Fully Digital Real-Time Simulation of Large EHV Transmission Systems for Control and Protective System Studies and Testing

by Bahram Khodabakhchian,TransÉnergie Technologies, Louis-A. Dessaint, Michel Lavoie, École de technologie supérieure,

Abstract

Real-time simulation of large AC/DC EHV transmission systems have been until now realized on costly and more-or-less-flexible hybrid simulators which offer some advantages in producing continuous real currents and voltages. Fully digital power system simulators used until now in limited scaled real-time simulations, have reached maturity due particularly to the development of high performance parallel computers. Recent real-time simulations of the Hydro-Québec main 735 kV transmission system with a time-step of 56 µs realized on a 30 processors parallel machine witness the sound applications of such technology in real-time control and protective systems testing of large transmission systems.

Sommaire

La simulation en temps réel de grands réseaux électriques de transport CA/CC à très haute tension a été réalisée jusqu'à maintenant à l'aide de simulateurs hybrides coûteux et relativement peu flexibles. Les simulateurs hybrides offrent néanmoins des avantages quant à leur capacité de produire des tensions et des courants réels. Par ailleurs, les simulateurs entièrement numériques relégués jusqu'à tout récemment à l'étude de réseaux électriques de taille relativement modeste, ont désormais acquis leur pleine maturité grâce à de nouvelles plates-formes basées sur des ordinateurs parallèles. Des simulations récentes du réseau de transport de 735 kV d'Hydro-Québec sur un ordinateur parallèle de 30 nœuds de calcul en utilisant un pas de calcul de 56 µs confirment la viabilité et la précision de cette nouvelle technologie pour la conception des systèmes de commande et de protection.

1.0 Introduction

Traditional power system simulators were assembled from purely analog miniature components for modeling transmission lines, transformers and loads. Hydro-Québec and more specifically IREQ are very well known for their contribution in building and operating one of the largest analog real-time simulator in the world. In the late 80's, computer processing power transformed the analog simulator to an hybrid (analog/digital) one in which fully digital synchronous machine models running on DSP's were interfaced to the rest through D/A conversions. In 1996, IREQ developed Hypersim, a fully digital power system simulator which compare to the hybrid version offers advantages such as compactness, flexibility and scalability. As of today, Hypersim runs on two different platforms: an in-house design based on 533 MHz Alpha processors and a general purpose high-performance parallel machine made by Silicon Graphics.

École de technologie supérieure, an engineering university located in Montreal, bought a 15 nodes in-house version of Hypersim with grants from the Canadian foundation for innovation, the Ministère de l'Éducation du Québec and TEQSIM International. As a result, IREQ, TransÉnergie Technologies and ÉTS recently teamed up to assemble a 30 nodes in-house version of Hypersim still considered to be the most powerful fully digital real-time power network simulator ever devised. The aim of this paper is to describe the large simulated network and some of the real-time simulation results.

2.0 Description of the simulated network

The Hydro-Québec network, one of the largest in North-America consists mainly of over 35000 MW remote hydraulic generation transmitted over 1000 km by eleven 735 kV transmission lines to two major load centers, Montreal and Quebec cities. Steady-state and transient stabilities of such a vast system are insured by the use of dynamic shunt compensation (synchronous and static compensators) and MOV protected series compensation. The actual transmission system simulated on Hypersim, corresponds to a realistic summer load-flow with simplifications in terms of regrouping some generation stations and sub-transmission lines and loads. This network contains:

- 6 hydraulic generators with full controls (exciter, speed regulator, turbine and stabilizer);
- 4 synchronous compensators with full excitation system;
- 5 static compensators (1 TCR and 4 TSC branches) with detailed internal controls;
- 20 saturable 2 or 3 windings transformers;
- 40 series-compensated transmission lines;
- 3 dynamic loads (transient stability type with adjustable load coefficients);
- 5 MOV for series capacitor over voltage protection;
- 1 gap and by-pass breaker with controls for MOV energy absorption protection.

Figure 1: 30 nodes digital real time simulator

Out of the 30 nodes assembled (Fig. 1), 28 nodes were used by the automatic task mapper to distribute different computing tasks of the simulated network with a time-step of 56 µs. It is also worthy to mention that some of the nodes were also equipped with I/O boards (16 D/A and 16 A/D) for the purpose of both analog and digital acquisitions.

3.0 Typical simulation results

Many different perturbation scenarios and statistical faults were applied on the system over a period of a week for various purposes such as testing the acquisition and I/O systems, long term numerical stability (over 72 hours) etc., and satisfactory results were obtained. Figures 2a and 2b shows a typical digital acquisition of nearby machine and SVC signals during a 3 ph-g, 6 cycles fault at LG2 735 kV busbar. The machine dynamics and SVC behavior are well

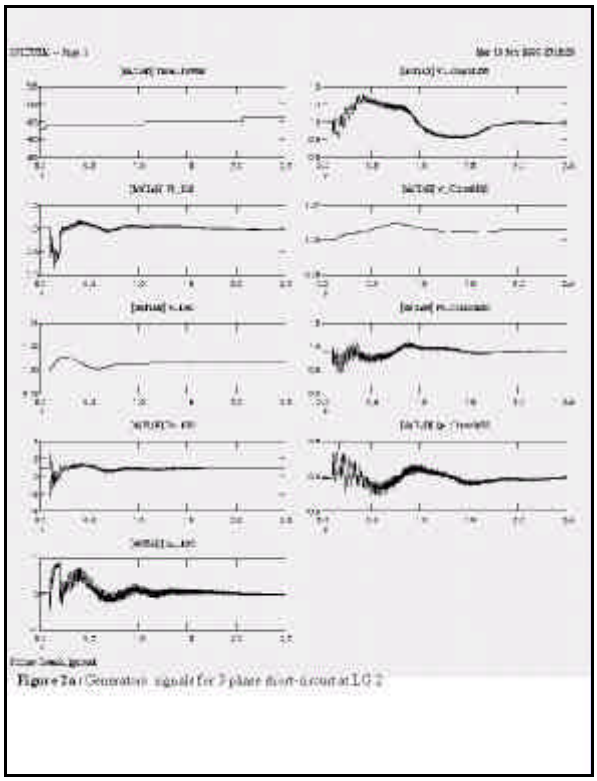

Figure 2a: Generator signals for 3 phase short-circuit at LG 2

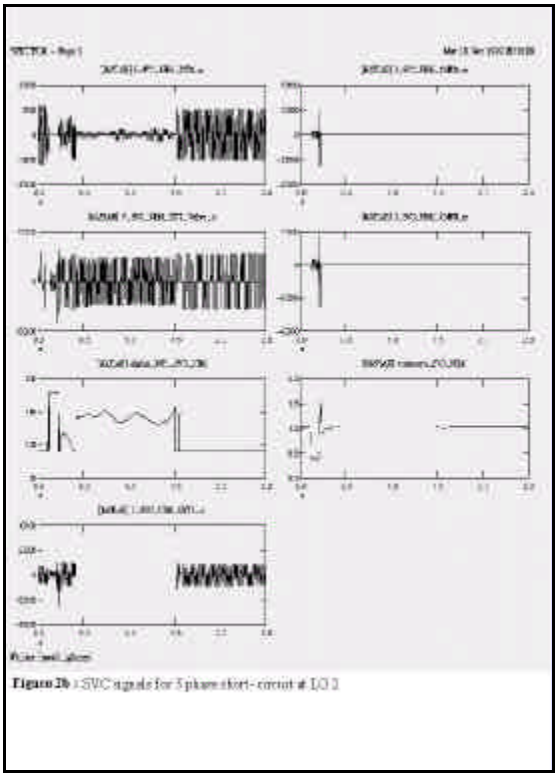

Figure 2b: SVC signals for 3 phase short-circuit at LG 2

within the expected range of variations. A full validation of the transient behavior is currently under way with EMTP and will be published in a later paper. Figure 3 focuses on the aspect of the comparison between digital and analog acquisitions of the TCR valve voltage of the SVC. Again the results show very good agreement in term of frequency bandwidth and time delay (less than 1,5 time-step or 85 µs).

4.0 Conclusion

High performance fully digital real-time simulation of a large EHV transmission system has been demonstrated on a Hypersim 30 processors simulator. Tests and simulation runs showed that the Hypersim technology is mature enough to be used cost-effectively in large scaled real-time simulations taking into account full machine dynamics and a more detailed power system representation. As a result, large fully digital real-time simulators now allow for very realistic control and protective system studies and testing.

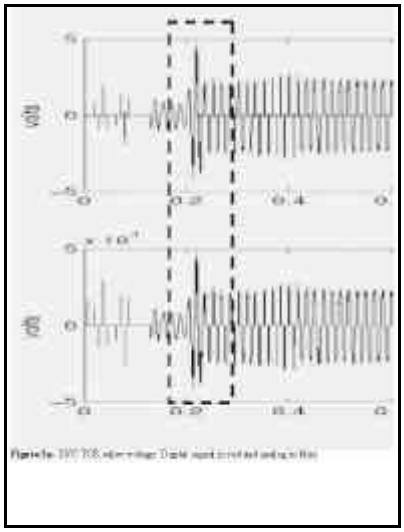

Figure 3a: SVC TCR valve voltage. Digital signal above and analog signal below.

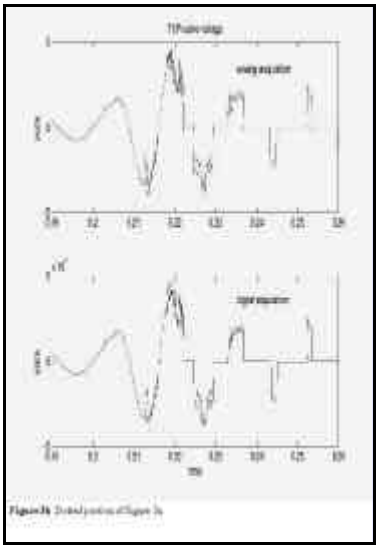

Figure 3b: Dotted portion of figure 3a

About the Authors

Bahram Khodabakhchian holds BS and MS degrees in electrical engineering from École Polytechnique de Montréal. He has over 18 years of experience in power system studies and real-time simulations. He is currently a Product Manager at TransEnergie Technologies which commercializes Hydro-Québec simulation technologies.

Louis-A. Dessaint is currently Professor in Electrical Engineering at the École de Technologie Supérieure, Montréal, P.Q., Canada and Director of GREPCI a research group on power electronics and digital control. He is an author of the MathWorks "Power System" Blockset and in 1997, received the "Outstanding Engineer Award" from IEEE-Canada.

Michel Lavoie is currently a Professor of Electrical Engineering at the École de Technologie Supérieure, Montréal, P.Q., Canada. He is a member of IEEE, and of the Ordre des Ingénieurs du Québec.