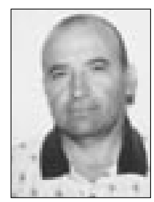
Precision Recloser Testing



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At the Hydro-Québec recloser maintenance and overhaul facility in Saint-Hyacinthe, Québec, the reliability centered maintenance (RCM) method is systematically applied. RCM is a method for developing maintenance strategy based on safety, operational, and economical considerations. To efficiently apply this method on recloser control cabinets, one of the necessary requirements is the recording and analysis of key data in order to evaluate their degradation over time. With this information, it is possible to predict the failure of a recloser, to establish a maintenance schedule that specifies what to do and when to do it, to decide to remove the recloser from service, and to help the manufacturer to improve and correct its designs.

To help understand the subject, we shall first define *recloser*. An automatic circuit recloser is described as *a self-controlled interrupting device which senses fault currents and proceeds through a predetermined sequence of opening and reclosing operations, followed by resetting, hold-closed or lockout*[1]. It also has provisions for manually opening and reclosing.

The recloser is divided into two distinct modules: the mechanical section, with the contacts; and the intelligent control cabinet which makes up the electronic section. Some popular recloser control modules are the Cooper types F3, F4, F5, F6, FXB, DC Nova, Westinghouse ESV, Joslyn TRIMOD 300, Joslyn 351J, ABB PCD2000 and the Schweitzer SEL-351R.

The way this intelligent fuse works is determined by the time-current curves (TCC) programmed into its controller (see example in figure 1). Three curve types are widely used: the Cooper recloser curves, the IEEE (or US) curves, and the IEC curves.

The curves most often used are the fast curves that have a minimum response time on the order of 15 milliseconds and the slow ones that have response times of about 250 milliseconds. A typical example of a programmed coordination sequence is two fast time-delay operations followed by 2 slow time-delay operations. If reclosing is not successful by the fourth attempt, the control goes to lockout.

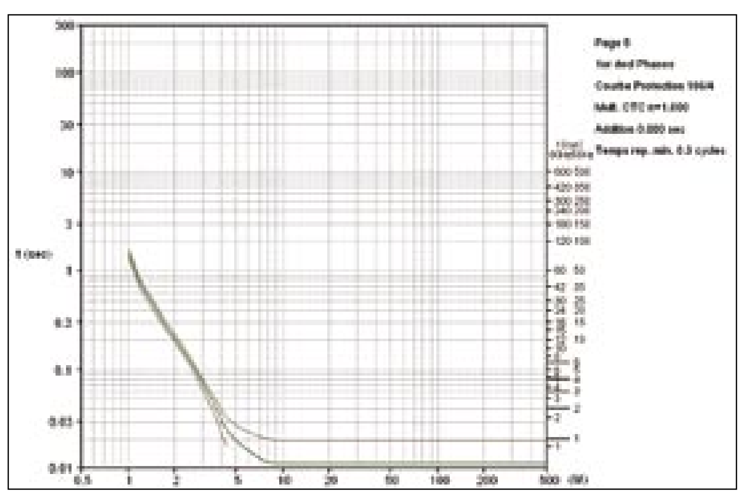

Figure 1 — Recloser curve no.106 with ±10% limits

We examined test procedures carried out on reclosers at Hydro-Quebec with regard to their effectiveness in RCM. We noticed that the test results, as collected, could not be used to evaluate wear on a recloser. In fact, the instrument most widely used for these tests is a completely manual device. It contains a current generator, an ammeter, and a timer with a digital readout. The main problems include inaccuracies in the measurements because of the unregulated current injector, the inability to measure reaction times with accuracies better than one millisecond, difficulties in obtaining stable measurements with fast reaction times, and the necessity to manually record all test results. It is impossible to see wear trends in the recloser with these methods..

Analysis of past failures has helped us to see that the components most prone to wear in a recloser are the analog inputs. The digital components simply operate in an on-off manner. They either work or not and have little importance in RCM analysis.

To fulfill our needs, we have defined the exact requirements for the ideal test instrument. We needed to create a highly specialized test device, reliable and with a good quality-to-price ratio, with the following features:

- Accurate and stable (±1%) injection of current into the control cabinet with accurate control of timing and amplitude.
- Measuring, recording, and viewing of the injected current with a time resolution less than 500 microseconds.
- Measuring, recording and viewing of the closing and opening commands generated by the control cabinet in response to the injected current.
- Fast processing of large amounts of data with a user-friendly display that is easy to understand and analyze.
- Quick recall of stored data for immediate analysis or for later use per the RCM method.
- Finally, the ability to test any existing or future recloser control.

Clearly, a highly integrated instrument, software driven, containing a current injector, an event recorder, and a user-friendly software interface, is needed.

As a starting point we selected the Zensol CBA-32P circuit breaker analyzer and its associated software, CBA Win. Test methods developed for circuit breakers are well-suited to the tests needed for reclosers.

The complete separation of the injection and recording process, and the computer processing the data is very advantageous because it allows us to use existing laptop computers for analysis rather than paying for that feature as part of the recloser test set. Our development effort was thus concentrated only on electronic design and the software interface, taking advantage the impressive power of portable computers. The result of this development effort was the GEN-3/12 as seen in Figure 2.

Figure 2 — Installation of the recloser analyzer, GEN-3/12, on a Cooper recloser with F3A control at a Hydro-Québec substation

Figure 3 shows the waveform of injected current that is very accurately controlled in amplitude and time. The timing is accurate to within 10 microseconds, an accuracy considerably better than required for the application! This waveform is easily designed by the operator in the GEN Win software. One of the principles that we hold dear is to always be able to see the shape, period, and amplitude of the injected current. The goal is to always check what the GEN-3/12 instrument and its software are doing relative to what we ask for. This gives us the information to act accordingly if the instrument or the software are suspect.

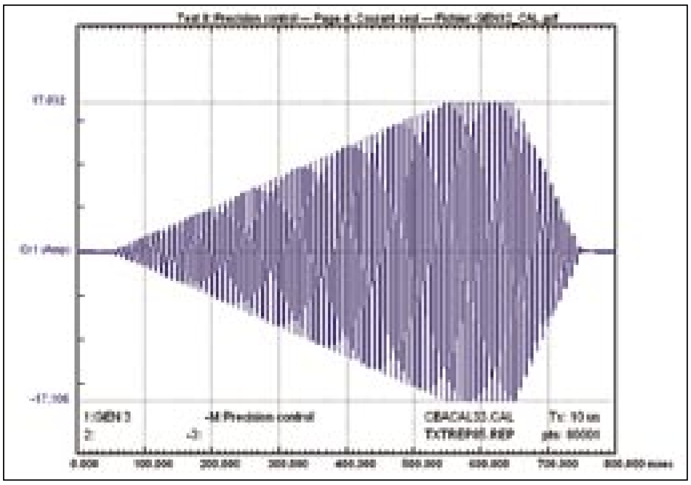

Figure 3 — Example of amplitude control

Figure 4 shows a summary result display that we have favored. Test points of current versus time are plotted on the same graph with protective device TCC and also curves plus and minus 10 percent of the TCC's times. This graph helps the operator make a quick go/no-go diagnosis on the spot. All the points (the crosses on the graph) must be within the plus/minus 10 percent limits of the curve. If not, the operator has uncovered a problem with the recloser.

To achieve this level of analyzing power, we had to integrate the ability to calculate and trace the protection curves already described (recloser, IEEE, and IEC curves) into our software, as defined in the IEEE standard [1].

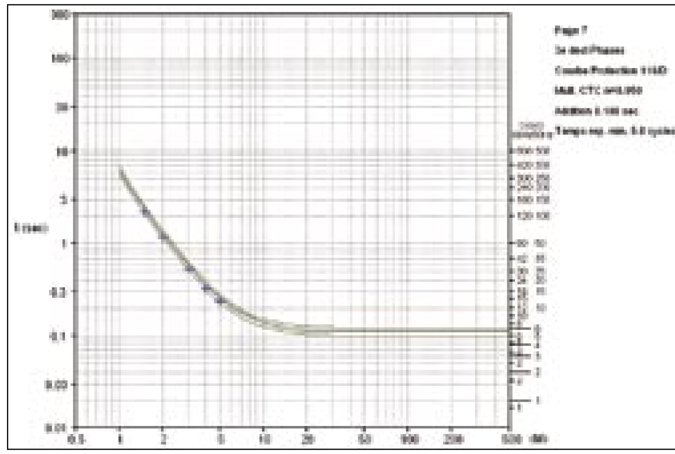

Figure 4 — Example of TCC curve and plotted points

Figure 5 shows the recorded open and reclose command sequence.

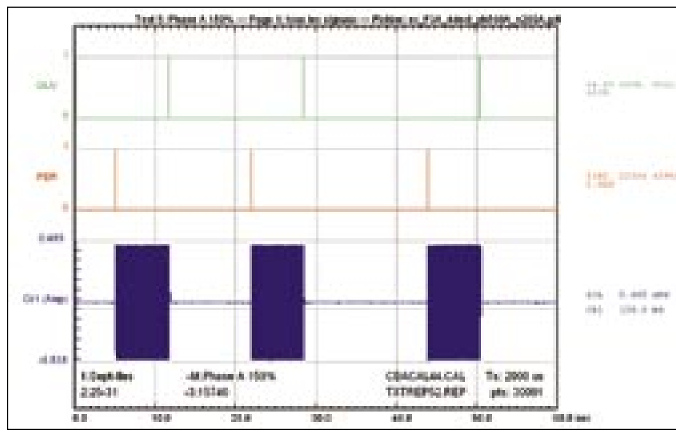

Figure 5 — Sequence of open and close commands

Figure 6 shows one of the many possible tabular reports. The example shown here shows the logical sequence programmed into the control cabinet. The opening and reclosing times are automatically calculated and easily checked using the graphic analysis tools (Figure 7). Moreover, it is the accuracy of this section that will help study the degradation trends in line with the RCM method. Finally, it is possible to recall, at any time, the recorded raw data and to recheck all calculations and the automated processing.

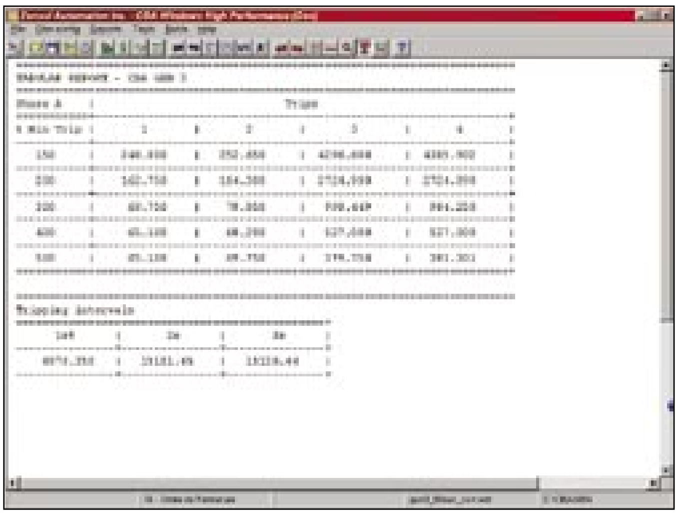

Figure 6 — Typical tabular report

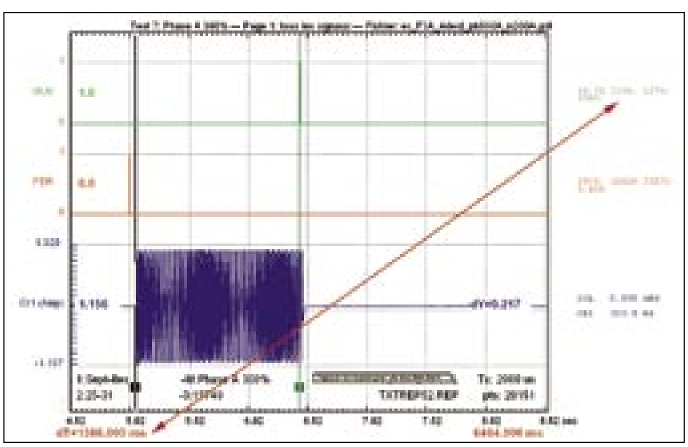

Figure 7 — Using graphic tools to check calculations

Producing an instrument for all types of reclosers caused us to redesign the GEN-3/12 several times. We eventually opted for a single universal connector on the front panel which is used to connect an adaptor specially designed for each type of recloser.

Now, with only a few test reports (fig.4, 5 and 6) the maintenance crew is able to make a reliable diagnostic on the recloser status, consequently reducing expensive downtime.

Bibliography

[1] - ANSI C37.61-1973 and IEEE Std 321-1973

Dr. Fouad Brikci is the president of Zensol Automation Inc. He was the first to introduce the concept of truly-computerized test equipment in the field of circuit breaker analyzers. As a former university teacher in Ecole Polytechnique — Algiers and CNRS - LAAS researcher in France, Dr. Brikci has developed experience in the fields of electronics, automation, and computer science. Most activities were focused on the industrial application of computers. Among his achievements are the development of fully computerized measuring systems for quality control in circuit breaker manufacturing, laboratories, and maintenance services of electric utilities. Dr. Brikci holds a PhD in Electronics and a Master in Sciences in EEA (electronics, electrotechnics, and automation) from the University of Bordeaux, France.

Marc Roussel is a technologist in electrical engineering, specializing in electrodynamics.

Since graduation in 1976, he has worked in the field of production and distribution of electricity. He started his career as team leader and design engineer for transport and distribution transformer stations. Marc has been a technical consultant in the medium-voltage electrical equipment maintenance field for 15 years. He introduced the RCM (reliability centered maintenance) method to Hydro-Quebec maintenance department. He has devised various maintenance techniques for reclosers and voltage regulators, and has created automated systems to respond to the needs of owners of medium-voltage distribution systems.