Incorporating PSCAD/EMTDC into a Real Time Playback Test Set

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Abstract - **This paper describes a new playback simulator test set which incorporates a powerful emtp software program. Details are given of the main features of the test set.**

Keywords: real time playback, simulation, relay testing.

1. Introduction

Electromagnetic Transient Simulation Programs have been used for many years to generate and store test waveforms to be subsequently played out in real time at a piece of control apparatus. One such common example is the testing of protective relays [1] but other fast acting controllers can also be tested in this way. Figure 1 shows

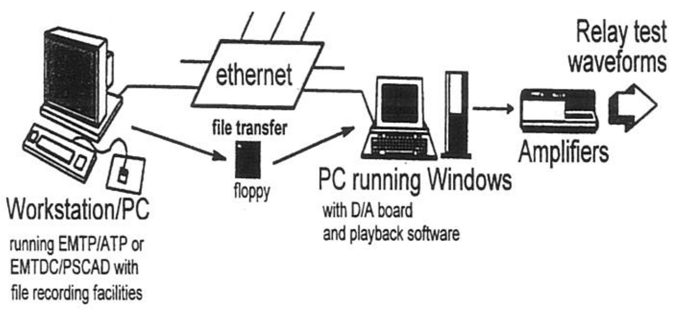

Figure 1 Typical playback simulator test set up

a typical playback test set up for testing protective relays. Modern Relay Test Sets incorporate a playback feature which will allow a COMTRADE format file from either an off-line study, or from a fault recorder, to be installed and played out in real time. These test sets very often have sufficient computation capability to handle a phasor based solution for a small network (typically a 2 or 3 busbar system). This allows testing with waveforms which change abruptly from say the prefault sinewaves to the fault sinewaves as shown in Figure 2. The waveforms may subsequently change to the post-fault state giving 3 successive steady state ac waveforms. The abrupt change between the states is of little significance for slow acting devices (RMS response) but it may cause mal-operation for fast acting devices. In the latter case it is essential to correctly model the transient waveforms which define the change from prefault to fault conditions. An emtp type solution is therefore required, and if a real time simulator is not available, a stored file from an emtp run or fault

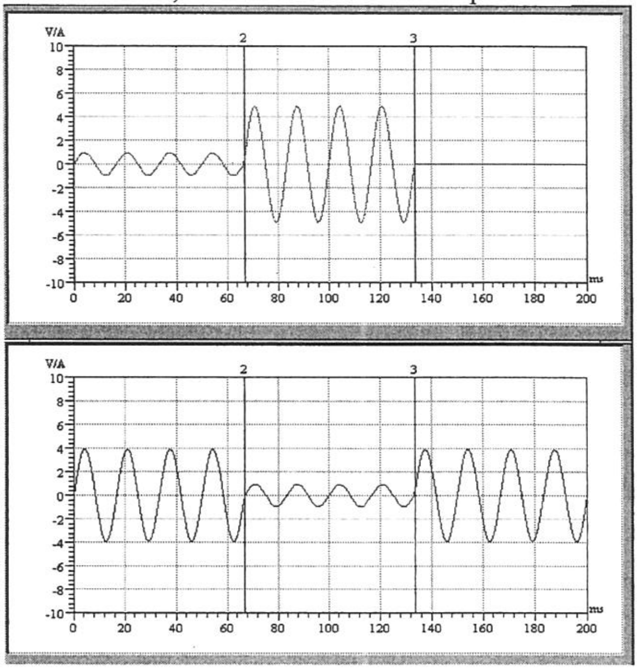

Figure 2. Current and voltage waveforms for a 3 state phasor solution

recorder is necessary (as in Figure 1). Generally the emtp off-line run will not be performed on the test set but will be run on a workstation possibly at a different location than that where the tests are being conducted. This can create problems if the test device response to the available stored emtp runs on the test set indicates that the response to a case which has not been run on an off-line emtp is needed. A Real Time Playback test set which is capable of running an emtp simulation and allows the test engineer to configure a real time playback using an elegant graphical user interface, is therefore an

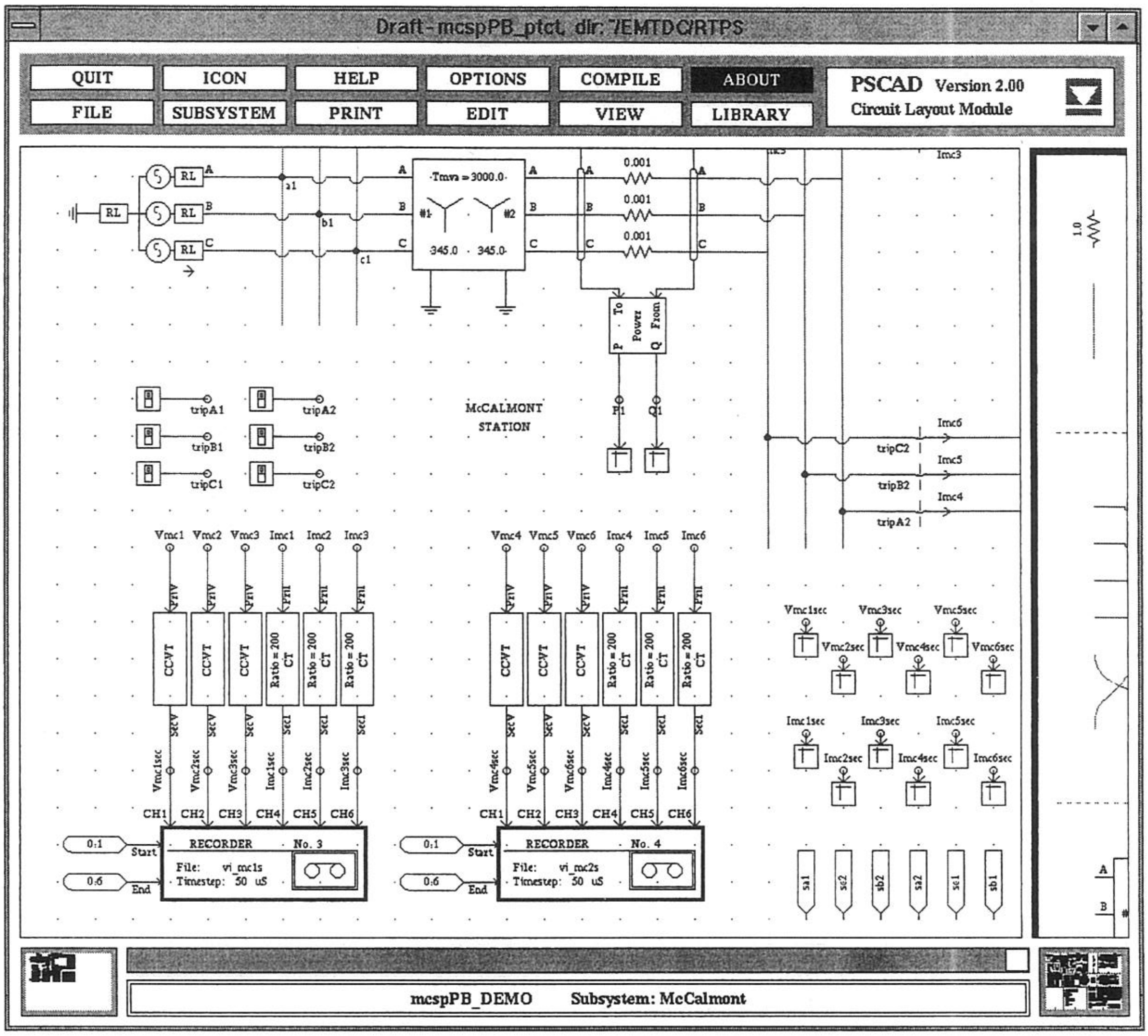

Figure 3. PSCAD screen during the set up of a simulation case

extremely useful test instrument. It allows the engineer to perform the extra runs at the test location and there is no problem of file transfer since the emtp and the playback software run on the same PC. The ability to run the graphical user interface to the emtp imposes limits on the minimum power of the PC. A Pentium (or equivalent) based PC is required.

A team of engineers at the University of Manitoba, the Manitoba HVDC Research Centre and Manitoba Hydro have designed and tested a Pentium based Playback Digital Simulator which can run EMTDC/PSCAD in addition to the usual features of a relay test set and a playback simulator. This paper will describe the major design features.

2. Design Features of the Playback Simulator

2.1. Software

There are two different sets of graphical interface software. The first set is PSCAD™ [2] and is the interface to EMTDC™. For this application, additional PSCAD Icons have been added to deal with "recording" the files to be used in the playback process. Figure 3 shows a typical PSCAD screen with two recorder Icons which are set up to record the voltage and current waveforms at the two opposite ends of a transmission line. It is a double circuit transmission line study with four recorder files being set up. These waveforms will be used to test a relay for a fault on one of the transmission lines. Figure 4 shows a close up of one of the recorder icons indicating that the waveforms are being taken at the outputs of voltage and current transducers connected to appropriate nodes in the primary system seen at the top of Figure 3. The recorder Icon has an editing box associated with it which allows the engineer to choose the length of prefault waveform, length of recording, recording timestep etc. prior to commencing the simulation run. There is also a COMTRADE recorder Icon (not shown here) which records the data in a COMTRADE format should the engineer wish to transport the files to another platform. Up to 10 recorders can be set up for a given run within the limits of available storage space on the hard disk. Once the run and recorders have been configured the case is compiled and run on EMTDC. Both PSCAD and EMTDC have been adequately described elsewhere. [2]

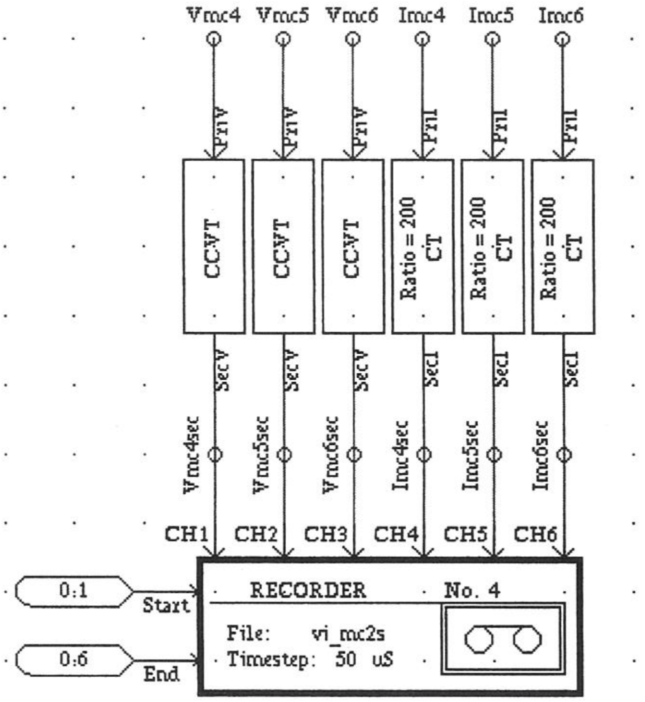

Figure 4 Detail of the recorder Icon

The second set of graphical interface software controls and configures the playback run. This software runs under MS Windows and allows the various recorded signals to be viewed along with the designated output channels. Figure 5 shows a typical viewing screen for waveforms recorded from an EMTDC run on a series compensation application. The voltage waveforms are flattened by MOV action before the bypass closes leaving only the "ringdown" waveforms. The channel allocation can be seen on the right of the screen for each set of waveforms and of course the originals are in colour which greatly clarifies the various waveforms.

Other editing screens allow the scaling factors applied to the output channels to take account of the gains of the conditioning amplifiers which connect the output channels to the apparatus under test. When PSCAD\EMTDC is installed on the PC, the test set up shown in Figure 1 now reduces to the PC plus conditioning amplifiers for full secondary transducer level signals. In some cases where digital apparatus is being tested it may be possible to bypass the amplifiers and access the A/D inputs on the apparatus under test [3]. This will obviously change the scaling factors on the output channels but it has the considerable advantage of not requiring the sometimes large conditioning amplifiers. The logic signals, e.g. relay trips, can be fed back into the simulator for recording or control purposes.

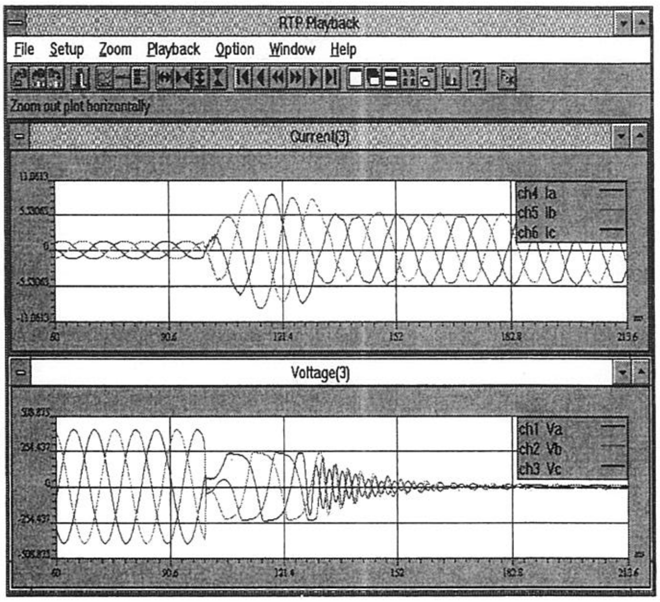

Figure 5 Typical viewing screen for voltage and current waveforms prior to playback initiation.

2.2. Hardware

The PC has to be capable of supporting PSCAD/EMTDC and the Real Time Playback(RTP). A Pentium processor or equivalent is recommended.

The RTP part of the system is capable of playing back 12 channels of analogue output data with 16 bit resolution and 16 channels of logic output data. It also has 16 channels of logic inputs which allow the recording of the logic signals from the apparatus under test. These functions are realised on a PC plug-in board with an FPGA configured to control the data flow and timing. On this board, D/A channels produce analogue voltage signals within the range ± 10V, while logic I/0 channels operate at 5V. The analogue signals can be used directly for low level testing (without the conditioning amplifiers) which makes the RTP a very convenient tool for the development of such apparatus as digital protective

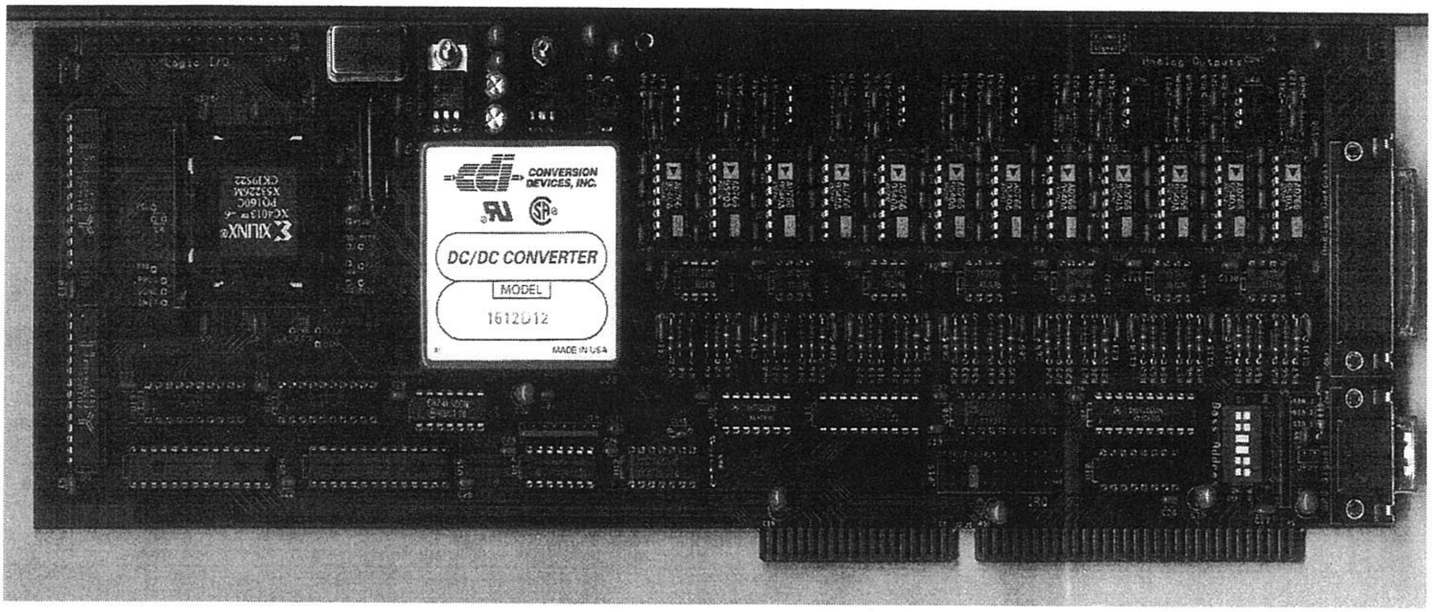

Figure 6. The custom plug-in board for the RTP

relays or for testing HVDC controls and protection systems.

To restore the playback signals to their original instrumentation transformer secondary levels for testing relays or control systems, voltage amplifiers and current amplifiers are used to amplify the voltage and current signals respectively. A logic interfacing unit is used to convert the 5V logic signal levels to and from the 128V power system substation logic signal level. In the interface unit, logic inputs are opto-isolated, while logic outputs are dry contacts. The timing lag of the dry contacts are calibrated and compensated in the playback data file.

The RTP also provides the function of GPS synchronisation which allows the operation of multiple RTP's at power system substations hundreds of miles apart for trouble-shooting the installed power system protective relays, controls, and communication links.

The original prototype RTP utilised an off-the-shelf 12 channel D/A board running under Windows but this was unable to take in logic signals in synchronism with the signals being played out at the device under test. This led to the need to develop an in-house board which would provide this facility and also free the engineers from many of the constraints imposed by a CPU running Windows controlling the playback output. The new unit is shown in Figure 6. The FPGA (Field Programmable Gate Array) chip (lettering is upside down) is to the left of the DC/DC converter and the 12 analogue channels with associated D/A's can be seen to the right of the converter. Each D/A is optically isolated and the opto-isolators can be seen just below the vertical D/A chips. Another reason for moving to an FPGA (Field Programmable Gate Array) was the need to convert a parallel set of signals to a serial data stream at a rate consistent with a sampling rate of up to 50kHz on each of 12 channels.

2.3. Additional RTP features

The functions of the "Relay Test Set" and the "Playback Simulator" have merged into a common device and, as discussed in previous sections, the "workstation" to run the off-line emtp cases is also incorporated into the same piece of apparatus. The software and hardware features described so far are those necessary to enable off-line simulations to be easily configured, run, stored and then played back at the device under test. For use as a relay test set the RTP must also incorporate a number of other features which relay engineers have come to expect.. As an example of some of those other features, the RTP has to be configurable as a 3-phase signal generator with easily set amplitudes and phase differences on voltages and currents. The GUI for setting up *steady state* signals on a typical test set is of the type shown in Figure 7. This is a screen for setting up 6 analogue channels in a balanced three phase format with 3 voltage channels and 3 current channels. The screen shows the position of the two sets of phasors, and the phase angle between the sets or their respective magnitudes can be changed either by using the mouse driven "hand" to grab and pull one of the phasors or, if a more precise adjustment is required, by inputting the numbers in the appropriate input box at the foot of the screen.

The control features of the test set allow the channels to be set independently to simulate unbalanced conditions. Other screens allow the engineer to add harmonics and/or exponential components to specific signals. When the engineer is satisfied with the waveforms on each channel (as previewed on the screen) the waveforms can be sent to output channels to drive the conditioning amplifiers. For *dynamic tests* it is necessary to build two or more "states" of suitable duration to represent the chain of events which might start out in the normal load condition, changing abruptly to the sine waves representing the fault steady state and then changing abruptly to the fault cleared sine waves. This feature has already been mentioned in the Introduction section. There is no attempt to represent the transient which governs the change from one state to the other and this type of testing cannot be used on high speed relays.

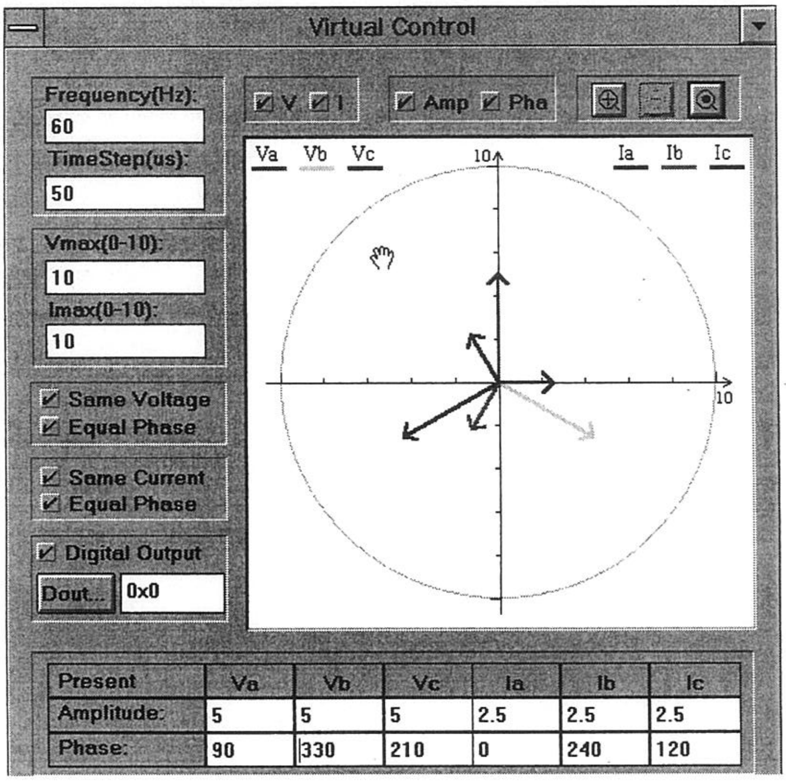

Figure 7 Screen to configure balanced 3-phase signals

Most playback, and some real time simulators, already incorporate "batch" testing features. This enables the simulator to run through a large number of pre-programmed tests without the test engineer requiring to be present. A typical batch test might include testing the relay for different types of fault, different point on wave of fault incidence, different fault resistance and different fault locations for a given test system such as that shown in Figure 3. The simulator or an associated event recorder must automatically collect the data from each test run for later inspection by the test engineer. This type of testing may reveal an unexpected operation or misoperation which could have been very difficult to predict in a one off basis. Artificial intelligence techniques may be used to scan these result files to isolate the unexpected results thereby minimising the time an engineer has to spend looking at the file. The batch testing feature on this RTP is currently under development.

3. Conclusions

When a Pentium or equivalent CPU based PC runs the graphics and computation required for electromagnetic transient simulation, the addition of a plug-in custom built D/A board allows the PC to combine the functions of a test set and a playback simulator into a compact Real Time Playback test set.

4. References

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