§3. LHD-Cryogenic Control System (TESS) for Emergency Operation

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LHD-TESS (TEion Seigyo System), utilizes the "open system", is designed to have high reliability and availability since the control system failure may result in significant damage and/or loss to the LHD operation. Spatial redundancy masks any error from programing as well as failed components in terms of automatic switch over. However, the system has to take into accounts of some emergency situations such as, magnet quench, power outage. These events are inevitable so that the sequence programs has to minimize any damage to the apparatus. Sequence programs against these failures are developed and implemented to the each subsystem.

I. Coil Quench

Even though the superconducting coils are designed to satisfy fully cryostable conditions, the coils may quench because of training or some other transient disturbances. Cryogenic system has to be protected in the case of quench, which results in high-pressure generation due to Joule heating and/or AC losses. Heat generation rates are depending on the transport current to the magnets. Sequence programs are considered based upon the transport current to each superconducting coil.

Fig. 1 shows a flow chart for the case of quench. According to the Fig. 1, LHD-TESS receives 1 Q digital signal from the main control room, the integrated controller send discharge sequence flags to subsystems. The fundamental design concept is fairly simple. Superconducting coils are isolated from helium refrigerator/liquefier and any pressure increase due to discharge within the coil is relieved through relief valves. Otherwise, the helium refrigerator/liquefier operation is failed due to compressor trip and/or turbine trip. The former situation is primarily caused by the large quantity of gaseous helium return from the helical coil. The later situation is associated with supercritical helium pressure increase within the poloidal coils.

To avoid turbine failure, poloidal coils are also isolated in terms of bypath line for the supercritical helium. Since the outlet of turbine #6 and #7 are directly connected to the coils. Therefore, inlet and outlet valves for poloidal coil system are closed with 15 min. ramp speed. A bypath valve is opened simultaneously as inlet/outlet valves. These operations protect any failure for the turbines. Any pressure instability associated with bypath line operation has to be controlled by the operators.

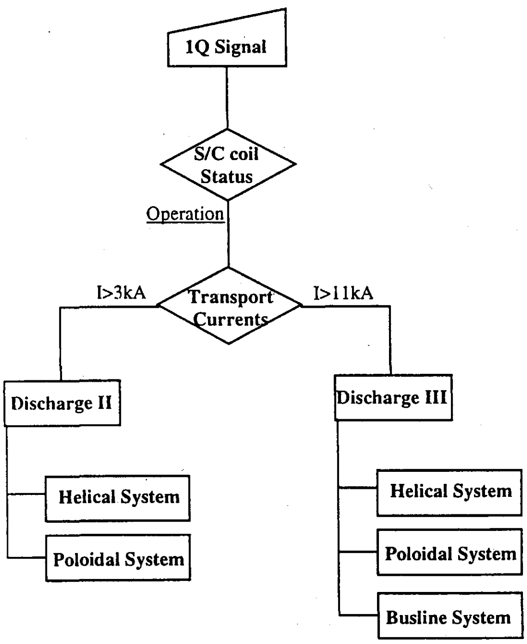

Fig. 1. Discharge Sequence Flowchart.

II. Power Outage

In the case of power outage, the main compressors of helium refrigerator are failed and a recovery compressor takes over the gaseous helium recovery operation. The integrated controller sends emergency signal to the subsystem and the sequence programs are executed to isolate each system. Any pressure build up in the system are relieved in terms of relief valves, which are controlled with setting pressure values. As a result, subsystems are now in the self sustaining mode.

Liquid helium evaporation from superconducting busline system is recovered as suction pressure of recovery compressor becomes 0.15 MPa. Poloidal coil and Helical coil system are followed as the suction pressure becomes 0.12 MPa. These operations are implemented independently to the each system.

LHD-TESS is now considered to have high reliability against failures. However, the system still required to develop automatic recovery mode after the failure.

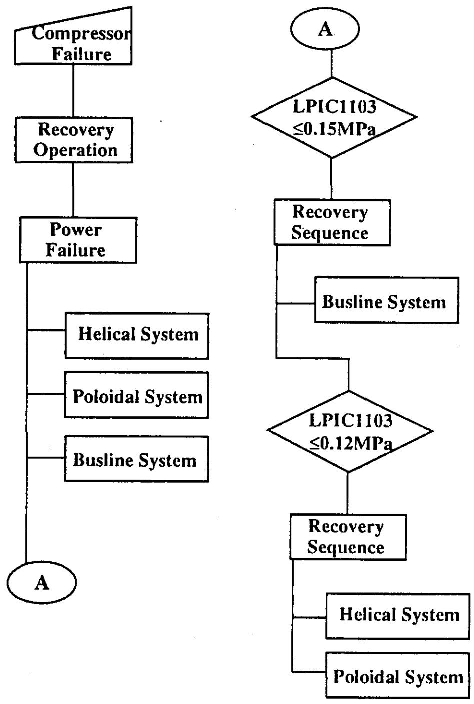

Fig. 2. Power Failure Sequence Flowchart.