Verification of Hybrid Real Time HVDC Simulator in Cheju-Haenam HVDC System

Byeong-Mo Yang† , Chan-Ki Kim*, Gil-Jo Jung and Young-Hyun Moon*****

Abstract - In this paper a Hybrid Real Time HVDC Simulator for both operator Training and Researching in the Cheju-Haenam HVDC System is proposed and its performance is studied by means of RTDS (Real Time Digital Simulator), EMTDC (Electro-Magnetic Transients system for DC), PSS/E (Power System Simulator for Engineering), and experienced scenarios. The objective of this paper is to represent the strategy in development for KEPCO's hybrid HVDC simulator for the Cheju-Haenam HVDC system. This simulator consists of two DC stations, DC cables, external digital/analog controllers, monitoring systems and control desk for education, and AC networks. Its suitability for operator's education is tested during startup/shutdown and normal state operations. Dynamic performances of it are also verified.

Keywords: Hybrid real time HVDC simulator, Cheju-Haenam HVDC system, RTDS

1. Introduction

The 180kV 300MW HVDC System of the Korea Electric Power Corporation (KEPCO), completed in 1988, conveys relatively cheap electric power by undersea 100 km dc cables from Haenam to Cheju C/S in Jeju Island. This 12 pulse bipolar system normally conveys 150 MW, which corresponded to 40% of the total load demand of Jeju Island. The HVDC system basically adopts inverter operation at Jeju in which current control is used as the main control and average gamma control is used as the secondary control. At Haenam, where rectifier operation is adopted, voltage control is used as the main control and current control is used as the secondary control. Fig. 1 presents the control scheme of the HVDC system[1].

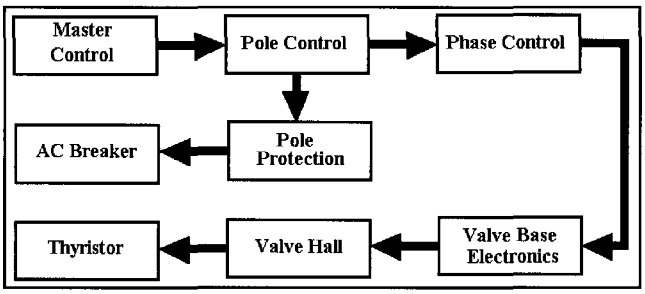

Fig. 1 Cheju-Haenam HVDC System Control Diagram

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Received August 3, 2005 ; Accepted September 12, 2005

Faults in the Cheju-Haenam HVDC System could be caused by the disturbances of the AC network, the ageing and self-malfunction of the DC system, and operator error. These HVDC faults cause serious effects on the stable power delivery in Jeju Island. Particularly, the prevention of operator's mistakes and system upgrades needs to be simulated by means of a reliable real time simulator. A fully digital, electromagnetic transient class of power systems simulator capable of continuous real time operation has been developed at the Manitoba HVDC Research Centre. Some studies were investigated expanding and enhancing the capabilities of a traditional analogue simulator using a real time Digital Simulator[2].

The main objective of this paper is to represent the strategy in development of the KEPCO Hybrid HVDC Simulator for the Cheju-Haenam HVDC system.

High powered semiconductor devices have revolutionized industrial equipments. Recently, more effective and flexible configuration and operation of power systems with semiconductor devices has made it possible to control transmission line power flow, resulting in electric energy increase to consumers.

2. Development of HVDC simulator

2.1 The Model and Development Approach

The approach taken usually depends on the simulation tool used and how the model is going to be utilized. The actual HVDC controls are partly digital and partly analog (OpAmps, Transistors, Resistors and Capacitors). At the outset, it was decided that both the controls & the protections and the control desk were going to be made exactly identical to the actual system in order to accurately represent its analog and digital behavior. Furthermore, the AC and DC network was determined to be modeled by RTDS (Real Time Digital Simulator) just as in the case of the actual system to represent its cables, filters, smoothing reactors, converter transformers, current source converters, ac networks including generators, transmission lines and load, etc.[3-4].

The manufacturing, modeling, testing and interconnecting of these are a significant task. Another requirement was also to confirm the dynamic performances, startups, and normal states by means of the comparison of both off-line simulation (EMTDC, PSS/E) and real field data in the Cheju-Haenam HVDC System.

2.2 Simulation Speed

Our goal was to be able to simulate the 12 pulse, bipolar HVDC System (both rectifier and inverter) with cable and sufficiently detailed AC system at both converter buses. With a detailed control system representation, the simulation case will be very large and very slow to operate. Normal HVDC simulations last for 1 or 2 seconds. Since we had plans for using the simulation for AC faults, testing relay settings, and etc, the length of our simulation could be in minutes. Hence, we used the verified RTDS (Real Time Digital Simulator) for a reliable real time simulation in the HVDC System.

2.3 Simulator Interconnection

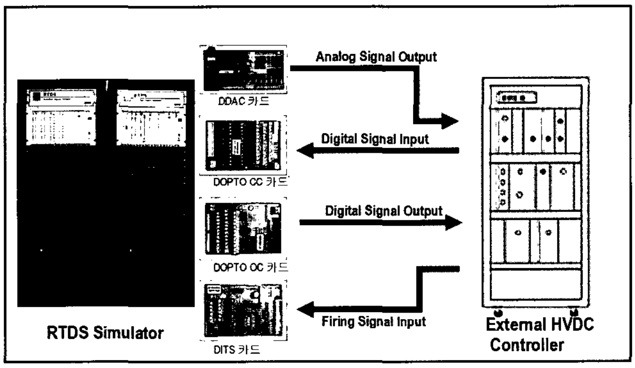

Fig. 2 Hardware Interconnection of Hybrid HVDC Simulator

The objectives of this simulator are both operator training and researching and it has a real time operation system in order to be operated exactly as done in the actual system.

Fig. 2 and Fig. 3 represent AC/DC interfaces of a Hybrid HVDC Simulator. They have 95 channels (mainland 48 channels, island 47 channels) of analog signal outputs, which cover from RTDC to the External HVDC Controller. Their contents are as follows.

- Line Winding Voltage
- Line Winding Current
- Valve Winding Current (Y-Connected & D-Connected)
- Synchronous Compensator Power & Frequency
- Pole DC Voltage
- Neutral DC Voltage
- Electrode Line Voltage
- Pole DC Current
- Neutral DC Current
- Electrode DC Current

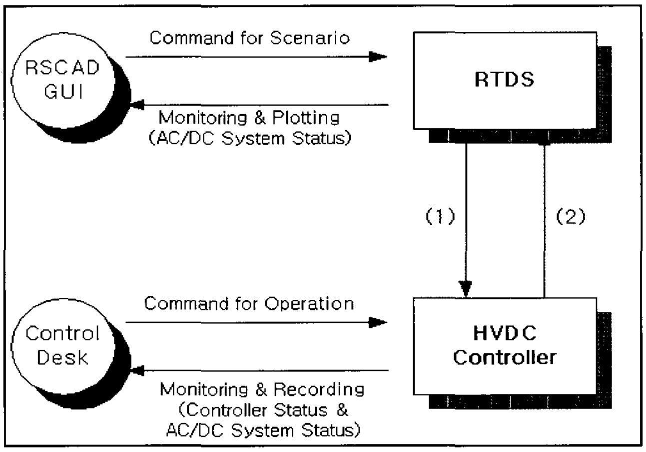

Fig. 3 Software Interconnection of Hybrid HVDC Simulator

In addition, it has 21 channels (mainland 10 channels, island 11 channels) of digital signal inputs, which cover from the External HVDC Controller to RTDS. Their contents are as follows.

- 12 Pulse Firing Pulses Per Pole
- Tap Up/Down Signal
- Switched Filter Bank
- AC/DC Switch

3 Verification of HVDC simulator

3.1 Hybrid HVDC Simulation Setup

The Hybrid real-time simulator was applied to dynamic testing, normal state operating, and startup/shutdown operating in the Cheju-Haenam HVDC System.

Fig. 4 shows a one-line diagram of the Hybrid HVDC system, and consists of detailed AC networks (including generators, ac transmission line, load, etc., in Fig. 5), current source converters, converter transformer, smoothing reactor, shunt capacitor, double-tuned filter, synchronous condenser. DC cable. and so on.

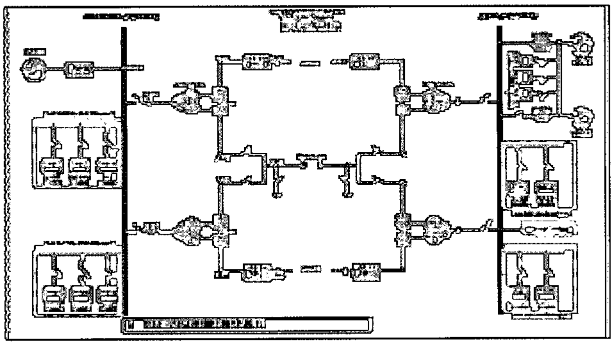

Fig. 4 One-Line Diagram of Hybrid HVDC Simulator

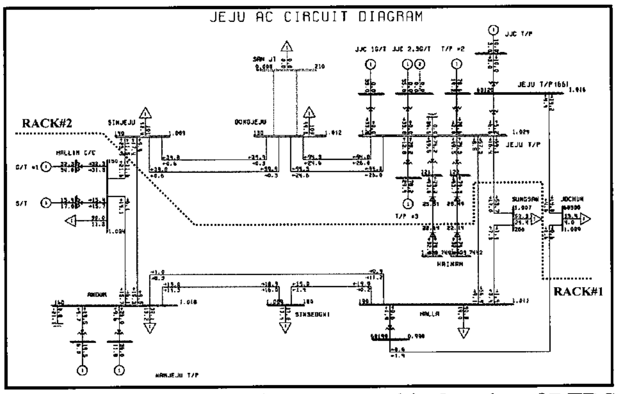

Fig. 5 Cheju AC network represented in 2 racks of RTDS

Fig. 6 illustrates the setup and the simulator consists of RTDS, External HVDC Controller (Digital + Analog), Monitoring System, and Control Desk.

Table 1 Hybrid HVDC Simulator Signal Flow

	From	To	Signals
1	PCCS(H)	Analog(H)	I Order, V Order, Gamma Disable
2	Analog(H)	RTDS(H)	Firing Pulses
3	Analog(J)	RTDS(J)	Firing Pulses
4	PCCS(J)	Analog(J)	I Order, V Order, Gamma Disable
5	Maste(J)	Master(H)	Remote Start/Shutdown
6	Analog(H)	PCCS(H)	AC Network Data
7	RTDS(H)	Analog(H)	AC Network Data
8	RTDS(J)	Analog(J)	AC Network Data
9	Analog(J)	PCCS(J)	AC Network Data
10	Master(H)	PCCS(H)	Block/Delock Command
11	Master(J)	PCCS(J)	Block/Delock Command, I/P/F Command
12	PCCS(J)	Control Desk	Monitor Values
13	Control Desk	Master(J)	Start/Shutdown, Mode Selection
14	Master(J)	Control Desk	Lamp Indication
15	Analog(J)	Monitoring	SER, DTR Data
16	PCCS(J)	Monitoring	SER Data (Alarm), MPM
17	Master(J)	Monitoring	SER Data (Service State, Filter)
18	Master(H)	RTDS(H)	Filter Control
19	PCCS(H)	RTDS(H)	Tapup/Tapdown
20	PCCS(J)	RTDS(J)	Tapup/Tapdown
21	Master(J)	RTDS(J)	Filter Control

* H: Haenam, J: Cheju

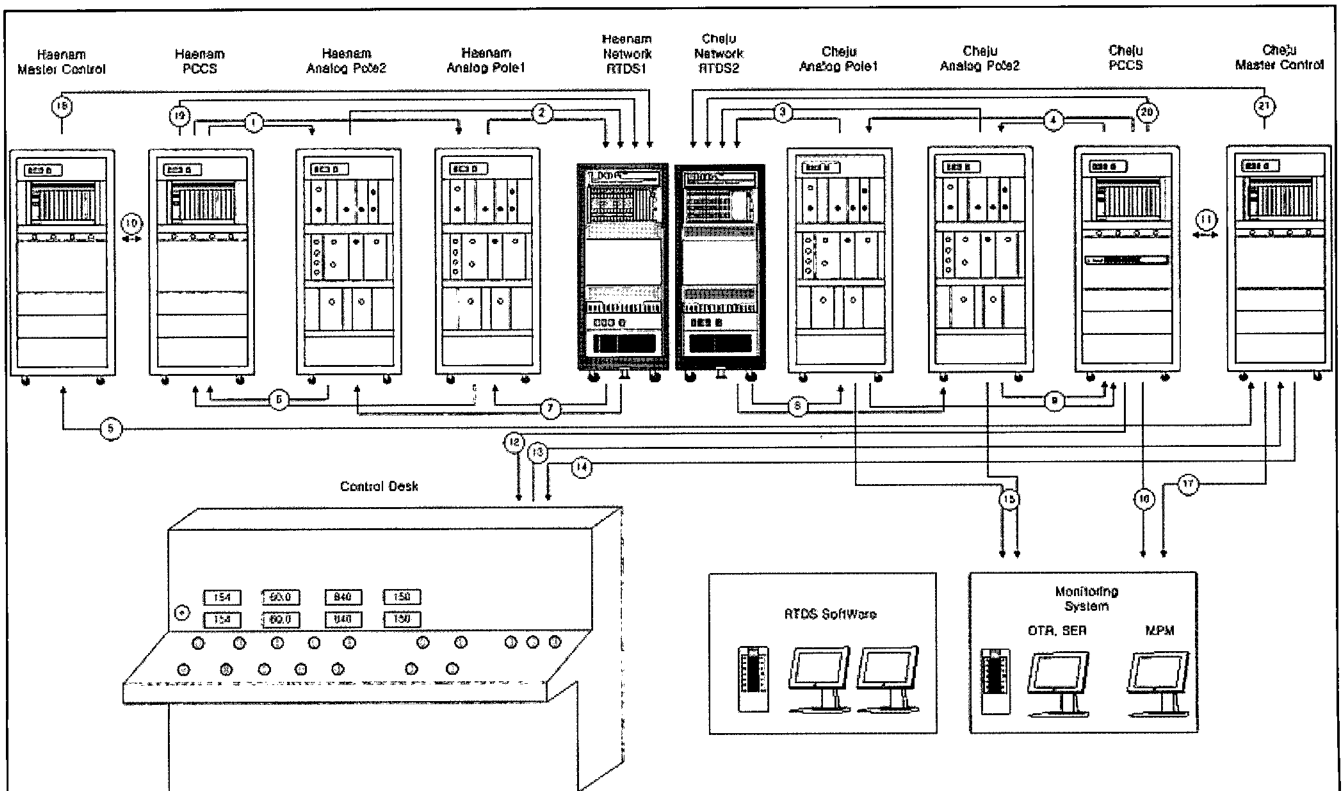

Fig. 6 KEPCO Real Time Hybrid HVDC Simulator Configuration

2 racks of RTDSs represent AC Networks and DC stations. Each RTDS has 2 WIFs, 20 3PC cards, 2 RPCs for network solution, 2 IRCs for RACK communication (mainland and island), 2 3PC - DOPTO pairs, 8 DDAC cards for analogue outputs, and 4 DITS cards for firing pulses from the physical controller.

External Digital Controllers have a Digital Input Module, Digital Output Module, 32bit CPU, VME32 Standard, RAM 128Kbyte, DPRAM 2kbyte, and real time Vxworks Operating System using VMEbus.

The Monitoring System for operator training is equipped with a MPM (Master and Pole Monitor), SER (Sequence Event Recorder), and DTR (Digital Transient Recorder).

3.2 Verification of HVDC Simulator

The dynamic response of the HVDC system and associated AC network systems, during and after operational changes and systems faults has to be tested and recorded. The following criteria have been verified in the Hybrid real time HVDC simulator[5, 6].

3.2.1 First Step: Verification of AC Network

- Acquire Real Field Data from SCADA.
- Write reliable PSS/E data and verify PSS/E simulation in comparison with SCADA data.
- Confirm modeling of hybrid real time HVDC simulator in comparison with PSS/E. (Fig. 7): in case of 3 phase fault occurring in the Dong-Jeju 154kV Line during 3 cycles.

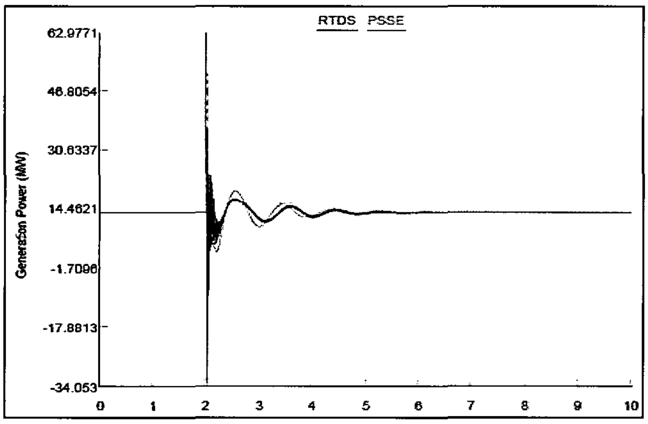

Fig. 7 Verification of RTDS AC Network Characteristics in Comparison with PSS/E (red: PSS/E, black: hybrid HVDC simulator)

3.2.2 Second Step: Verification of Bi-pole HVDC System

- Make models of Hybrid Real Time HVDC Simulator except for HVDC controller[7-9].
- Make simplified Hybrid Real Time HVDC simulator model represented external HVDC controller.
- Confirm modeling of RTDS in hybrid real time HVDC simulator in comparison with EMTDC (Fig. 8): in case of 3 phase fault occurring in the inverter side during 3 cycles.

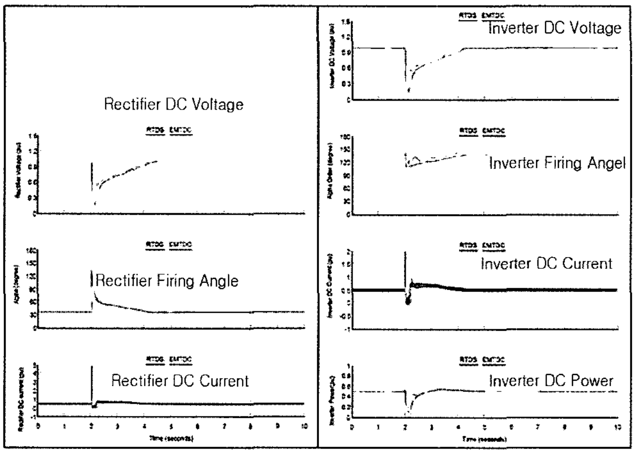

Fig. 8 Verification of HVDC Controller Characteristics in Comparison with EMTDC (red: EMTDC, black: simulator)

3.2.3 Third Step: Integration for RTDS, External Digital Controllers, and External Analog Control & Protection Cards[8].

- Confirm interaction of RTDS/External Controller interface (Fig. 9): in case of 3 phase fault occurring in the inverter side during 3 cycles, the frequency is stabilized after 3 seconds without load shedding.
- Verify Hybrid Real Time HVDC Simulator in comparison with experienced scenarios (Fig. 10): in case of 50% load rejection in the Cheju AC system, the frequency is stabilized after 30 seconds without load shedding.

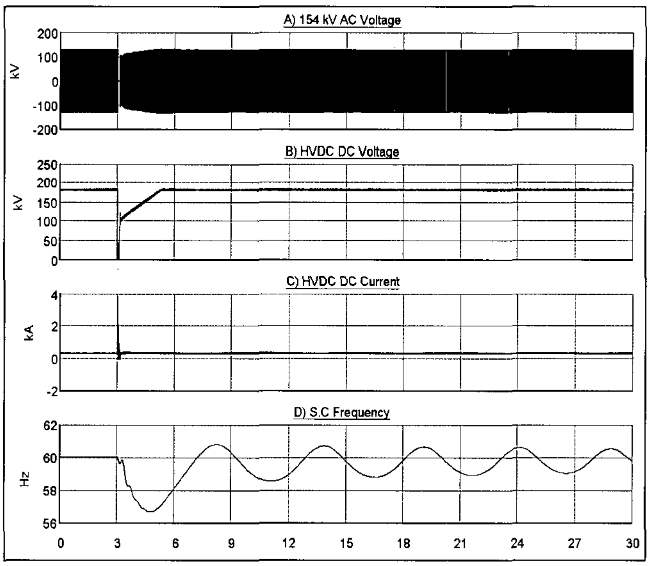

Fig. 9 Three Phase Fault in Cheju AC System

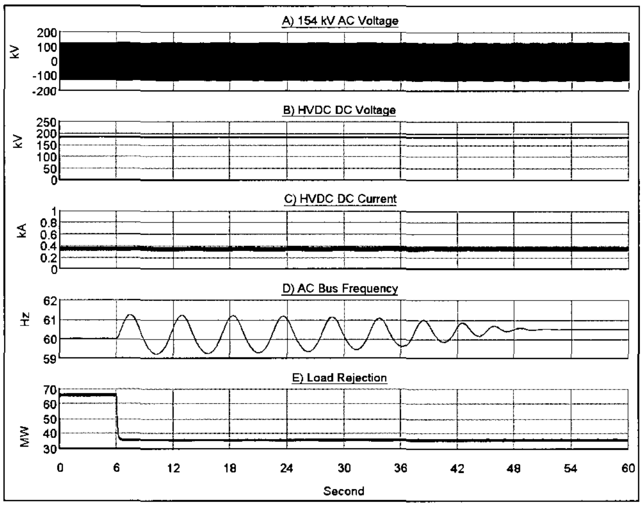

Fig. 10 Load Rejection in Cheju AC System

4. Conclusion

The application of RTDS for a fully digital and external controller composed of both digital and analog systems opens simulation capacities in a variety of power system areas. For high accuracy firing and complete AC/DC system interaction dynamic testing of the HVDC, an optimal method is to use the Advanced Hybrid Real Time HVDC Simulator. It is also highly suitable for both operator's training and researching.

In verification of the Cheju-Haenam HVDC System's control and protection, the Advanced Hybrid Real Time HVDC Simulator exhibits accuracy and reliability. Its performance has been verified compared with EMTDC, PSS/E, and experienced operating scenarios.

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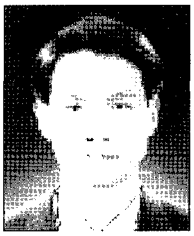

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