§25. Dynamic Simulation System for Cryogenic Plant

Maekawa, R., Ooba, K., Ando, K.*, Nobutoki, M.*, Nakashima, T.*, Iimura, K.*, Ohmura, K.**, Mito, T.

*Nippon Sanso Co.
**Omega Simulation Co.

A dynamic simulation system for a cryogenic plant has been developed in NIFS as a part of collaboration with industries. The development program was lunched to perform optimization, to increase safety and to train operators. Further, the system is utilized to validate advanced control algorithms and sequence programs, and potential to use for a new process design and analysis. Fundamental design concept of the simulator was based on LHD cryogenic control system.

The hardware architectures for the simulation system (see Fig. 1) include: a simulation computer, operating console, work stations and VME. Dynamic simulation model for the helium refrigerator is developed in PC with Visual Modeler™ (VM) that has been used primarily for simulating petrochemicals, petroleum refining and utility boiler plants.

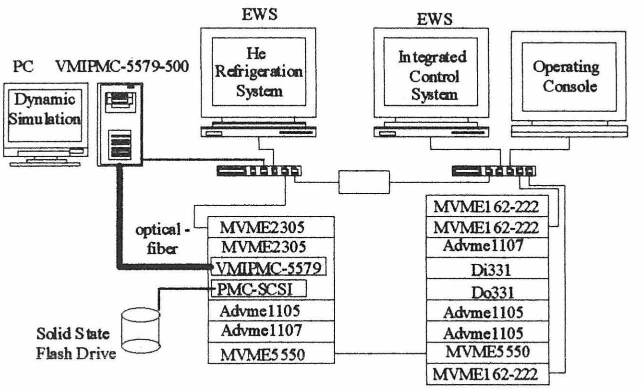

Fig. 1. Schematic of simulation system.

Bryton cycle refrigerator (see Fig. 2) is used to confirm the system fidelity, which consists of three heat exchangers, two expansion turbines with brake valves, an electric heater and a control valve. To control refrigeration process, feed back programs and sequence programs were implemented to VME with EWS and dynamic simulation was performed during cooldown and steady-state conditions, using automatic sequence program.

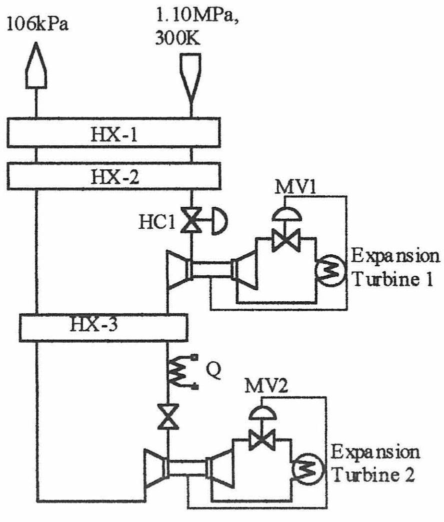

Fig. 2. P&I diagram for the simulation.

Execution of dynamic simulation was conducted based on the refrigerator operation and the sequence program. Expansion turbine (ET) speeds were controlled by brake valves as shown in MV1 and MV2. The system was operated until the inlet temperature of ET2 became 50 K, at this point, HC1 was opened to 88% and expansion turbine speeds were set at ET1 = ET2 = 3900 rps. In addition to that, the heater was ramped up to 280 W (see Fig. 3) at the inlet of ET2. Finally, the inlet pressure of refrigerator increased from 1.10 MPa to 1.40 MPa and heater power to Q = 400 W (see Fig. 3) for steady state operation. The dynamic simulation was well performed, using sequence programs. PID loop controls for ET1&ET2 were necessary during the operation, with PID parameter adjustment from operating console. The error bars are used to see the validity of simulation, and comparison shows within 10% agreements. The dynamic simulation system demonstrated successful operation with operating console, and its simulation program.

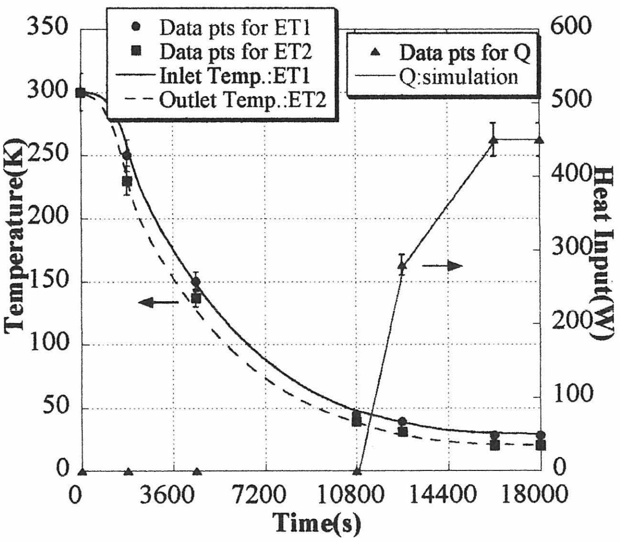

Fig. 3. Simulation results compared with experimental results in solid circles, squares and heat input Q.

Cryogenic simulation system has been developed not only to study process performance of helium refrigerator/liquefier but also to train operator. Validity of simulator is confirmed, using Bryton cycle refrigerator to evaluate the accuracy of process dynamics. Dynamic simulation results are compared with operation results and showed within ±5% agreements. Consequently, the system showed the dynamic simulation can be done as operating a real helium refrigerator. Now, the goal of simulator is modeling helium refrigerator/liquefier for LHD. Since the system utilized open system, the dynamic simulation model for the superconducting coil system is also implemented in the next step.