DISTANCE PROTECTION APPLICATION TEST USING A REAL TIME DIGITAL TRANSIENT NETWORK ANALYSER

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INTRODUCTION

Real-time power system simulator testing has proven to be an invaluable mean to evaluate relay performance under realistic conditions. This paper will expose the configuration and the performance of a Real Time Digital Transient Network Analyser (DTNA) in closed loop testing of a distance protection system in a series compensated network.

A power system simulator for relay testing should be flexible in configuration and parameter adjustment and it should provide for a rapid execution of test cases. It must not only function in real time, but in a closed-loop mode with relays tripping circuit breakers within the simulator. To meet such requirements ABB in Sweden developed in 1980 a digital, computer-controlled, electronic, analogue power-system simulator, Nimmersjö et al (1). This simulator was used to evaluate new protection concepts in connection with product development, type testing of new products and verification simulations for various customer applications. Since then digital solutions have been developed and the older simulator is today replaced by a new flexible digital TNA, ARENE™, Levacher et al (2), Nimmersjö et al (3).

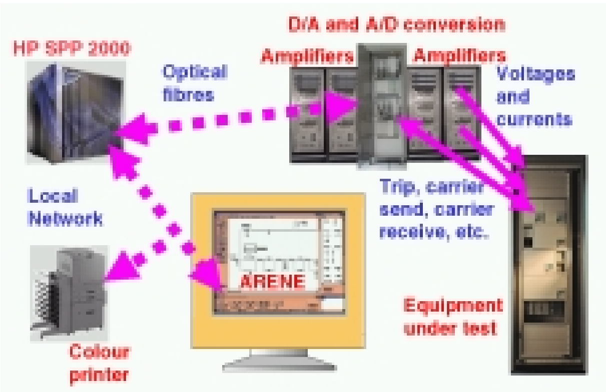

Figure 1: Configuration of the digital real time simulator, ARENE™, at ABB Automation Products AB.

An example of a verification application test is a simulation of a part of TRANSENER SA transmission network in Argentina where a new series capacitor was installed. This study of the reliability of a distance protection type REL 531, Saha et al (4), was performed at the Simulation Centre of ABB Automation Products AB in Västerås.

SIMULATOR CONFIGURATION

The Real Time Digital TNA ARENE™ installed at ABB Sweden and used during the presented simulations was developed by the French utility Electricité de France (EDF). An English Company Analogue Associates has delivered the amplifiers. The basic specifications of the simulator are:

1. The Real Time DTNA software is implemented in a HP SPP 2000/S-16 computer with 16 parallel processors and 1024 MB memory.
2. The computer is connected via a low latency communication system using optical fibres to I/O-equipment for D/A and A/D conversion.
3. The I/O equipment is connected to amplifiers, providing current and voltage signals to the tested equipment.
4. The connections of logical signals to and from the tested equipment are made directly to the simulator I/O equipment.
5. The total possible number of input signals to the tested equipment in the ABB installation are:
   - 12 currents from power amplifiers for current designed to give a peak current of 160 A at a voltage of 100 V (type Techron 7790 RLY)
   - 12 voltages from power amplifiers for voltage (type Crown 3622)
   - 48 logical signals indicating breaker position, blocking or permissive signals from remote end, etc.

6. Possible feed back from the tested equipment:
   - 80 logical signals: trip signals, signals to remote end, etc.
   - 20 analogue signals from amplifiers or tested equipment

BATCH TESTING FACILITY

The flexibility to change the power system network connected to the protective relay(s) being tested is important. Using a batch-testing feature, it is possible to automatically test the relay in varying network configurations and with different fault-types. The batch-testing mode in ARENE™ meets the need to have many simulation results for varying parameters; for example: length of a line, source impedance, location of a fault, fault type, fault resistance etc. The batch session summary reports show the operating time of different signals essential for analyses of the relay performance.

SIMULATED NETWORK

A part of TRANSENER SA transmission network (figure 2) has been modelled using the digital TNA ARENE™. In the substation Recreo, a series capacitor was installed in the beginning of Recreo-Malvinas line. The purpose of the verification application test was to verify the distance protection of the lines between El Bracho and Recreo and between Recreo and Malvinas during external and internal faults. 192 cases with different fault positions, different fault types and different fault inception angles were simulated and registered. Batch testing sessions were programmed to make variations of parameters and to register the results for analyses.

The currents and voltages in both ends of the protected line were registered in graphs showing the results as well as different logical signals, for example tripping signals. An example of presentation using the postprocessing facility in ARENE™ in a simulation of single-phase to earth fault is presented in figure 4.

MODELS

The substations in the model of the network are El Bracho, Recreo, Malvinas and Almafuerte (figure 3). For the lines El Bracho – Recreo, Recreo – Malvinas and Malvinas – Almafuerte the model used is based on Bergeron's method. The resistance, inductance and capacitance per km, positive and zero sequence, as well as line length are the parameters in the line model. Those line parameters are independent of the frequency. Other parts of the network are modelled using linear dipoles where the positive, negative and zero sequence resistance and inductance are defined. The generator models are infinite busses. The current transformers (CT) are linear and the capacitive voltage transformers (CVT) are modelled with capacitance and tuning inductance and linear magnetic part.

In the model the series capacitor bank is modelled by a capacitor dipole in parallel with a non-linear resistance (MOV). Seven points of the characteristic curve define the MOV voltage versus current. In two of the lines linear shunt reactors are installed in the modelled network. Breakers are modelled with an opening delay of 40 ms and are breaking the current at a zero crossing of the current.

The faults are modelled using a fault-switch with programmable inception angle. Resistance can be defined from phase to neutral point and from neutral point to the ground. The different fault points are marked F11, F13 etc.

In figure 3 two blocks can be seen representing the I/O objects where the connection to the two tested relays can be defined. There are also connections going to a special network, not shown in the diagram, used to measure and register incoming logical signals from the test relays. The performance of I/O equipment is monitored during the test by sending one signal to the I/O equipment and receiving same signal in return.

The carrier-send signal from one protection to the other was passing a delay circuit, called “carrier 1” in the diagram of figure 3.

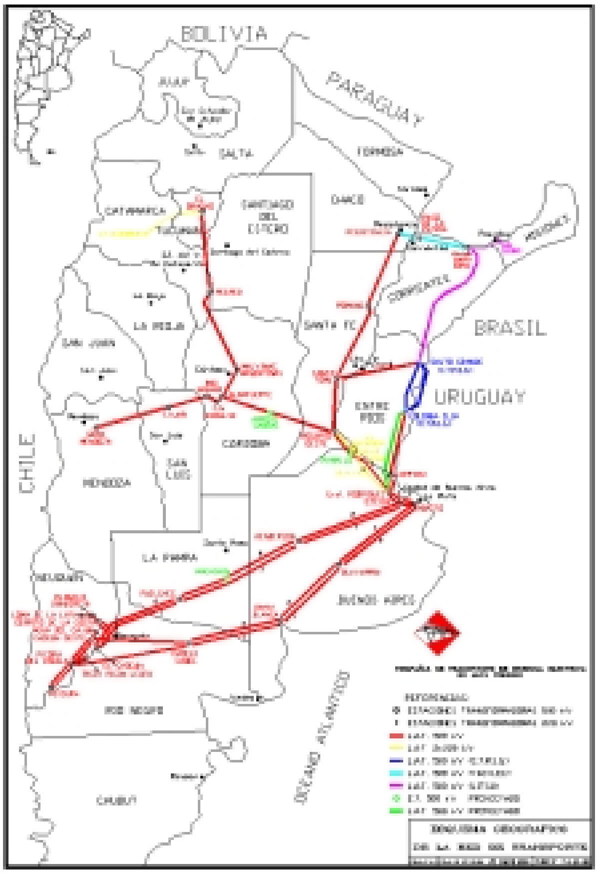

Figure 2: Transener S.A. network.

SUMMARY OF A BATCH SESSION

When the cases defined by the batch program have been run, ARENE™ returns user-defined tables showing the result of the test. Table 1 shows, as an example, the result from a short batch sessions having fault-position F22 (Figure 3) on the 257 km long line Recreo – Malvinas at 33 % from Recreo. The scenarios are defined as follows:

Scenario 1: Phase to ground fault, 0.2 ohm
Scenario 2: Phase to ground fault, 20.0 ohm
Scenario 3: Three phase to ground fault, 0.1 ohm phase to neutral and 0.5 ohm neutral to ground.

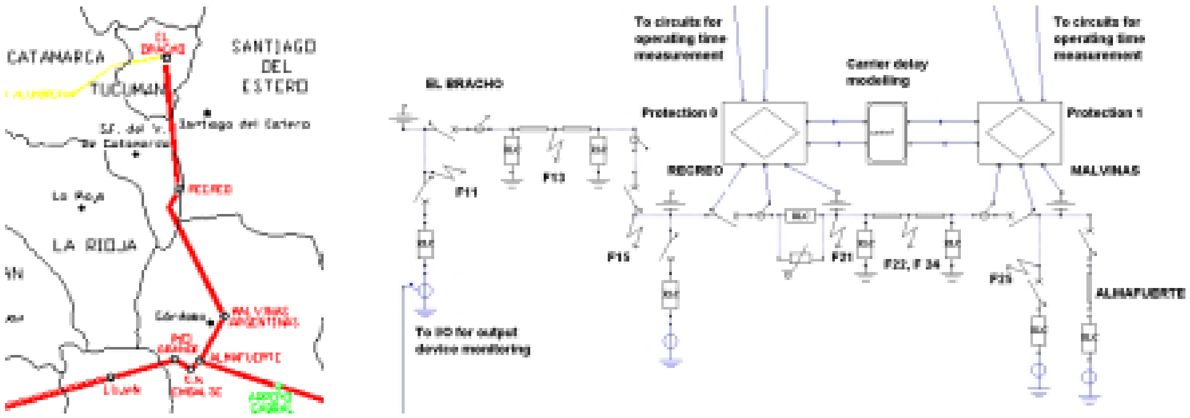

Figure 3: Model of a part of the Transener S.A. network.

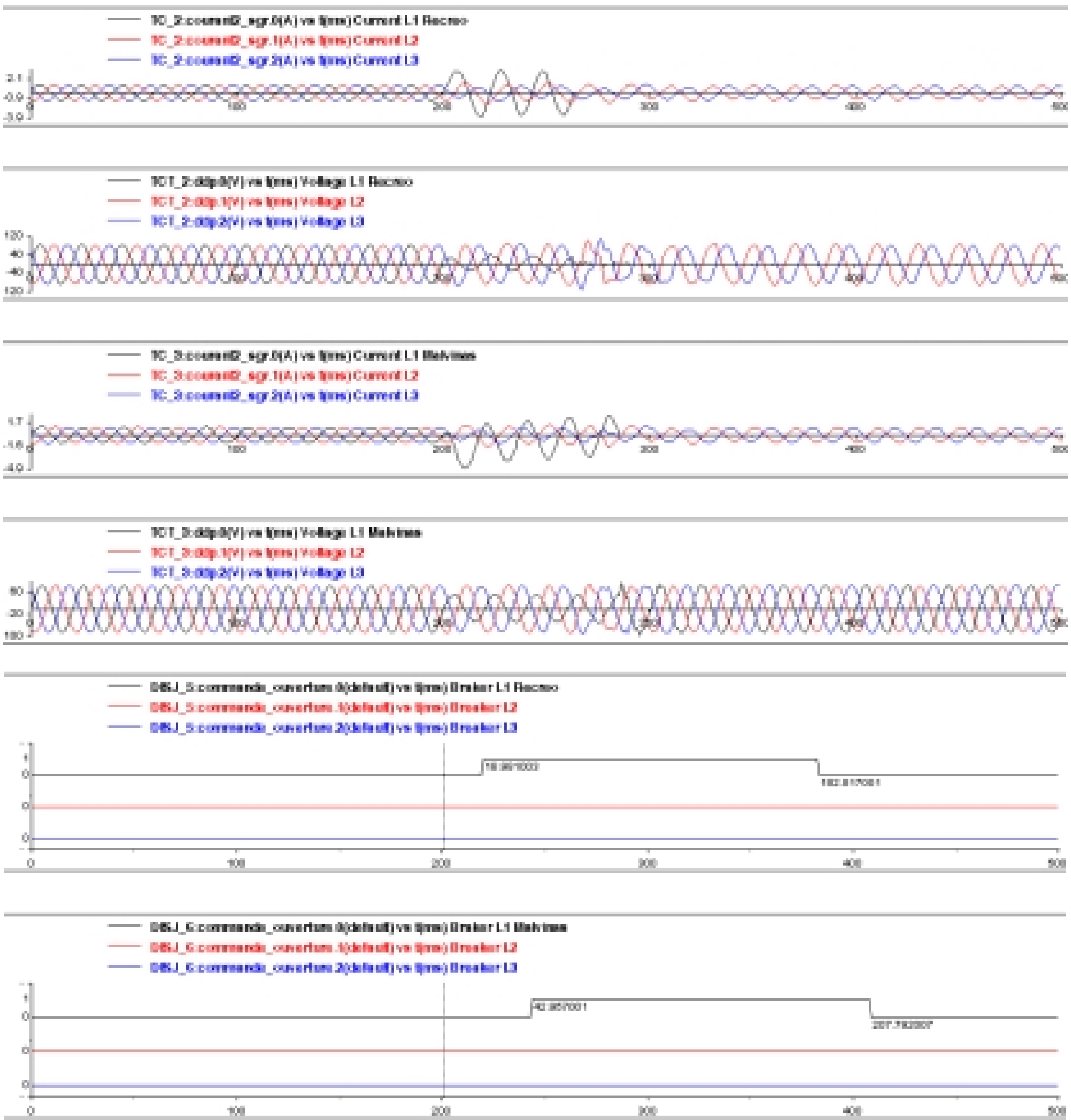

Figure 4: Example of a simulation result presentation of a single phase to earth fault on the 257 km long line between Recreo - Malvinas. The distance to the fault is 85 km from Recreo. Fault resistance is 0.2. From the top of the figure the currents in Recreo, the voltages in Recreo, the currents in Malvinas, the voltages in Malvinas, the tripping signals in Recreo and the tripping signals in Malvinas are shown.

```
Ilv Version: 2.4
File generated:
Thu Oct 28 10:35:37 1999

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Fault = F22 (33%)
REL531 C / RECREO
REL531 D / MALVINAS
Load = Maximum

Scenarios:
L1N       0                  1
L1N      20                  2
L1L2L3N  0                   3
-----------------------

Scenario no 1   1   2   2   3   3
Shot no:    1   2   3   4   5   6
Angle       0  90   0  90   0  90

C_TRL1     19  34  26  32  36  32
C_TRL2    999 999 999 999  35  32
C_TRL3    999 999 999 999  36  32
C_PHSL1    33  34  30  32  36  39
C_PHSL2   999 999 999 999  35  32
C_PHSL3   999 999 999 999  35  32
C_ZM1ST    33  34  30  31  35  32
C_ZM2ST    33  34  30  31  35  32
C_ZM3ST    33  34  30  31  35  32
C_ZM4ST   999 999 999 999 999 999
C_CS       14  14  22  29  10  12
C_CR       51  59  62  49  46  44
D_TRL1     43  45  52  58  40  42
D_TRL2    999 999 999 999  40  42
D_TRL3    999 999 999 999  40  42
D_PHSL1    35  29  33  28  33  31
D_PHSL2   999 999 999 999  33  31
D_PHSL3   999 999 999 999  33  31
D_ZM1ST   999 999 999 999 999 999
D_ZM2ST    36  30  33  35  33  31
D_ZM3ST    36  30  33  28  33  31
D_ZM4ST    36  30  33  28  33  31
D_CS       15  27  30  16  10  12
D_CR       47  48  58  60  45  49
```

Table 1: Result from a batch session

The table shows the operating times of different logical signals from the two relays (999 = no operation). The tripping signals in each phase, TRL1, TRL2 and TRL3, the carrier send signals CS and carrier receive signals CR are also monitored as well as signals indicating direction, phase selection etc. The fault inception time is defined by an angle with reference to the first phase voltage (90° corresponds to a peak value at fault point).

COMPARISON ARENE™ AND EMTP/ATP

The currents and voltages produced in the real time simulations were compared to the results calculated by the well-known software, EMTP/ATP. Application of an impedance algorithm similar to the REL 531 algorithm showed very similar impedance variation during the fault using data from the simulations (figure 5). The small difference observed was explained by the difference in load flow, which can be observed in the starting point of the impedance in the R-X plane. The example shown in figure 5 is a phase to ground fault at El Bracho (F11) at a fault resistance of 0 ohms. The impedance seen in Recreo is calculated.

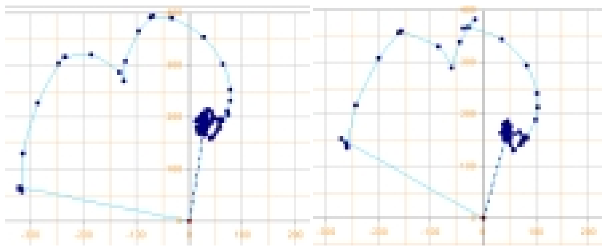

Figure 5: Comparison of results from ARENE™ (left) and EMTP/ATP (right). The diagrams show reactance (vertical axis) versus resistance (horizontal axis).

CONCLUSION

The introduction of a new digital real-time technique for power system simulations has given a digital transient analyser, DTNA, well suited for protection system application tests. It meets the demands of flexibility, illustrated by the presented line protection test.

By using the batch mode operation for automatic testing the simulator is very suitable for test sessions having a great number of fault cases with the purpose of verifying the reliability of the protection.

REFERENCES

1. Nimmersjö G, Hillström B, Werner-Eichsen O and Rockefeller G D , 1988, "A digitally-controlled, real-time, analog power-system simulator for closed-loop protective relying testing", IEEE Trans. Power Delivery, vol. 3, no.1, 138-152.

2. M. Jerosolimski M, Descausse D, Devaux O, O. Huet O, Levacher L and Meyer B, 1995, "A real-time Digital transient network analyzer for testing equipment on a general purpose computer ",ICDS Proceedings , 3-8 , College Station, USA.

3. Nimmersjö G, Saha M M and Hillström B, 2000, "Protective Relay Testing Using Modern Digital Real Time Simulator", Proceedings of PES Winter Meeting, IEEE Catalogue no. 00CH37077C, CD-ROM 0-7803-5938-0, Singapore

4. Saha M M, Wikström K and Holmström A, 2000, "High speed protection scheme for EHV lines", Proceedings of PES Winter Meeting, IEEE Catalogue no. 00CH37077C, CD-ROM 0-7803-5938-0, Singapore