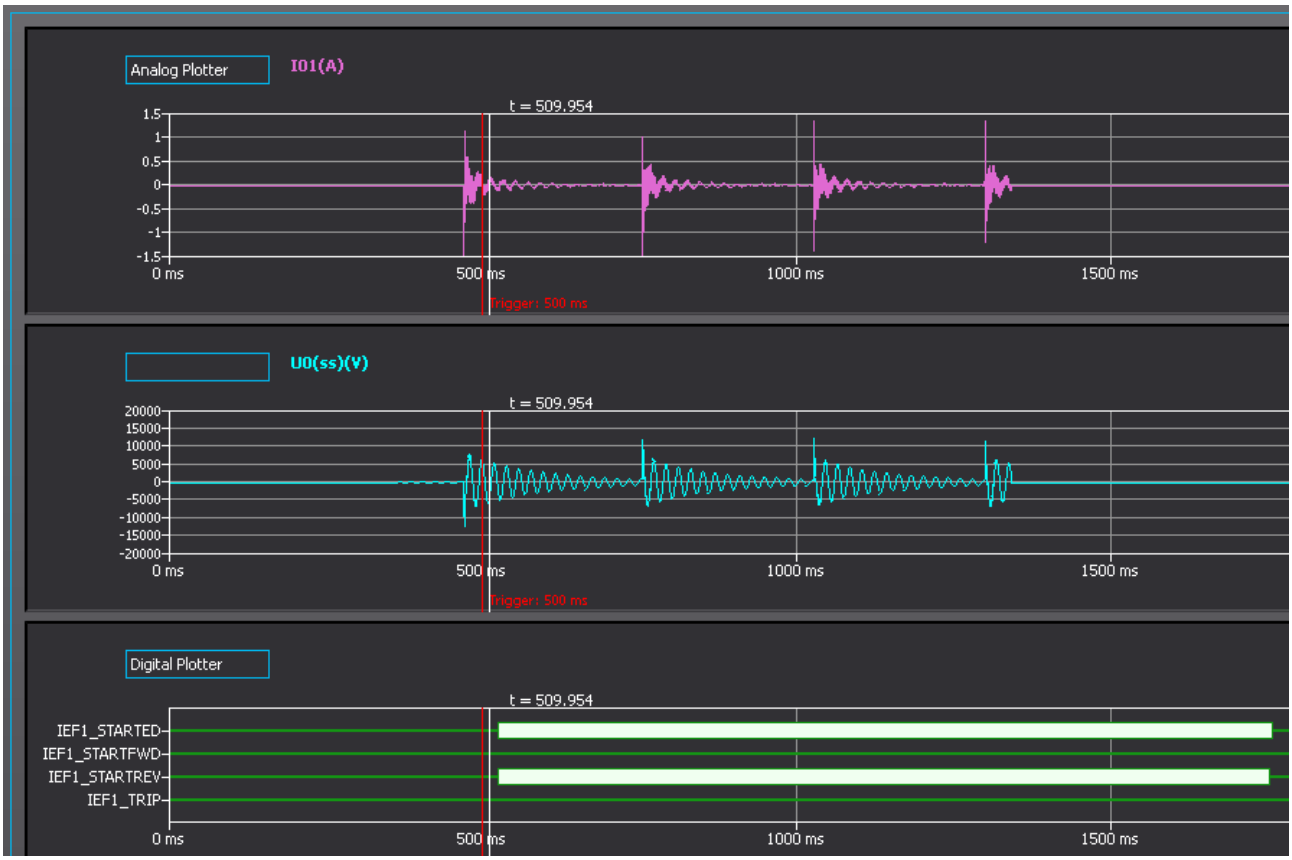
PKVerkko kansiossa.

Second test case Sim2_1_1.DAT:

Network in close to resonance point, background feeder I0TAUSTA, fault 3km from station.



It shall be noted from disturbance recorder that relay will not start or trip.

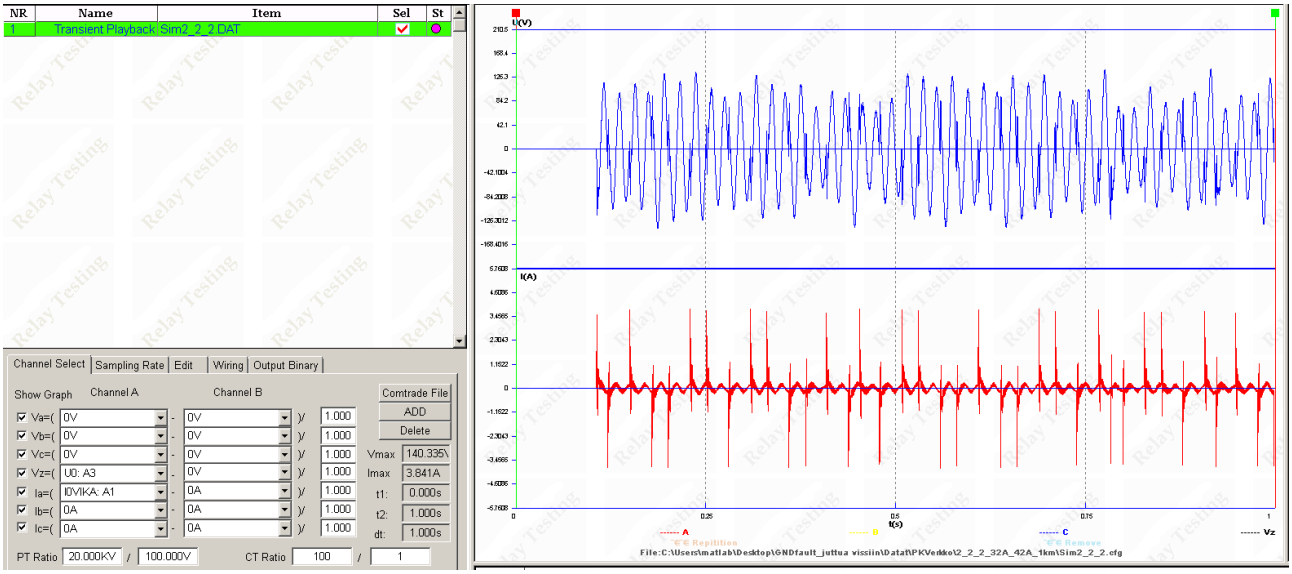


Needed files:

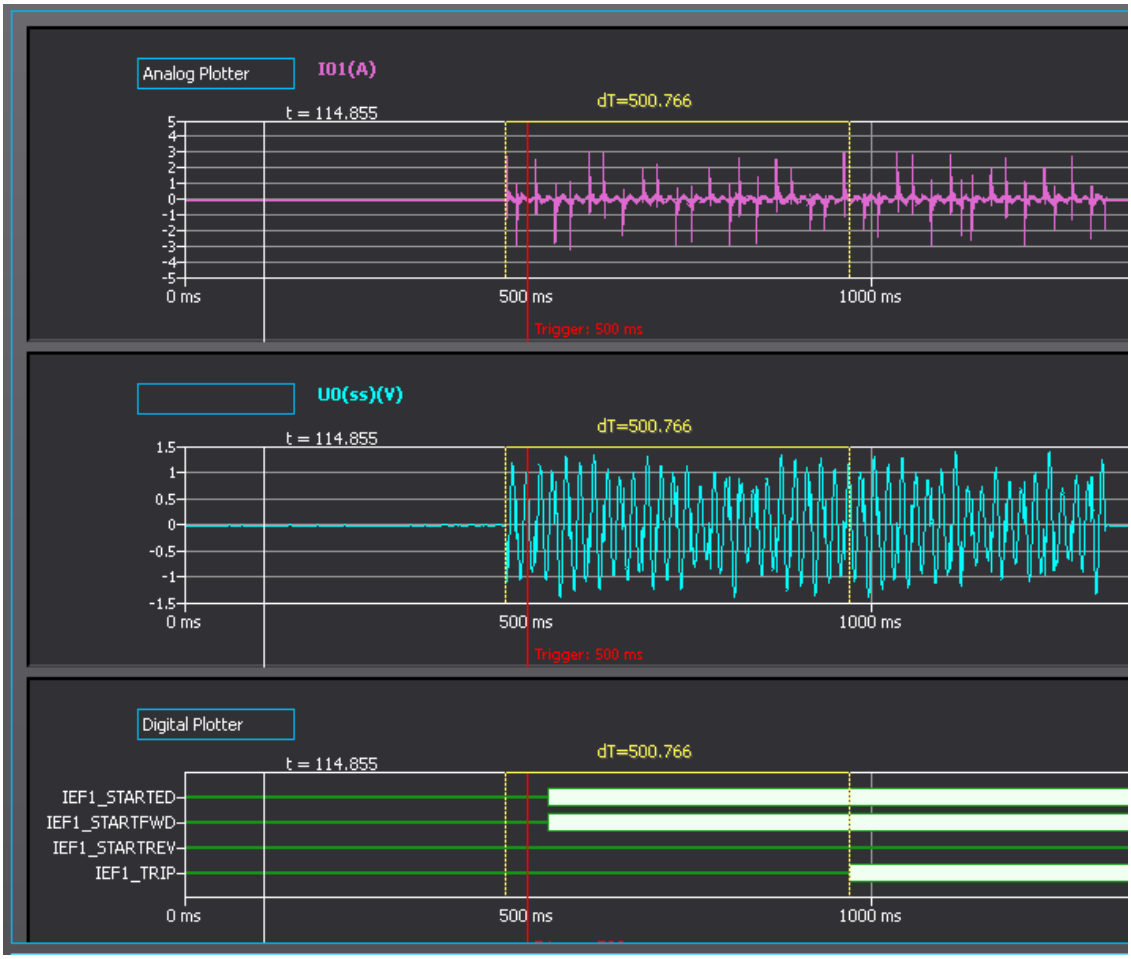
PKVerkko folder.

Third test case Sim2_2_2.DAT:

Strongly over compensated network, faulty feeder I0VIKA, fault 1km from station.



The protection operate time shall be noted

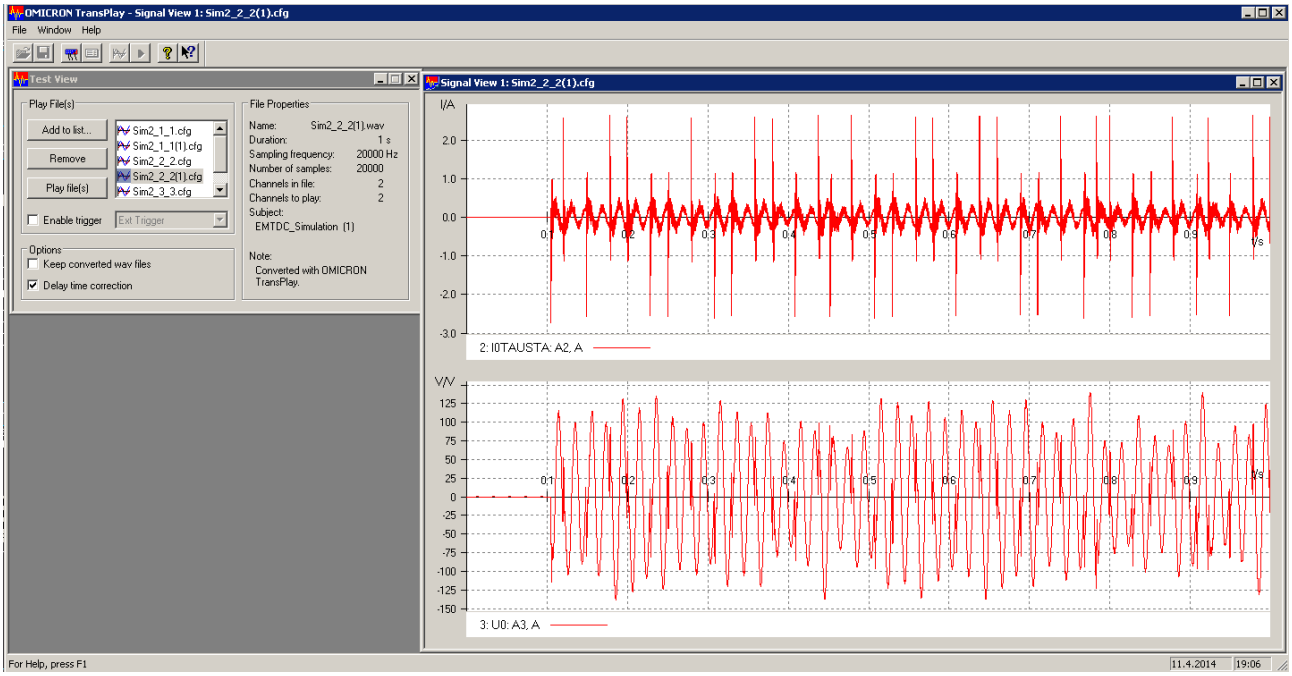


Needed files:

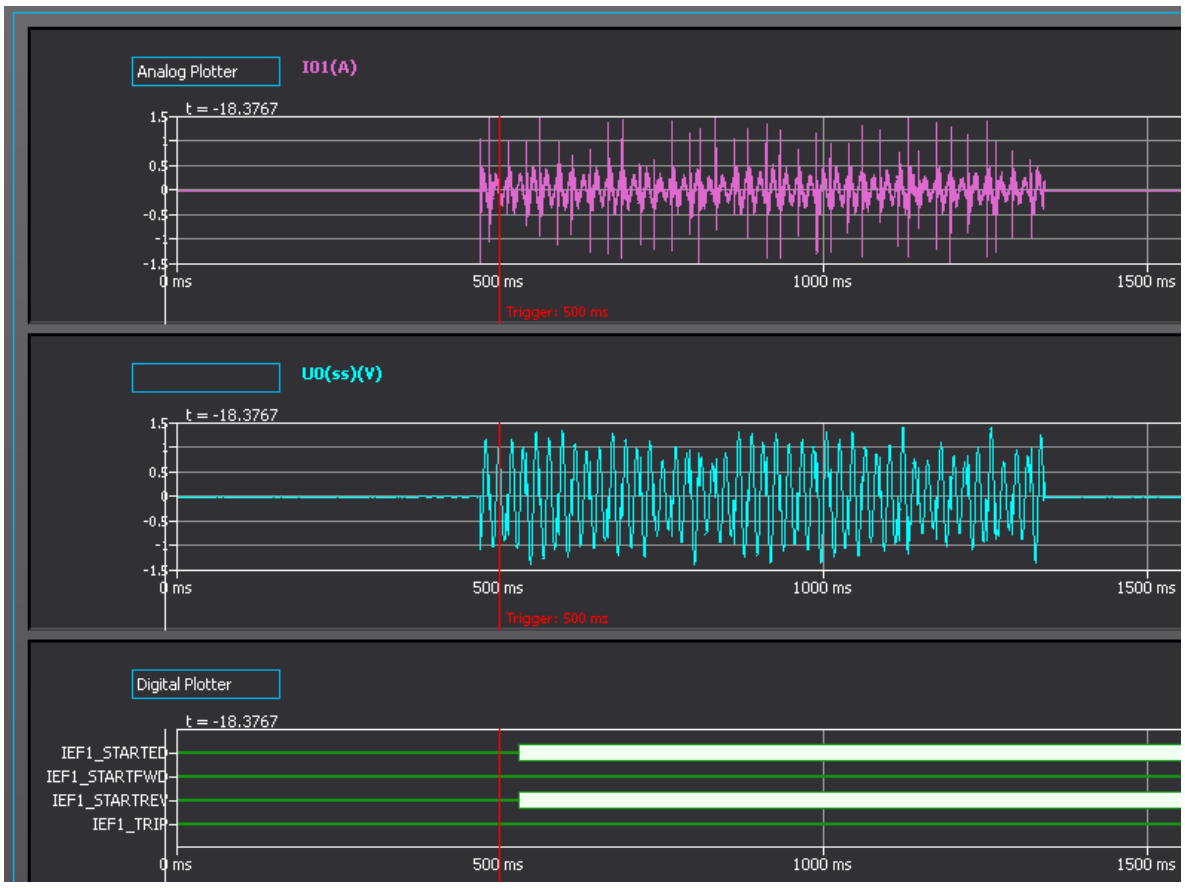
PKVerkko folder.

Fourth test case Sim2_2_2.DAT:

Strongly over compensated network, background fault I0TAUSTA, fault 1km from station.



It shall be noted from disturbance recorder that relay will not start or trip.

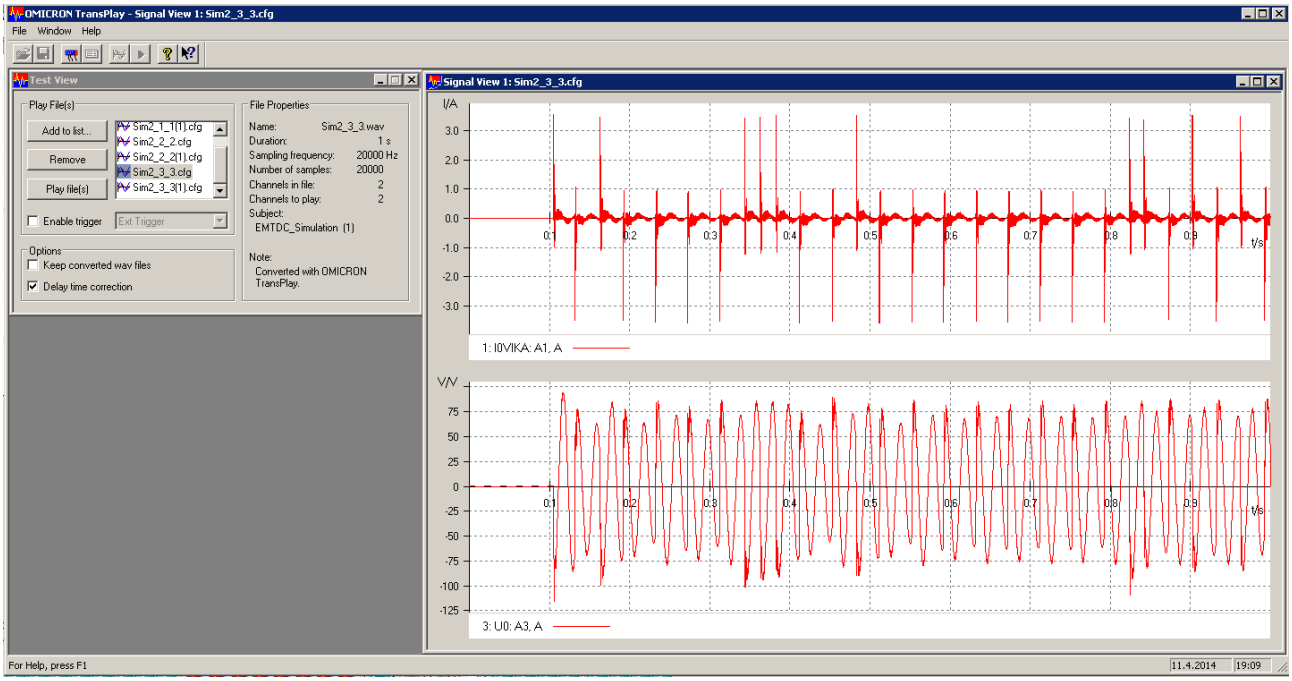


Needed files:

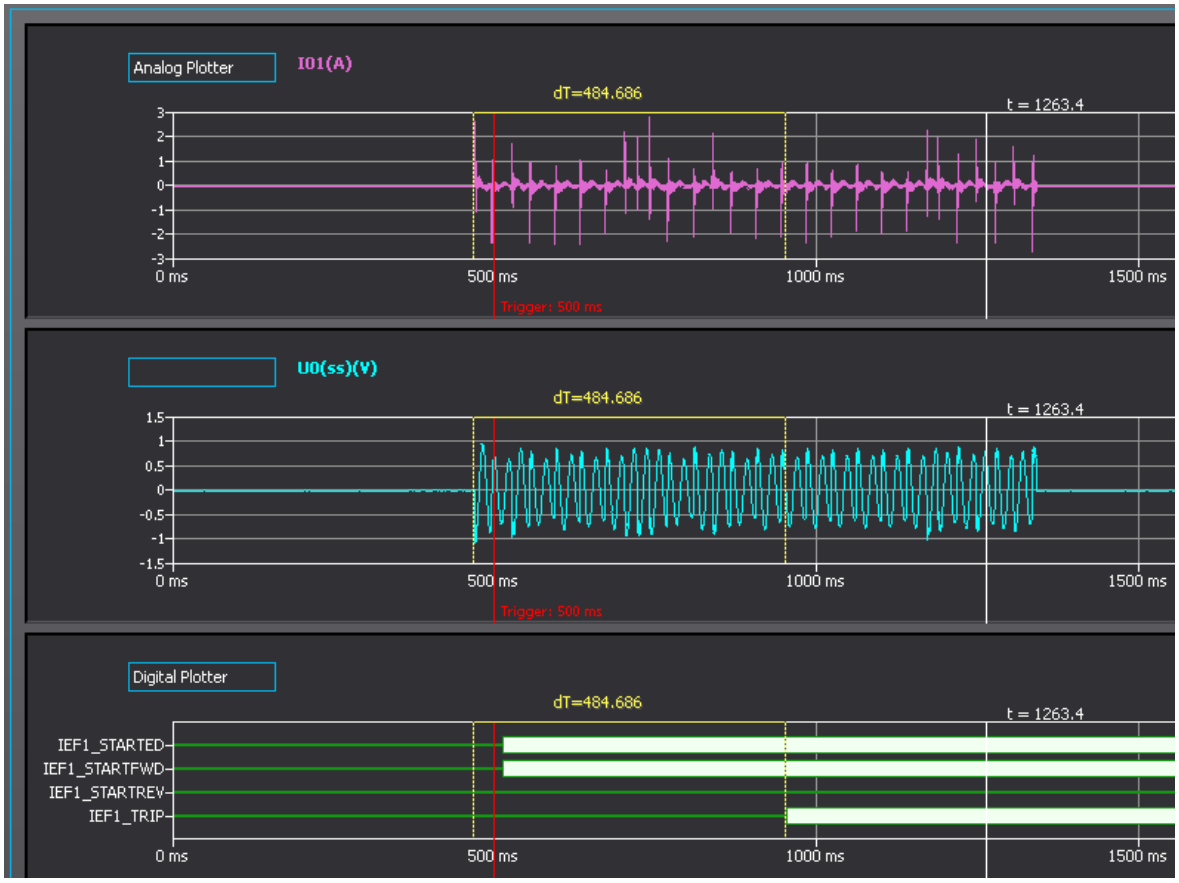
PKVerkko folder.

Fifth test case Sim2_3_3.DAT:

Strongly under compensated network, fault feeder I0VIKA, fault 50m from station.



The protection operate time shall be noted

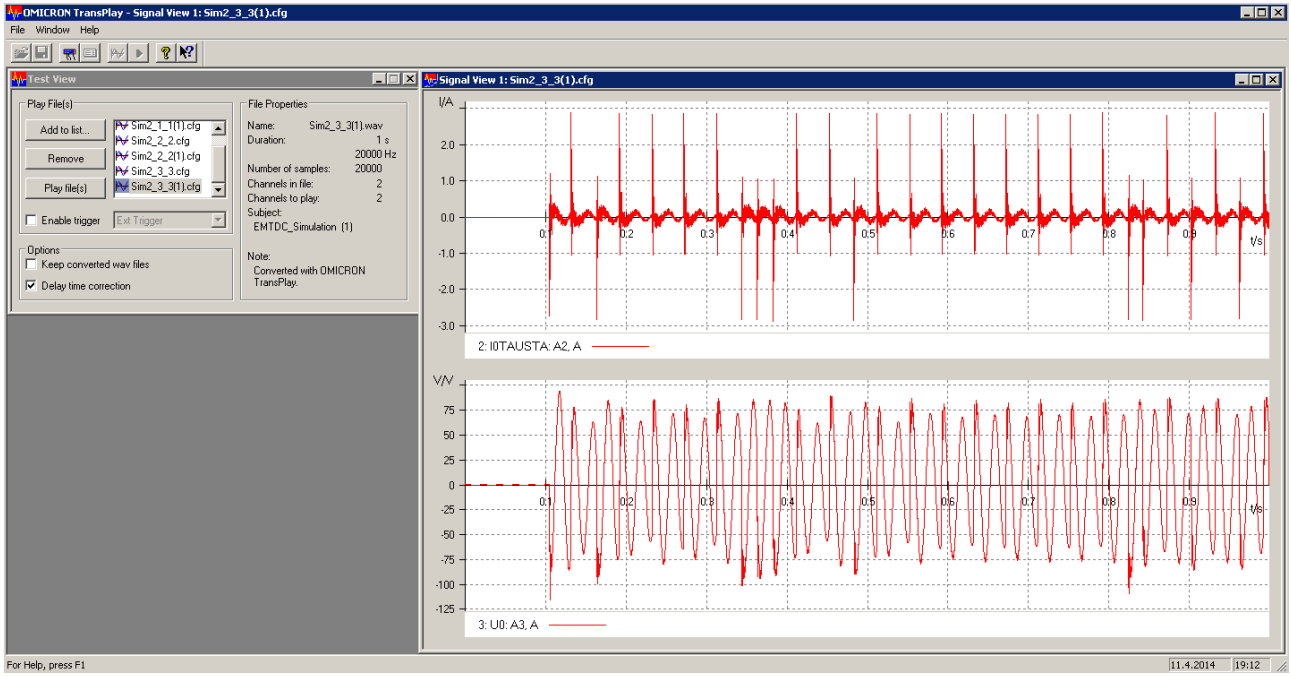


Needed files:

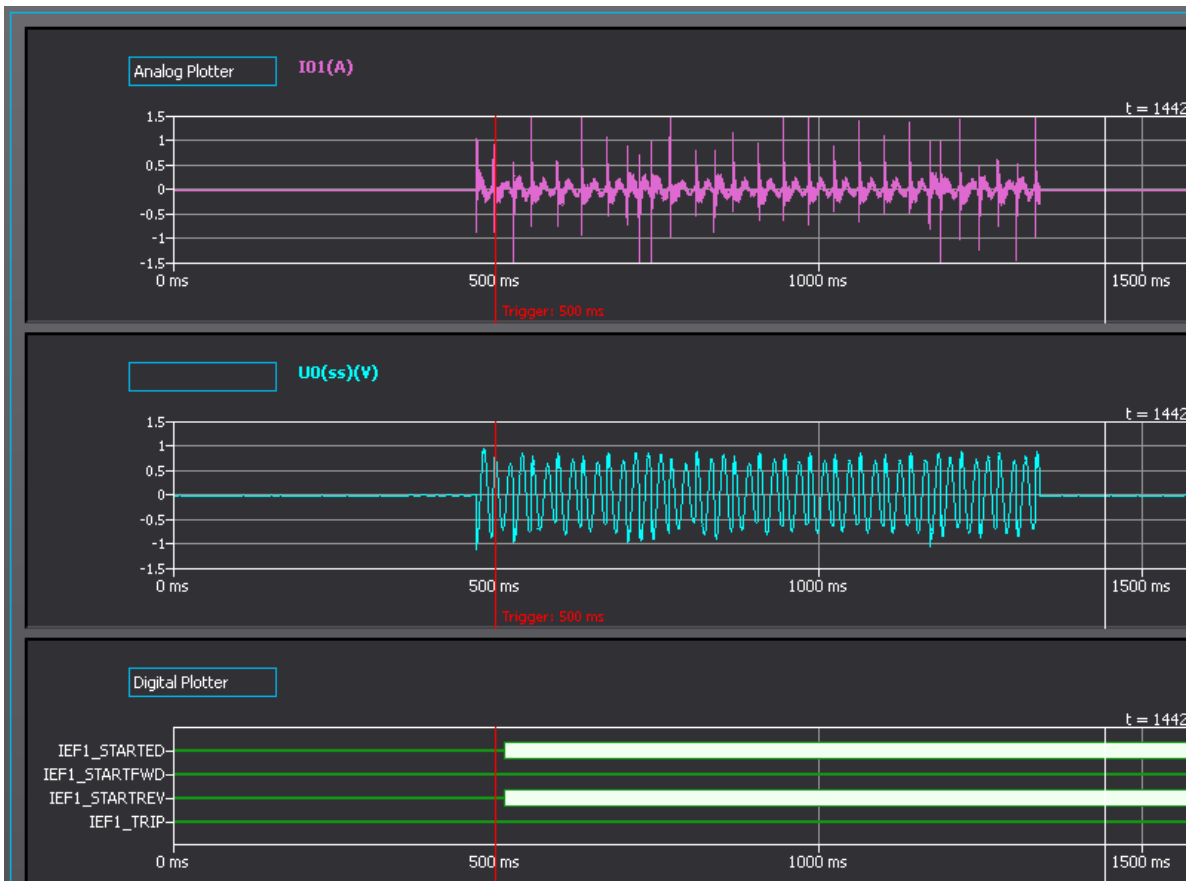
PKVerkko folder.

Sixth test case Sim2_3_3.DAT:

Strongly under compensated network, background fault I0TAUSTA, fault 50m from station.



It shall be noted from disturbance recorder that relay will not start or trip.



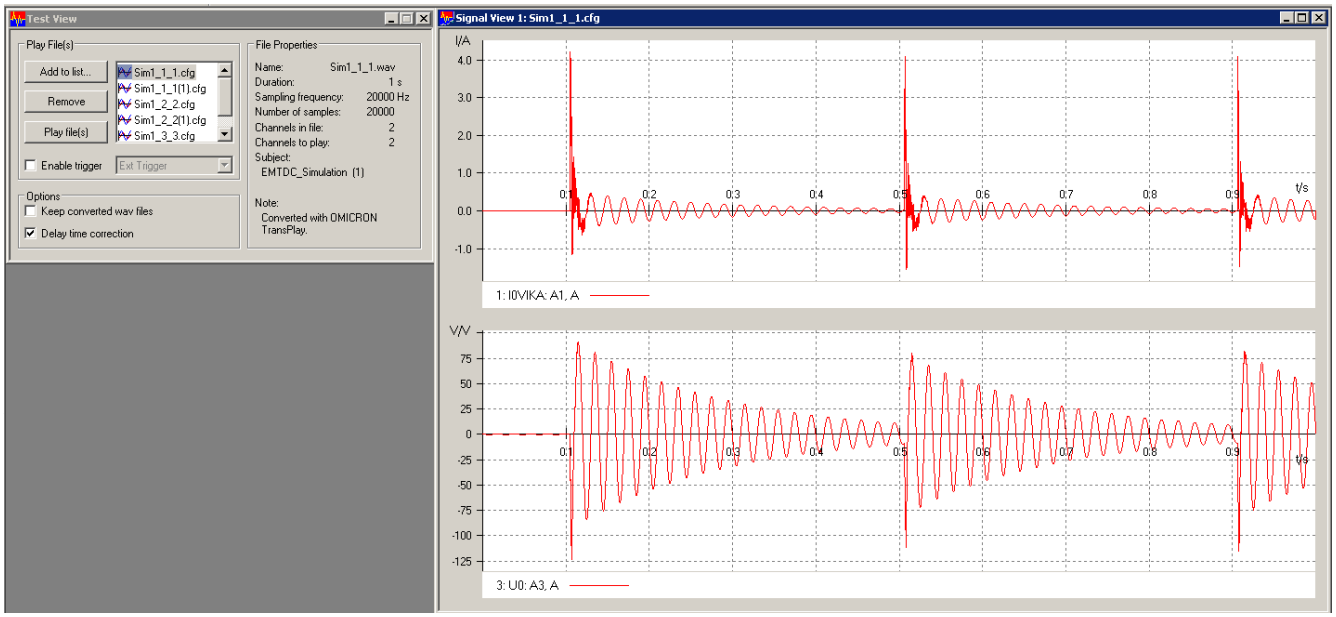
3.3 TESTING OF RELAY IN LARGE NETWORK (~100A)

Needed files:

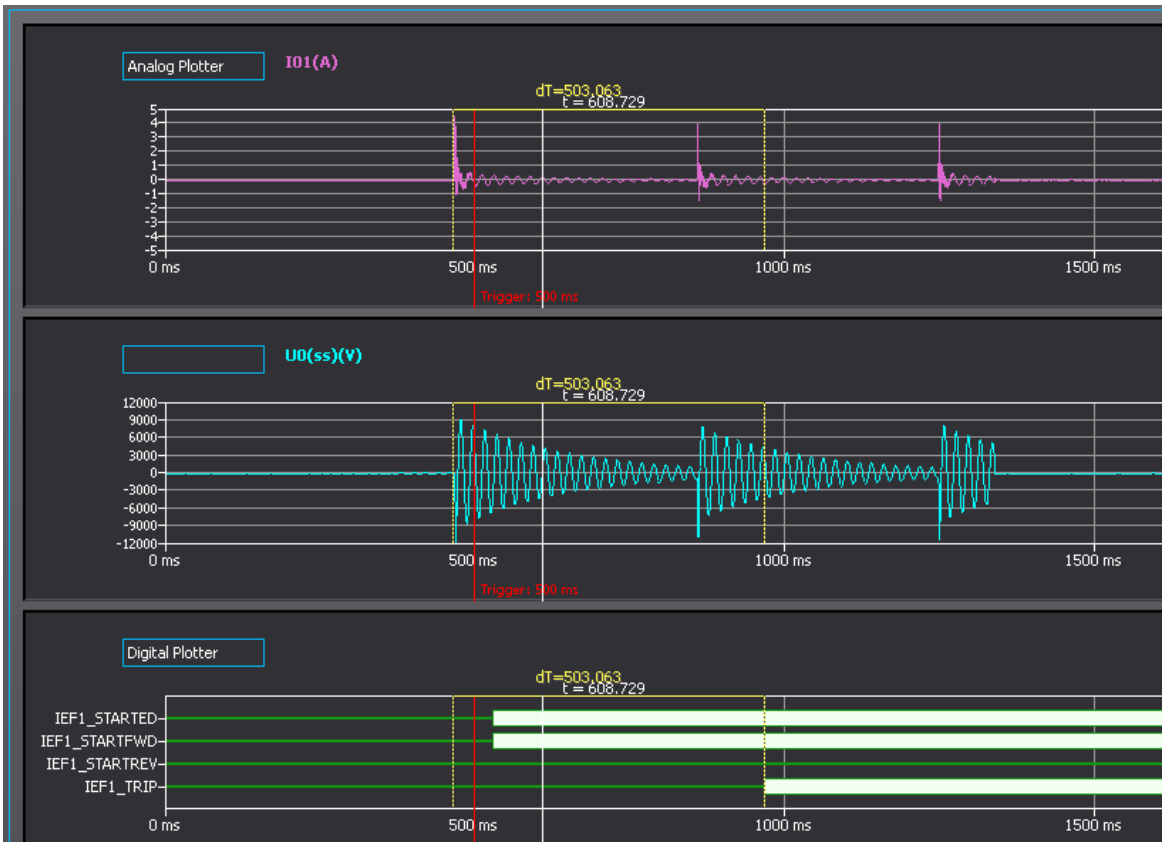
Isoverkko folder.

First test case Sim1_1_1.DAT:

Network in close to resonance point, faulty feeder I0VIKA, fault 3km from station.



The protection operate time shall be noted

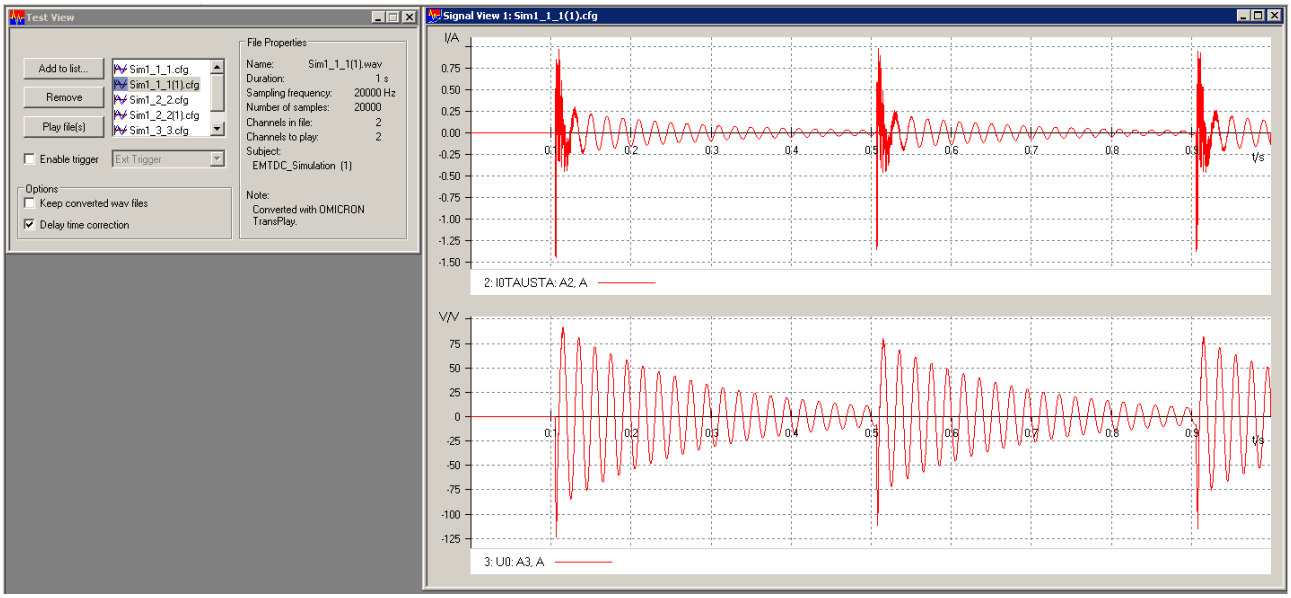


Needed files:

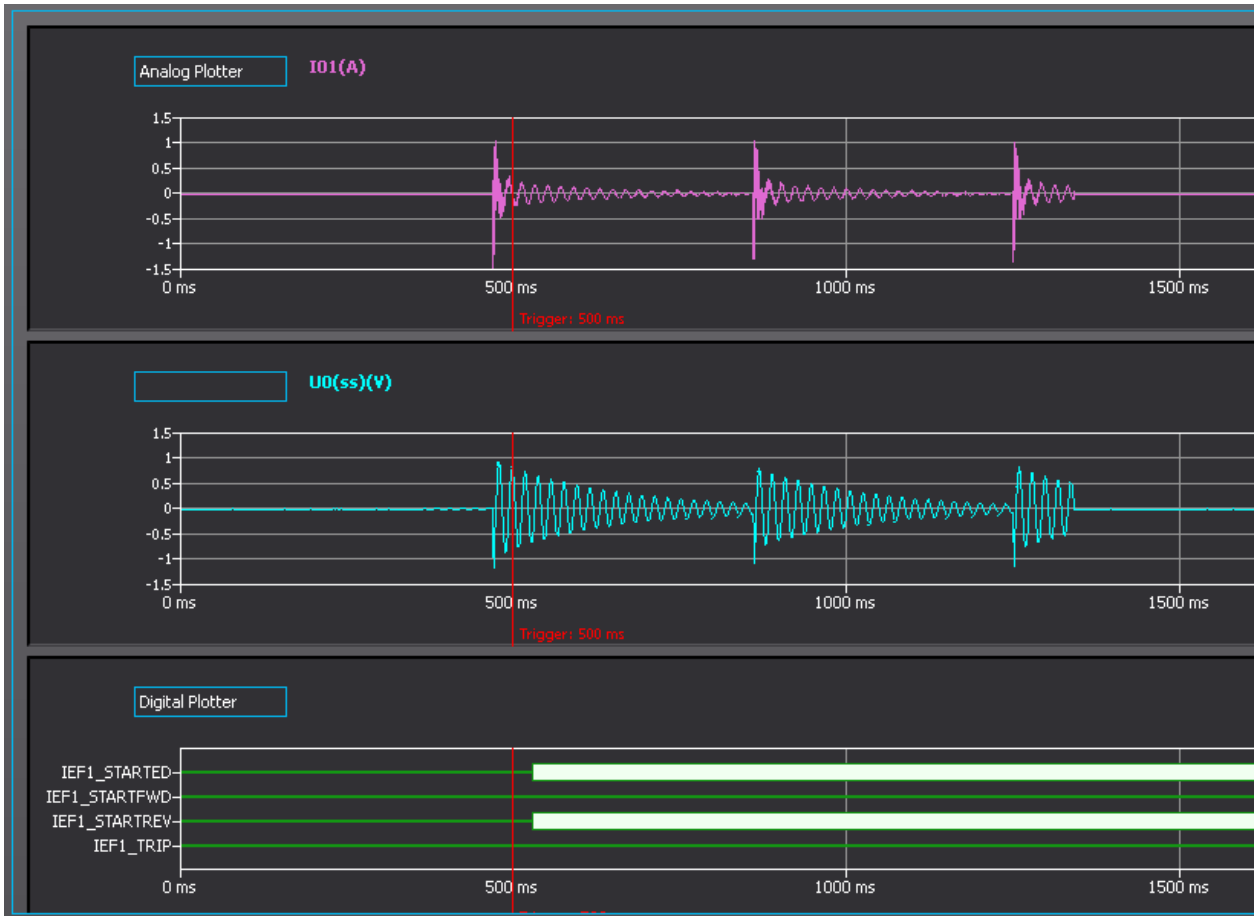
Isoverkko folder.

Second test case Sim1_1_1.DAT:

Network in close to resonance point, background feeder I0TAUSTA, fault 3km from station.



It shall be noted from disturbance recorder that relay will not start or trip.

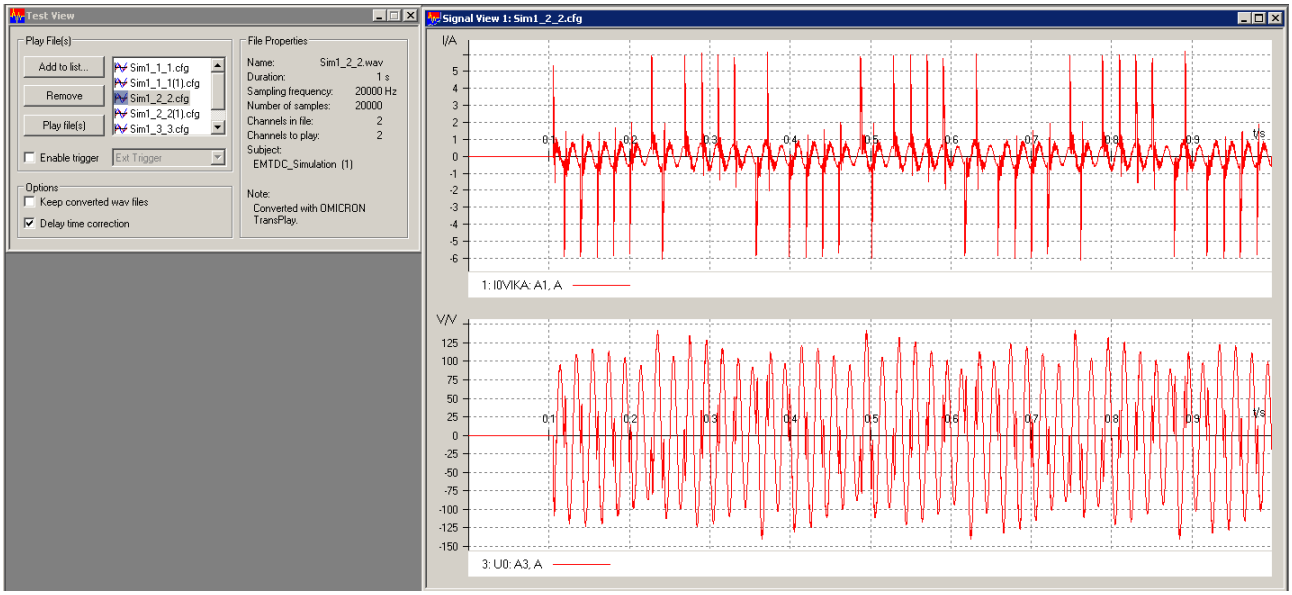


Needed files:

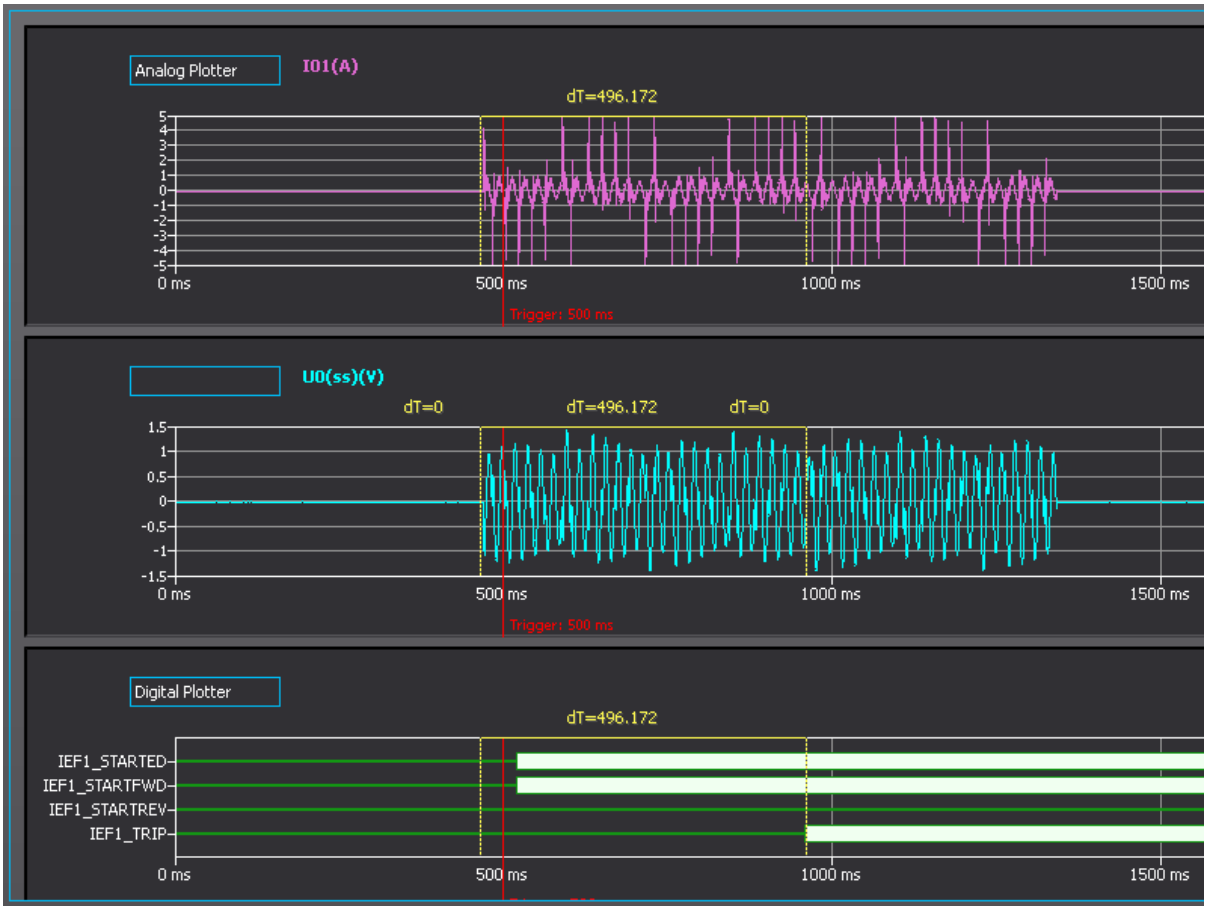
Isoverkko folder.

Third test case Sim1_2_2.DAT:

Strongly over compensated network, faulty feeder I0VIKA, fault 1km from station.



The protection operate time shall be noted

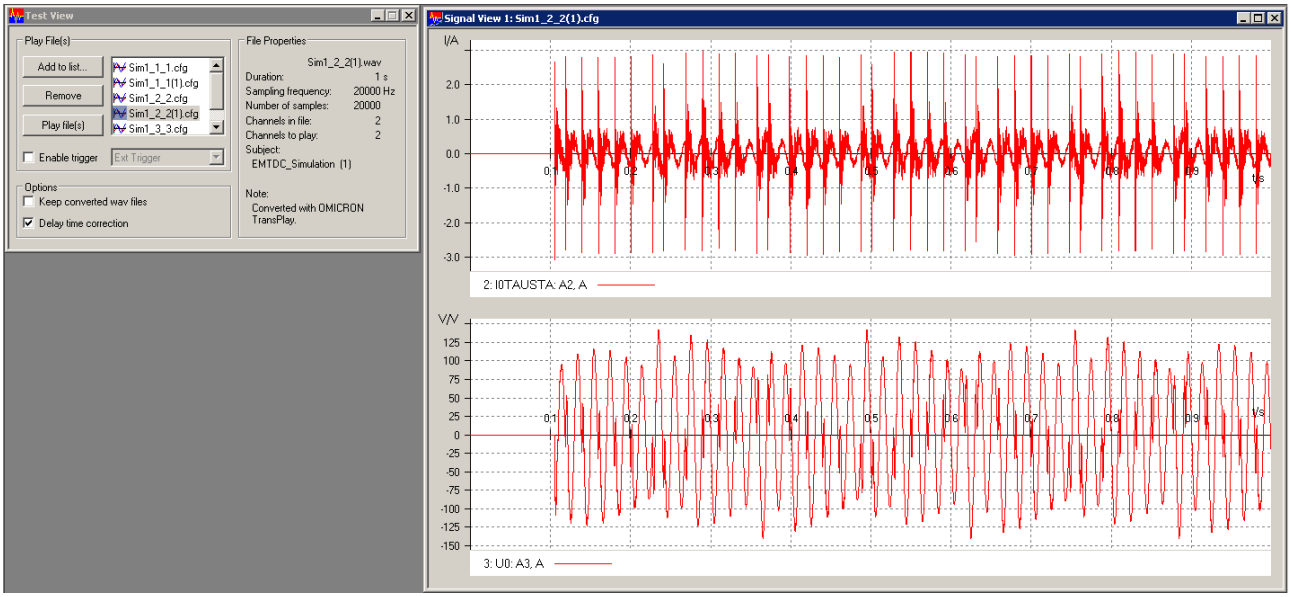


Needed files:

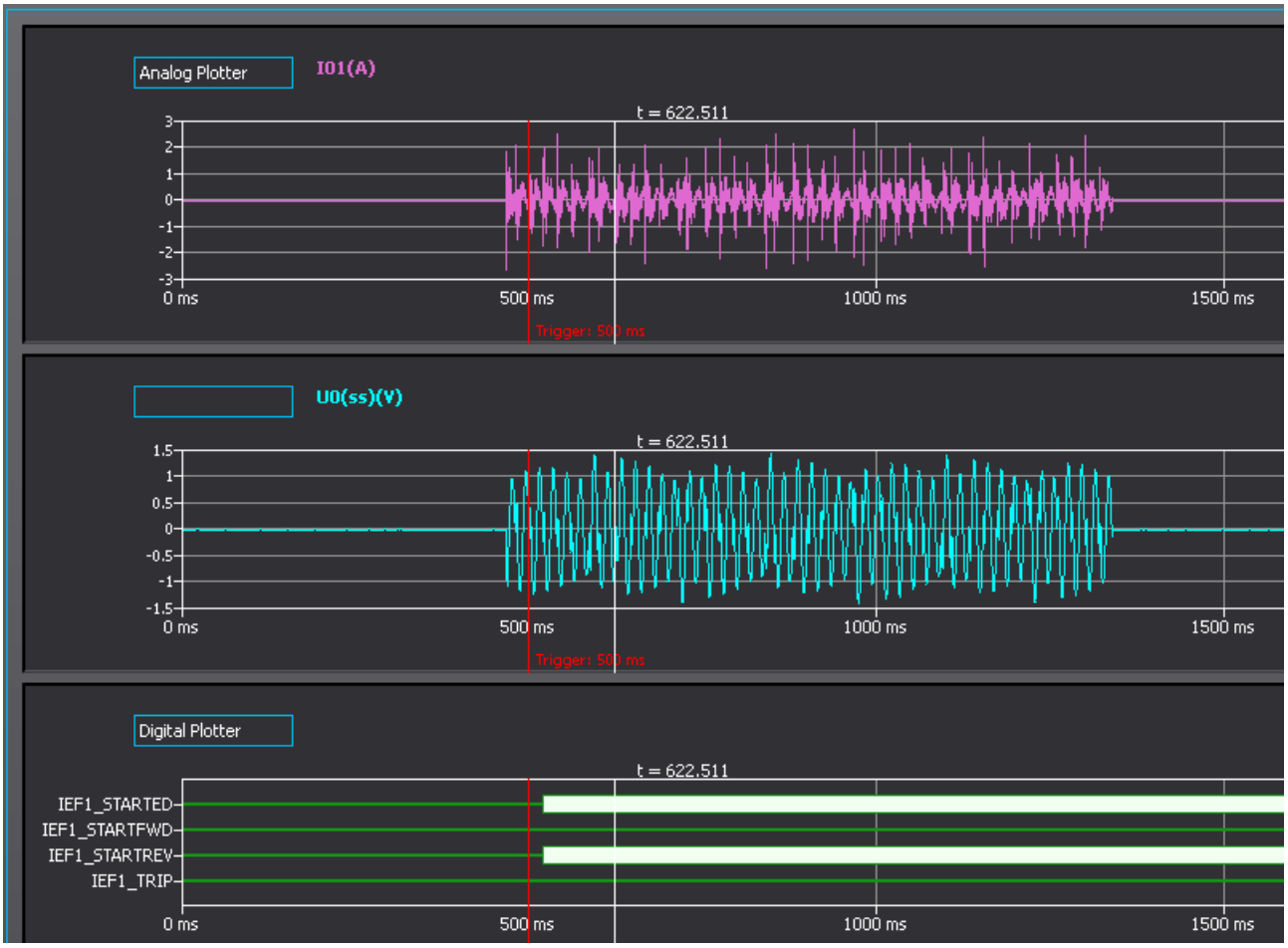
Isoverkko folder.

Fourth test case Sim1_2_2.DAT:

Strongly over compensated network, background fault I0TAUSTA, fault 1km from station.



It shall be noted from disturbance recorder that relay will not start or trip.

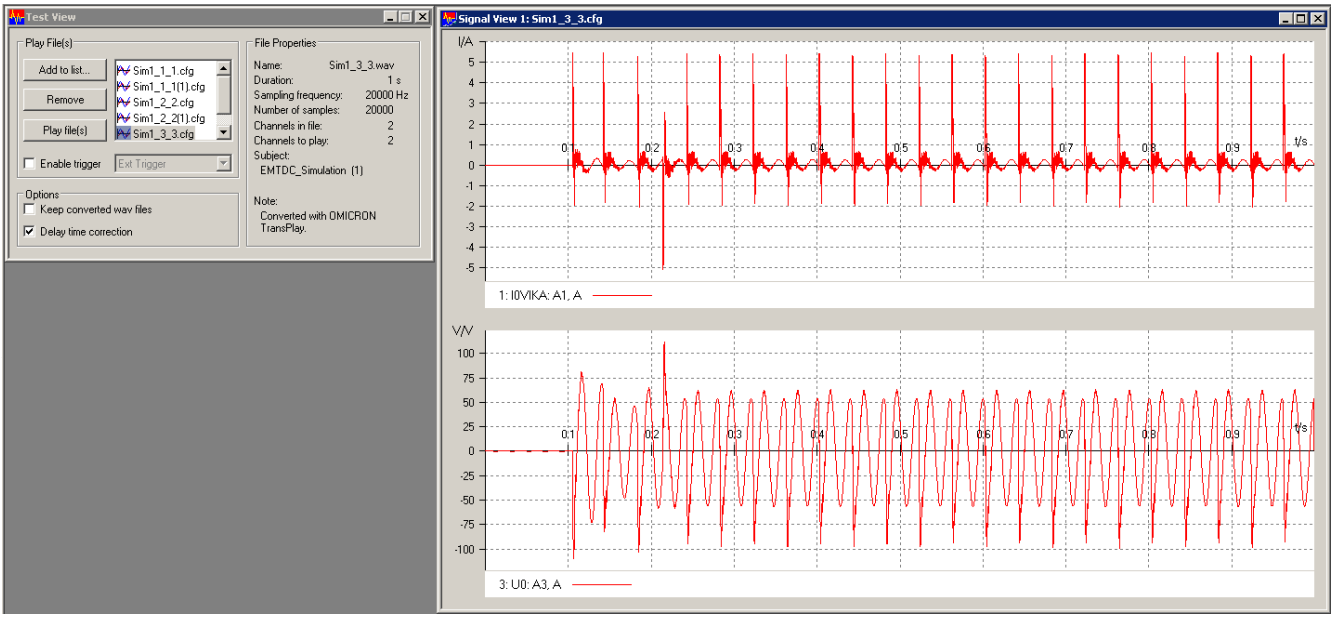


Needed files:

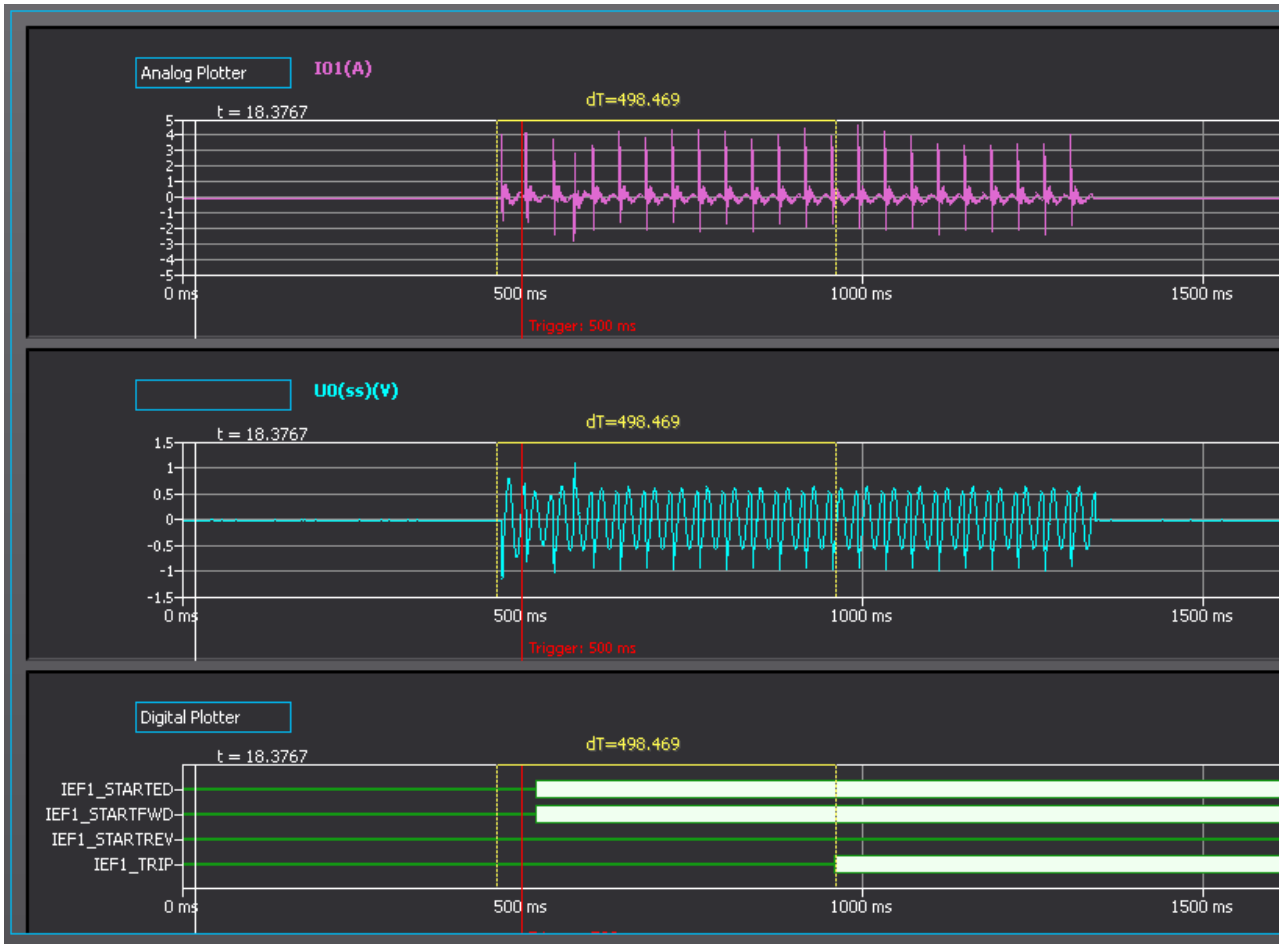
Isoverkko folder.

Fifth test case Sim1_3_3.DAT:

Strongly under compensated network, fault feeder I0VIKA, fault 50m from station.



The protection operate time shall be noted

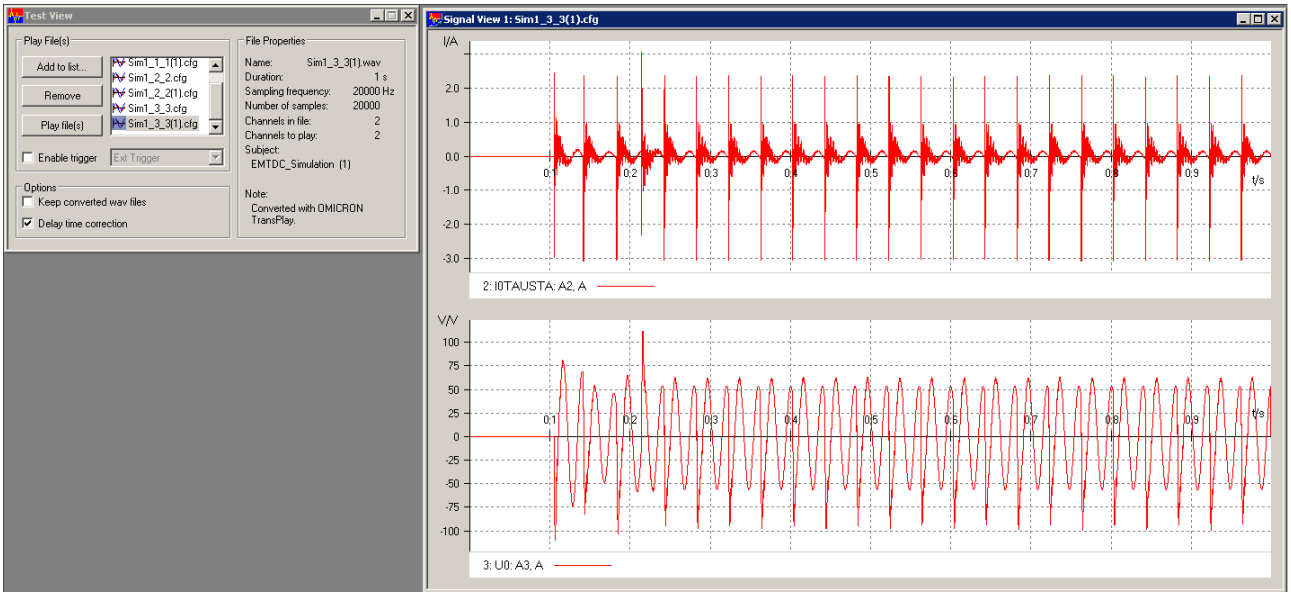


Needed files:

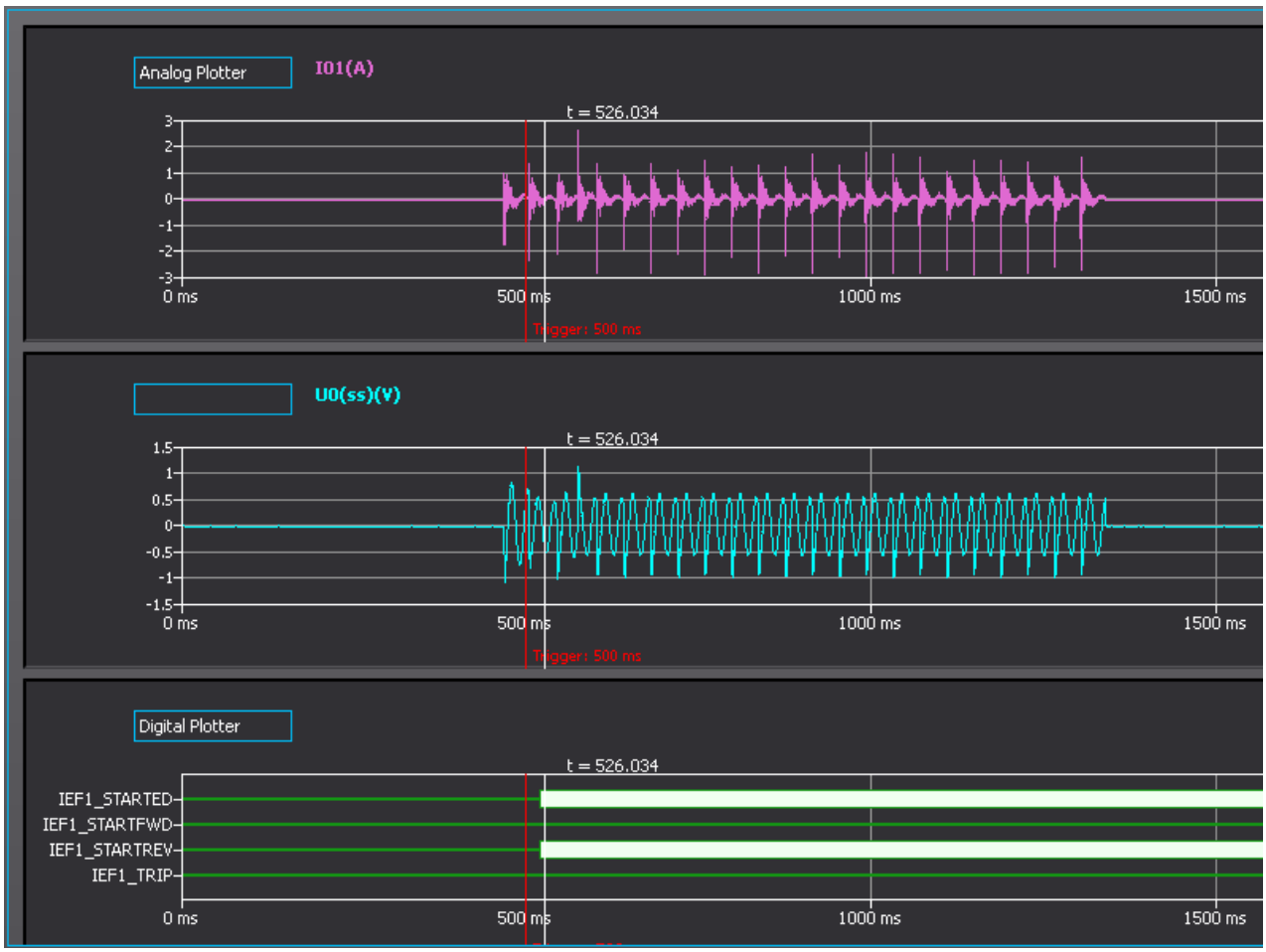
Isoverkko folder.

Sixth test case Sim1_3_3.DAT:

Strongly under compensated network, background fault I0TAUSTA, fault 50m from station.



It shall be noted from disturbance recorder that relay will not start or trip.



3.4 REPORTING RESULTS

Example of succeeded test protocol

Test no.	Test	Setting	Network tuning	Start	Trip
1.	Fault 3km	500ms	98 %	X	498ms
2.	Background	500ms	98 %	-	-
3.	Fault 1km	500ms	130 %	X	501ms
4.	Background	500ms	130 %	-	-
5.	Fault 50m	500ms	72 %	X	484ms
6.	Background	500ms	72 %	-	-

Test report should demonstrate at least that relay operation has been tested with different fault locations and compensation states. The files attached to this document can be used to test relay performance in close by and farther away faults in different network resonance states. When analyzing the results it is recommended to verify disturbance records of each test case even if relay would operate correctly. Additionally it is worthwhile to verify relay's fault registers to confirm that relay operation has been as expected. Example of Arcteq AQ-F215 type of IED fault records of intermittent earth fault test runs is presented below. (Faulty feeder and healthy background feeders in turns)

I> [50/51] | IODir> [67N] | Transient IOInt> [67NT]

Transient IOInt> 67NT [IEF1]

INFO | SETTINGS | REGISTERS | IO | EVENTS

REGISTERS: Transient IOInt>

Operation event register | General event register

	Event	Time	Trip time remaining	Started fwd	Spikes fwd	Started rev	Spikes rev	Spikesto trip	Setting Group in use
1	Start REV ONIntermittent EF detected ON	11.04.2014 19:38:59.912	0.450	No	0	Yes	23	2	SG1
2	Trip ON	11.04.2014 19:38:53.060	0.000	Yes	13	No	0	0	SG1
3	Start REV ONIntermittent EF detected ON	11.04.2014 19:38:44.944	0.450	No	0	Yes	24	2	SG1
4	Trip ON	11.04.2014 19:38:38.430	0.000	Yes	12	No	0	0	SG1
5	Start REV ONIntermittent EF detected ON	11.04.2014 19:38:30.558	0.450	No	0	Yes	3	2	SG1
6	Trip ON	11.04.2014 19:38:23.753	0.000	Yes	2	No	0	0	SG1
7	Start REV ONIntermittent EF detected ON	11.04.2014 17:35:03.536	0.450	No	0	Yes	22	2	SG1
8	Trip ON	11.04.2014 17:34:57.072	0.000	Yes	10	No	0	0	SG1
9	Start REV ONIntermittent EF detected ON	11.04.2014 17:34:49.775	0.450	No	0	Yes	22	2	SG1
10	Trip ON	11.04.2014 17:34:43.373	0.000	Yes	12	No	0	0	SG1
11	Start REV ONIntermittent EF detected ON	11.04.2014 17:34:36.018	0.450	No	0	Yes	4	2	SG1
12	Trip ON	11.04.2014 17:34:29.614	0.000	Yes	2	No	0	0	SG1

In general analysis of relay's performance should be based on following factors:

Relay should operate correctly in three type of cases. The first and commonly most attention attaining case is the faulty feeder where relay should trip in a set operate time. Second case is a healthy background feeder where relay should not operate or start falsely. Third case is a normal non-intermittent earth fault. In this case the intermittent earth fault stage should not react especially if it is set to block directional earth fault protection.

If relay starts in background healthy feeder (forward direction) without tripping can this result be marked as a "start" and it this result does not necessarily mean that settings are wrong in case starting is relatively short in its duration. In case relay does not operate even within 1 second (duration of the used records) in case of faulty feeder the result should be marked as failed. In a case where protection trip is delayed significantly from the set operate time result should be reported as a serious loss of function, especially if operate time is close to that set time of busbar residual voltage protection. If protection trip is delayed so that busbar residual voltage protection would trip prior to intermittent earth fault function the result should be marked as fail. In case relay trips on healthy background

feeder measurement the result should be marked as a fail since the protection would de-energize clearly a healthy part of the network without a reason.

Some functional deficiency cases may be improved by relatively simple setting changes. If the relay does not perform correctly during testing contact the manufacturer to make sure of the correct setting of the unit. For contacting the manufacturer it is helpful to load the disturbance records and setting files to be readily available to the manufacturer. As a useful additional information be prepared to provide the size of the network in amperes and the network tuning state on the network in question.

It is good to note that if setting changes are applied to pass one of the above test cases all cases should be repeated with new settings since all cases should be passed without change of settings in between tests.