New Requirements Aiming at the Reusability of Real Time Digital Simulations of Control and Protection System - FURNAS Experience

Victor Alexandre Belo França
Department of Studies and Electrical Planning of Operation
FURNAS CENTRAIS ELÉTRICAS S.A.
Rio de Janeiro, RJ, BRAZIL
vfranca@furnas.com.br

***Abstract* – The electrical system has become much more complex, as a consequence of the increasing use of power electronic devices and the number of coupled systems. Therefore, analysis has also become much more complex and simulation has been playing an important role in this case. During the design and commissioning tests of important control and protection systems, it is common to evaluate their performance using real time simulators running closed loop tests. There were very few real time simulation centers in the past due to the cost of analog technology and because simulators were very specific for each project. The digital technology facilitates for companies to have their own simulator or, due to the flexibility of digital simulators, hire another company to perform tests anytime by modeling the system involved or even using the same case used during the commissioning tests. In order to meet both criteria, the company must order, by the time of purchase, an extra hardware set of the control or protection system. Additionally, access of the simulation case should be negotiated with the supplier.**

The main purpose of this article is to present and discuss the advantages of having the possibility to perform simulation tests even after the commissioning period is over. Simple items included in the purchase order could save costs and make it easier to verify occurrences that demand new simulations to be carried out in the future. The development of this article will be based on FURNAS experience, including practical cases of control and protection systems where the procedures described above were followed.

I. INTRODUCTION

The modern world, due to new technologies, offers humankind conveniences that were not available in the past and that make for the improvement in quality of life. On the other hand, the complexity of the systems involved has increased dramatically. In order to analyze and guarantee the performance of the system, simulation has been widely used.

Particularly, when the focus of the test is the behavior of control and protection systems, real time simulation is the best choice to be used. In this case, the equipment under test interacts with the simulated network creating a closed loop test. Such kind of testing is mostly performed only by the time of the commissioning in the laboratories of the suppliers and under their supervision. Once the equipment is approved, it is fairly to state that its performance complies with the requirements. On the other hand, it is only true under the configurations of the networks and the settings used during the tests. As long as the electrical system is very dynamic, in a near future new elements or topologies could be inserted in the network, creating a new configuration that was not fully covered during the commissioning tests. A solution, in this case, is to have the possibility to run additional evaluations aiming to ensure that performance of the equipment and its effectiveness would not be affected. If the client intends to cover this possibility, it should be negotiated during the purchase process otherwise the costs could increase significantly.

II - REAL TIME TESTS

In the past, these real time simulators, usually known as TNA (Transient Network Analyzer), were based on analog technologies using reduced scale models to represent the electrical system. With the advent of digital technology, real time simulators have become digital and increased in terms of number of installations and capacity of modeling. Besides, simulators have become much more flexible and their price has been decreasing encouraging more and more users. Different from the analog modeling, that uses real components such as capacitors, resistors, inductor and others to represent each component of the network, digital models represent the behavior of the component by using mathematical equations. Real Time Digital Simulators such as RTDS^{TM} [1] are based on special hardware and software elements, creating an environment capable of solving all the mathematical equations of the system and producing results at a rate that could represent the real system, i.e., performing a simulation in real time of the electrical system. The main advantage of real time simulation is the capability of connecting real equipment with the simulated network.

III - FURNAS CENTRAIS ELÉTRICAS

FURNAS [2] is one of the largest power utilities in Brazil. Considering the traditional area where FURNAS is present, the Southeastern and Midwestern regions that together hold 50% of Brazil's population, where 63% of the GDP(Gross National Product) is concentrated and where almost 60% of the Country's energy is consumed, the Company's invoiced energy amounted to 200 TWh. It has an installed generated capacity of 9,458 MW, an installed transformation capacity of 97,007 MVA and a total extension of 19,227 km of transmission lines. It includes 7,247 km of 500 kV lines or above and 1,612 km of 600 kV DC line.

The first experience regarding Real Time Simulation occurred during the project of FURNAS HVDC link that transmits energy from ITAIPU power plant. During the commissioning tests, the real control system was connected to a scale-down analog model of the DC and also AC networks involved. Upon the finalization of the project, FURNAS made a deal with the manufacturer and purchased the simulator. Since then, the HVDC simulator has been used to perform additional performance tests, reproduction of disturbances, training and also to develop new features that could be implemented in the real system. Figure 1 shows FURNAS HVDC control and protection cubicles.

Fig. 1 - FURNAS HVDC control and Protection cubicles

The experience encouraged FURNAS to pursue Real Time Tests and from then on, in deliveries of important control systems, FURNAS included in the purchase order items for performing Real Time Tests, during the commissioning, and delivering an extra hardware set of the real control in order to be connected to its own simulator and perform additional tests in the future. After this procedure, two SVC systems were purchased and the extra hardware set connected to the analog simulator. Additional cases were simulated after commissioning and training for operators was also performed.

The AC system representation of the analog simulator was very limited, due to the fact that it was primarily designed in order to have a good representation of the DC system. This characteristic resulted in a non-detailed representation of the AC system of the AC inverter side of the HVDC link, and also in the AC systems where the SVC controls were connected to. In order to overcome this limitation, in 1996, FURNAS purchase a Real Time Digital Simulator (RTDS™). Since then, the RTDS™ has been used to represent the AC system connected to the inverter bus. Although the main reason for purchasing a Real Time Digital Simulator was the HVDC system, due to its flexibility, it has been used to perform protection system tests. Furthermore, FURNAS has been hired by other companies to perform protection system tests using its RTDS™. Figure 2 shows FURNAS RTDS cubicles

.

Fig. 2 - FURNAS RTDS

IV - PROCEDURES TO ALLOW REUSABILITY OF REAL TIME DIGITAL SIMULATIONS

The main idea of having the possibility of running simulations, after the commissioning tests, is a security policy concerning future demands for new evaluations. If Real Time Simulations were not possible for any reason, off line models could be used. Unless the modeling of the equipment is very accurate, the results may not represent the reality. In order to assure that the results of the simulation will not be affected by the modeling of the equipment, real equipment must be used. Therefore, Real Time Tests must be performed. It should be guaranteed that the equipment being tested and the electrical system modeling, coupled, could represent all the dynamics involved in the process. In most cases, real time tests were performed during the commissioning period, but hardly ever after the delivery of the project. In order to allow for the reusability of Real Time Digital Simulations, some actions should be followed by the time of the BID. The purchase order must include items in order to assure that Real Time Tests performed during the commissioning could be reproduced in the future using the same hardware tested and a standard simulator. The following items will discuss hardware and software items to be included.

V - HARDWARE ITEMS

The purchase order must include at least one extra hardware set, identical to the real equipment to be installed in the plant. The additional hardware set must be mounted in a cubicle if the set is composed of more than one card or needs additional hardware necessary to be interfaced with the simulator. It is more common in control systems where different cards, connected by a bus or communication links, perform different tasks. Most of the current protection systems need only one device (relay) to perform all the tasks. Also, the manufacturer must provide everything necessary to interconnect the hardware with the simulator and allow for the system to be controlled by an operator such as in the plant. Therefore, support equipment such as computers and cables must also be provided, and all the hardware revision must be also implemented in the extra hardware set. Another item that must be considered is that the additional hardware set must be used during the real time commissioning tests. This will certify all the connections and the functionality of the hardware set. It must be taken into account that this extra hardware should not replace the purchase of regular spare parts of the delivery because it is not the primary reason for purchasing it. Conversely, it can be used as a special set of spare parts. It can be considered as “special” because it can replace the whole set of hardware once in an emergency and the problem may be tracked later on. All the items must be clearly expressed in the purchase order in order to avoid any future concern.

VI - SOFTWARE ITEMS

It must be guaranteed that all the software and firmware versions, running in the extra hardware set, have the same version applied in the plant. Therefore, software revisions and upgrades must also be installed in the extra hardware set. Any support software necessary to allow for the simulation to represent the same environment applied in the plant should also be included in the revisions and upgrade processes.

Regarding the simulation case, the data base used, including the network modeling must be provided. It can be used as a starting point for future modeling in order to represent new configurations of the electrical system. Batch mode facilities have been widely used when the simulation demands for a great number of cases. It this case, it can also be included in the negotiation, although it does not impose any limitation for the simulations, it only facilitates them.

VII- FURNAS EXPERIENCE: CONTROL SYSTEMS

The technical evaluation of the voltage profile of the Espirito Santo region in Brazil indicated that the area demanded for a voltage support. The studies indicated that a Static Var Compensator System, installed at the CAMPOS Substation, would be the best cost-effective and technical solution. The Campos SVC provides a fast voltage control in the 345kV busbar following a pre-defined VxI curve. Figure 3 shows the one line simplified diagram of Campos Substation.

Campos SVC system is composed of two thyristor-controlled reactors, four filter capacitor banks and one step-down transformer (345kV/15kV). Each reactor has a nominal reactive power of – 80 MVAr and the total reactive power of the filters is 100 MVAr. As the filter banks are always connected, the range of the SVC is from – 60 to + 100 MVAr.

There are 16 mechanically switched reactive elements – 10 capacitors and 6 reactors - at Campos Substation. The SVC control has a function, named MSRE, which defines a strategy to switch those elements. It has the purpose to keep the TCR elements in a region of operation that assure a supply of dynamic reactive power.

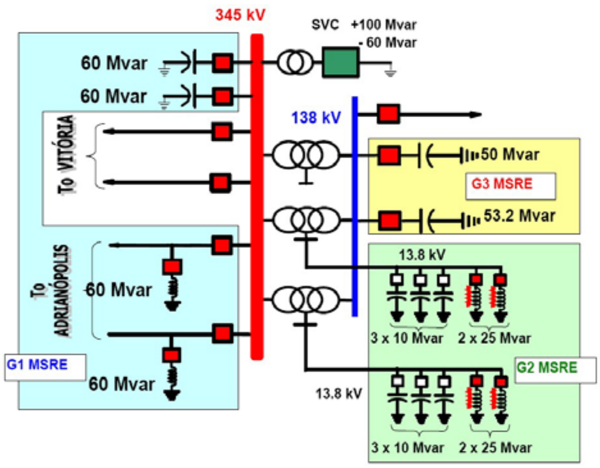

Fig. 3 - Campos Substation Diagram

VIII - CAMPOS’ SVC SPECIFICATION REQUIREMENTS

The acquisition of the Campos SVC was executed through a bid process, as usual for a government company in Brazil. Following FURNAS strategy regarding real-time tests, technical specification included that the factory tests should perform real-time tests of the SVC Control. Besides, the scope of the supply included an extra control, as well as any additional hardware necessary to connect it to the FURNAS RTDS Simulator.

IX - FACTORY REAL TIME TESTS AT RTDS TECH

The electrical systems were modeled in an RTDS simulator and the tests were performed at RTDS Tech laboratory in Winnipeg, CA. The evaluation was carried out by the RTDS Tech staff together with the manufacturer staff. FURNAS representants from different areas such as simulation, engineering and operation took part in the test as observers.

The results indicated that some final adjustments, mainly in the MSRE logic, should be necessary. These modifications demanded for a new evaluation of the behavior of the SVC control system. In the meantime, while the modifications were being implemented, the manufacturer purchased an RTDS and carried out the complementary test in its own simulator.

X - COMMISSIONING OF THE SVC CONTROL AT FURNAS LABORATORY

The real-time tests at FURNAS had the purpose to set up the Campos SVC control system ready for RTDS studies and to verify its overall performance [3]. The tests were performed at FURNAS Simulator in Rio de Janeiro.

For this study, the power system represented in the previous test was updated considering the network configuration for the year 2005.
Figure 4 shows the modifications implemented by FURNAS concerning the original system modeled. The color elements indicate the elements included in the modeling.

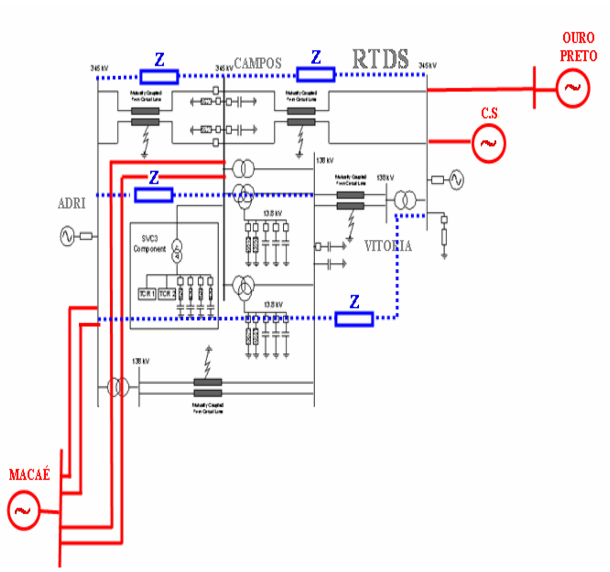

Fig. 4 – System Modeled for the Commissioning Tests

After the tests, the extra hardware set from SVC control has been used for any additional evaluation, when its characteristics of voltage regulation are important in the electrical system area being analyzed.
It must be emphasized that the presence of a simulator expert, during the commissioning tests, contributed in a positive way to help the conversion of the RTDS case to fit with FURNAS RTDS hardware configuration and also in the electrical system updated in the simulation.

X -FURNAS EXPERIENCE: PROTECTION SYSTEMS

FURNAS protection system of the 765kV transmission system, constituted by three transmission lines with three circuits each, passed through a retrofit process. An item concerning real time tests was included in the purchase order. The real time tests took longer them presumed and the time scheduled, in the manufacturer RTDS laboratory, were enough to test only two of the three protection systems.
It was decided that the remaining transmission line protection (Itaberá-Tijuco Preto) would be tested in FURNAS RTDS laboratory. At the first time, the manufacturer refused to make the simulation data base and the script file, necessary to run the cases in a batch mode, available but consent in the end. With the simulation case available, the first step was to convert it in order to fit FURNAS RTDS hardware configuration and then prepare the case for the last transmission line to be tested. Figure 4 shows a diagram indicating the points of fault applied. It took some time to understand the logic of testing implemented by the manufacture in order to perform the cases in a batch mode. This task would have been easier if a simulation expert had participated in the previous test. The main idea was to repeat the same test procedure used in the other transmission lines, but additional tests were applied and FURNAS own script file, used to generate reports from the case, were also used. Figure 5 shows the faults applied during the evaluation.

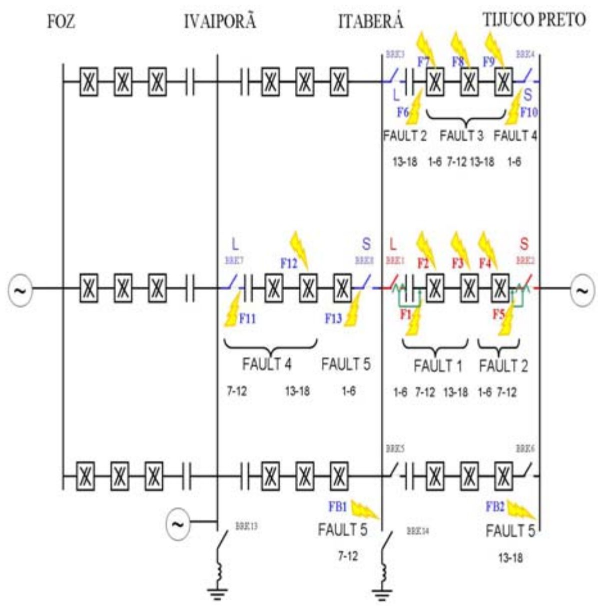

Fig. 5 – Faults Applied at FURNAS Laboratory

It can be pointed that in terms of learning the protection behavior, the tests performed at FURNAS laboratory were much more worthwhile because the operator had the chance to perform the settings on the relay and evaluate its results by himself.

XI- CONCLUSIONS

Simple items included in the bid to allow for the reusability of real time tests would not have a great impact on the final cost of the project but could prevent many problems and provide cost-effective results in the future. It doesn’t matter whether the company has or not a simulator at the time of the purchase; the simple inclusion of the items could generate benefits in the future if a situation demands for new simulations. All the items described should be included and discussed by the time of the purchase order, otherwise costs could increase significantly in case of negotiating those items after the final delivery of the project as supplement.
The acquisition of an extra hardware set, mainly in control systems, could be very useful if used for additional simulation tests, training and even as an emergency spare set.

XII. ACKNOWLEDGMENT

The author would like to remind that the experience shared in this paper is a result of several years of work of a simulator team from FURNAS staff.

XIII. REFERENCES

[1] Kuffel, R., et.al., “RTDS - A fully digital power system simulator operating in real-time”, Proc. of the ICDS 95, College Station, Texas, USA, April 1995, pp. 19-24

[2] FURNAS’ Statistical Annual Report 2006 – Year 2005”, available at“http://www.furnas.com.br/hotsites/anuario2006/index2.html”

[3] Nokian Capacitors and VA Tech, “Campos SVC Mini Simulator Commissioning Program”, version 1.0, March 2004

[4] França, V.A.B, “The FURNAS’ Experience on Real Time Simulation”, Proc. of the IX SEPOPE, Rio de Janeiro, BRAZIL, May 23-27, 2004

[5] França,V.A.B,et.al., “FURNAS Strategy Regarding Real-Time Tests: A Practical Case – Campos Static VAr Compensator”, Proc. of the WMSCI 2005, Orlando, Florida,USA, July2005

[6] McLaren, P.G, et al,“A Real Time Digital Simulator for Testing Relays”, IEEE Paper No 915M319 – pwrd, Summer Meting San Diego, July 1991

[7] França, V.A.B, “Utilização de Simulador Digital em Tempo Real na Execução de Testes de Proteção de Ondas Trafegantes” – XV SNPTEE, Foz do Iguaçu,PR, Brazil, Oct 1999 (in portuguese)

[8] Santo, S.E., et al, “Testing a FURNAS Protection System using the RTDS™ Batch Mode Facility” – Proceedings of the 2001 International Power System Transients, June 24-28, Rio de Janeiro, Brazil